History and co-management of the artisanal mutton snapper (Lutjanus analis) spawning aggregation fishery at Gladden Spit, Belize, 1950–2011

Pablo Granados-Dieseldorff a, b, *, William D. Heyman c, d, James Azueta e

a 810 Eller Oceanography & Meteorology Building, Texas A&M University, Department of Geography & Applied Biodiversity Science NSF-IGERT Doctoral Program (AB5), College Station, TX 77843-3147, USA
b Southern Environmental Association (SEA), ABS-SEA Internship Program, Placencia, Belize
c ERL Ecological Research Associates Inc., Bryan, Texas, USA
d Belize Fisheries Department, Belize City, Belize

A R T I C L E   I N F O

Article history:
Received 10 January 2013
Received in revised form 5 June 2013
Accepted 27 June 2013

Keywords:
Artisanal fisheries
Co-management
Data-sparse fisheries
Fishers’ knowledge
Reef fish spawning aggregations

A B S T R A C T

Since the 1950s, artisanal fishers from southern Belize have harvested mutton snapper (Lutjanus analis) from the Gladden Spit fish spawning aggregation site. In 2000, the Government of Belize partnered with stakeholders to conserve the area and co-manage the fishery. The objective of this study was to present the history of the artisanal mutton snapper fishery in its environmental and socioeconomic context and qualitatively evaluate its present status. We identified long-term trends in the fishing activity through historical catch reconstructions and estimation of fishing fleet size since the late 1980s, statistically compared inter-annual trends in catch per unit effort (CPUE) and in mutton snapper sizes between 1999 and 2011, and delineated possible factors that might have caused the observed patterns. Our data show a sharp reduction in total landings and fishing effort that started in the late 1980s, parallel to a rapid growth in the tourism industry and to a shift in the livelihoods of many fishers. Annual CPUE, individual sizes, and sex ratios have been relatively stable between 1999 and 2011, indicating persistence of the fishery during this recent period. Key to successful long-term, adaptive co-management of the fishery is a continued involvement of fishers and other stakeholders in resource monitoring and evaluation, as well as in policy and decision making.

© 2013 Elsevier B.V. All rights reserved.

1. Introduction

Snappers (Lutjanidae) have historically been among the most economically important reef fisheries of the Caribbean (Munro, 1983; Pauly et al., 1996; Salas et al., 2007). Throughout their ontogenic development, they share coastal and open-water habitats and are often exploited as part of multiple species fisheries of peculiar seasonality at different locations, including fish spawning aggregations sites (Lindeman et al., 2000; Claro et al., 2001; Claro and Lindeman, 2003). Typical Caribbean fisheries, they are largely artisanal (i.e., those pursued in small scale for commercial purposes, using traditional fishing methods; sensu Berkes et al., 2001) and because of their multi-cultural, multi-scale, multi-species, and data-sparse nature, they are difficult to assess and manage using conventional methods (Medley et al., 1993; Pauly et al., 1996; Frédo et al., 2009). Moreover, uncontrolled fishing pressure, weak fisheries management and law enforcement, piecemeal governance, and degradation of critical life-history habitats by natural and anthropogenic stressors continue to threaten their sustainability (Munro, 1983; Claro et al., 2009; Freitas et al., 2011).

Because several snapper species are highly desirable food fish, top carnivores, long-lived, relatively slow to reach reproductive maturity, and aggregate to spawn in highly predictable dense concentrations of individuals, they are considered highly vulnerable to overexploitation (Domeier and Colin, 1997; Claro and Lindeman, 2003; Sadovy and Domeier, 2005). Historical reef fish spawning aggregation declines, mostly grouper (Epinephelidae) fisheries, have been reported for the Caribbean, highlighting the need for protecting and managing fish spawning aggregations across the region and for regulating their regional and global markets (Pauly et al., 1996; Claro and Lindeman, 2003; Sadovy De Mitcheson and Erisman, 2012). Despite recent progress in the study of Caribbean fish spawning aggregations, many of their ecological and behavioral dynamics are still unclear (Sadovy De Mitcheson et al., 2008), and their response to fishing pressure remains poorly understood.

a Corresponding author. Tel.: +1 979 845 7141; fax: +1 979 845 4487.
E-mail addresses: pablogd@tamu.edu, pablogd3@gmail.com (P. Granados-Dieseldorff).
0165-7836/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.fishres.2013.06.007
As a result, management approaches to fish spawning aggregation fisheries in the region have been predominantly “data-less” (sensu Johannes, 1998), prompting the adoption of precautionary strategies such as the establishment of marine reserves, while more information on the protected resources becomes available.

In the western Caribbean, fishers from Belize, Guatemala, and Honduras have traditionally harvested snappers during spawning aggregations (Craig, 1966; Heyman and Granados-Dieseldorff, 2012). Gladden Spit, a reef promontory in the southern Belize Reef and a multi-species reef fish spawning aggregation site (Heyman and Kjerfve, 2008), has been known as a productive ground for snapper artisanal fisheries since the 1950s (Bradley, 1956 in Craig, 1966). Mutton snapper (Lutjanus analis Cuvier 1828, Lutjanidae) fisheries from the area have prevailed in national finfish yields since the 1990s (Koslow et al., 1994; Aul et al., 1999). The biological richness and tourism values of the Gladden Spit area, as well as the plea from local fishers for regulation of illegal fishing and poaching (Heyman and Graham, 2000; Heyman, 2011), led the Government of Belize to declare the Gladden Spit and Silk Cayes Marine Reserve (GSSCMR) in 2000 (Government of Belize, 2000). As part of a network of marine reserves and protected spawning aggregation sites throughout the nation (Fig. 1), GSSCMR is currently co-managed by the Belize Fisheries Department (BFD) and the community-based non-government organization Southern Environmental Association (SEA).

The artisanal mutton snapper fishery at Gladden Spit presents a valuable opportunity to assess responses of fish spawning aggregations to fishing and to evaluate approaches to adaptive co-management of artisanal fisheries. With the exception of a short-term study (Graham et al., 2008), a comprehensive evaluation of the history of this fishery does not exist. In response and in the interest of expanding baseline information for the adaptive co-management of the artisanal mutton snapper fishery at Gladden Spit, we present a retrospective analysis of the history of the fishery in its environmental and socioeconomic context. Using information gathered from fishery landings surveys conducted by the co-managers in the area, as well as from national fisheries statistics reports, published and gray literature, and knowledge of expert fishers and stakeholders (sensu Grant and Berkes, 2007), we were able to (1) identify long-term trends in the fishing history with reconstruction of annual catches and estimation of fleet size since the late 1980s; (2) compare inter-annual trends in catch per unit effort (CPUE) and in fish length and weight at harvest for the last decade (1999–2011); and (3) delineate possible factors that might have caused the observed trends in the fishery, including social changes, environmental and biological factors, and management measures.

2. Materials and methods

2.1. Study area and fishery

Gladden Spit (Fig. 1) is a promontory in the southern Belize Barrier Reef, 40 km east of the village of Placencia, Stann Creek District (Heyman et al., 2001; Heyman and Kjerfve, 2008). Managed as a no-take zone (NTZ) inside GSSCMR (Government of Belize, 2003a, b), Gladden Spit remains closed to fishing during most of the year, except for limited traditional fishing for mutton snapper between March and June. Using hand lines, artisanal fishers from the villages of Placencia and Seine Bight initially, and later from Independence, Hopkins, and Monkey River (Fig. 1), have harvested mutton snapper from the site. Traditional timing of the monthly fishing activity follows the lunar cycle (Heyman and Graham, 2000) and depending on the calendar year, fishing may be interrupted if it coincides with Easter or with the beginning of the lobster (Panulirus argus, Panuliridae) fishing season, which typically starts on June 15. The fishing fleet at Gladden Spit transformed from traditional Belizean smacks and dugout canoes (see Craig, 1966; plates 1–III) to motorized Mexican-style skiffs (see Heyman and Graham, 2000; p. 16) that were introduced to Belize in the early 1980s (Gray, 2009). Every year, and following the current legislation, the co-managers (i.e., BFD and SEA) should issue “special licenses” to a limited number of traditional fishers for harvesting mutton snapper at this spawning aggregation site. Fishing is allowed only during daylight hours (6:30–17:00 h) and only during two weeks each month of the fishing season (Government of Belize, 2003a, b).

The fishery targets the peak periods when mutton snapper aggregate to spawn along the shelf break on the fore reef area at Gladden Spit. For a period of 10–14 days each month between March and June every year, typically starting 2 days prior to full moon, fishers set up base camps on sand cayes and commute daily 10–15 km to Gladden Spit. The fishery fleet consists of Mexican-style fiberglass skiffs (7–7.6 m hull), equipped with four-stroke outboard engines (40–60 hp), and with no more than three fishers on board, including the captain. Fishers use a monofilament line (25–60 m long), weighted with steel rebar, and with between one and three baited hooks. At the end of the day, fishers return to their base camps, clean their product, and preserve it in ice before transportation to the mainland. Butterwood Caye (Fig. 1) is the primary base camp and landing site for mutton snapper from Gladden Spit. The Placencia Producers Cooperative Society Ltd. (Placencia Cooperative, hereafter), created in 1962 by fishers from Placencia, has been the major collecting cooperative for mutton snapper from Gladden Spit (Aul et al., 1999; Key, 2002). Typically sold whole, selling price for 1 kg of mutton snapper has varied little from US$ 2.75 in 2000–2002 (Graham et al., 2008) to US$ 3.50 in 2011 (this study).

2.2. Data collection

Quantitative historical fishery data were obtained from reports on finfish production from the Placencia Cooperative to the Belize Central Statistical Office (BCSO, currently known as the Statistical Institute of Belize) for 1988–1992 (Belize Central Statistical Office, 1991, 1994). Detailed mutton snapper landings data were obtained from the SEA database for 1999–2010 and from surveys in the field for 2011 (by co-author PGD). The SEA database harbors fishery data from Gladden Spit, systematically collected during the mutton snapper fishing season since 1998, first by The Nature Conservancy, and later, by the local non-government organizations Friends of Nature and SEA, with constant supervision from the BFD.

Following the GSSCMR management plans and with continued collaboration from fishers in the field, landings data were collected at Butterwood Caye by teams of 4–6 persons that included local and international researchers and volunteers. Landings data forms were in accordance with national protocols for monitoring fish spawning aggregations and their fisheries (see Heyman et al., 2002, 2004), and which have combined fishery-dependent data on mutton snapper with socioeconomic and demographic profiles of fishers. Finally, for complementary historical data about the fishery, as well as for data on the environmental and socioeconomic factors that might have affected the fishery’s trends, we integrated information from published and gray literature with local fishers’ and stakeholder’s expert knowledge collected systematically through participant observations in the field since the early 1990s (by co-authors WDH and JA).
2.3. Data analysis

2.3.1. Long-term trends in the mutton snapper fishery at Gladden Spit

The earliest available quantitative data for reconstructing historical catches from the mutton snapper fishery at Gladden Spit were those provided in the reports on finfish production from the Placencia Cooperative to the BCSO for 1988–1992 (Belize Central Statistical Office, 1991, 1994). To the best of our knowledge, quantitative data prior to 1988 and for 1993–1998 were not available.

Annual catches for mutton snapper were reconstructed assuming that approximately 50% of the total finfish catches reported by the Placencia Cooperative corresponded to mutton snapper from Gladden Spit. Our estimates concurred with those expressed by several experienced fishers and former cooperative directors from the late 1980s. Annual catches for 1999–2011 were reconstructed from the landings dataset of SEA. Since these included only boats landing at Buttonwood Caye, mutton snapper catches landed at Buttonwood Caye were extrapolated to total catches at Gladden Spit using (1) reports on total number of boats actively fishing at Gladden Spit from Graham et al. (2008) for 1999–2005 and (2) reports from SEA park ranger patrolling the area for 2006–2011.

2.3.2. Annual trends (1999–2011) in the fishery CPUE and individual sizes

Landings data collected at Buttonwood Caye were used to estimate fishing effort, catch per unit effort (CPUE), fish size distributions by sex, and sex ratios between 1999 and 2011, excluding years 2002, 2005, and 2010 for which data were not available. Female and male data were combined in analyses of individual total length (TL, mm) and total weight (TW, kg) as no significant differences in TL and TW between sexes were a priori detected.

Total fishing effort was estimated as the number of boat-daysfishing, assuming that the maximum fishing effort per boat during an active day was 3 hand lines*boat*1 and that effort was constant throughout the entire data period. It was also assumed that one boat-day-fishing was equivalent to ≥8 h of soak time (i.e., round-trip travel time to Gladden Spit from Buttonwood Caye and fishing time). Following Malvestuto (1996) and Fabrizio and Richards (1996), catches per boat were first estimated by the total number of fish landed (total catch abundance) and their corresponding weight (total catch weight). Using the total-ratio method, catches were then standardized to CPUE and expressed as kg*boat*day−1. Since fishing activity at Gladden Spit follows a traditional lunar periodicity and overlaps with Easter and the lobster season (see Section 2.1), the use of the total-ratio estimator allowed to standardize for uneven contributions in monthly fishing effort and

Fig. 1. Map of the study area, showing the location of the marine reserves of Southern Belize, Buttonwood Caye, and the villages of origin of the fishers from the mutton snapper (Lujanus analus) fishery at Gladden Spit. The sites where mutton snapper aggregate to spawn along the Barrier Reef (Caye Bokel, Long Caye, Gladden Spit, Seal Caye, and Rise and Fall Bank) are indicated in italics. Data for GIS themes in map were extracted from Burke and Sugg (2006) and Meerman (2011).
landings, and to control for temporal variability in the fishery’s catchability (P. Granados-Dieseldorff, unpublished data). Moreover, since May was the only month consistently sampled in each of the available years and since it is traditionally known as the peak of mutton snapper fishing season at Gladden Spit, only May data were used in inter-annual comparisons of fishery variables (i.e., total catch abundance and weight, fishing effort, F:M ratios, CPUE, individual TL and TW).

To test for inter-annual changes in CPUE and in individual TL and TW, univariate one-way PERMANOVA routines (Permutational MANOVA/ANOVA — Anderson, 2001a; McArdle and Anderson, 2001), using PERMANOVA+ (Anderson et al., 2008) in PRIMER 6 (Clarke and Gorley, 2006) were performed in an approach similar to parametric ANOVAs. PERMANOVAs were used as more versatile and robust non-parametric tests (Anderson, 2001b) suitable for the sparse and non-parametric nature of the fishery data in this study. As a permutation-based test routine and using resemblance distance measures, PERMANOVA is distribution free and does not assume linearity of response variables nor normally distributed errors. Data were log-transformed (log(x + 1)) a priori and tests were based on Euclidean-distance matrices. Mean-squared errors, pseudo-F ratios (analogous to F-ratios in ANOVA), and p-values were obtained from 9999 permutations (α = 0.05). Posterior pair-wise tests were performed for significant year (1999–2011) effects.

3. Results

3.1. Long-term trends in the mutton snapper fishery at Gladden Spit

Based on our reconstructed catches, the fishery endured a sharp decline in the late 1980s, seeing a decrease of 76.4% in catches over 5 years between 1988 and 1992 (Fig. 2). During this period, two important socioeconomic changes occurred simultaneously in Belize and likely contributed to this observed trend. In 1985, fishing cooperatives across the nation were impacted by the precipitous decline in the production and export of lobster and conch (King, 1997; Huitric, 2005). This led fishers from the Placencia peninsula and surrounding areas to reduce considerably their commodity contributions to the Placencia Cooperative and several of them forfeited their cooperative membership (Key, 2002). In the mid-1980s, tourism development began to expand rapidly in Belize (Key, 2002; Alexander, 2008; Gray, 2009). In the late 1980s, many fishers in the study area, a region with great tourism potential, left their fishing profession for jobs in the tourism industry, in search of more stable and predictable profits (Key, 2002; Key and Pillai, 2006). Between 1988 and 1998, the number of hotels in Placencia increased 390% (from 10 to 49 hotels) (Fig. 2), while in the entire country, revenues from tourism quadrupled (Key, 2002). In contrast, during the same period, the maximum number of boats actively fishing at Gladden Spit on a daily basis dropped 78.6% (from 70 to 15 boats) (Fig. 2).

Although no data exist for most of the 1990s, total annual catches in 1999 continued to be low (Fig. 2). From then on, catches fluctuated, with peaks in 2001 and 2006, followed by a constant increasing trend after 2007, when annual catches reached the yields from those in the early 1990s. The number of boats actively fishing also remained low through the 2000s, in contrast of those reported for 1988. Again, this low level of fishing activity at Gladden Spit may be in part explained by the continuous growth of the tourism industry in the area and the associated employment opportunities. The increase in tourism in Placencia is evidenced again by the surge in number of hotels which reached 79 in 2011 (Fig. 2).

3.2. Annual trends (1999–2011) in the fishery CPUE and individual sizes

Between 1999 and 2011, landings surveys at Buttonwood Caye registered a total of 17,754 adult mutton snapper (49.0t) that were caught at Gladden Spit during 626 boat-d-fishing, allocated between March and June. From these total annual estimates, 11,460 mutton snapper (31.3t), caught during 414 boat-d-fishing at Gladden Spit, corresponded to May landings (Table 1). The maximum number of boats landing at Buttonwood Caye on a single day was 15, recorded in May 2011, when the maximum number of fishing boats at Gladden Spit was 23 (Fig. 2), based on patrol reports from Park Rangers of GSSCMR. As explained before, we based our inter-annual comparisons on May estimates, the best available representative data for our study fishery (see Section 2.3.2).
Summary of the data estimated for the artisanal mutton snapper (Lutjanus analis) fishery at Gladden Spit, Belize. Annual variables (1999–2011) were estimated from data in the electronic database of the Southern Environmental Association and collected during landings surveys conducted in May at Buttonwood Caye, the primary landing site for mutton snapper from Gladden Spit. Data were not available for years 2002, 2005, and 2010.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean number of boats landing daily (range)</td>
<td>3 (2–5)</td>
<td>5 (4–6)</td>
<td>7 (4–8)</td>
<td>3 (2–5)</td>
<td>3 (1–4)</td>
<td>4 (2–9)</td>
<td>5 (3–5)</td>
<td>6 (3–8)</td>
<td>6 (4–8)</td>
<td>9 (1–15)</td>
</tr>
<tr>
<td>Total fishing effort (boat-d-fishing)</td>
<td>13</td>
<td>16</td>
<td>42</td>
<td>13</td>
<td>22</td>
<td>47</td>
<td>44</td>
<td>82</td>
<td>62</td>
<td>73</td>
</tr>
<tr>
<td>Total catch abundance (number of fish)</td>
<td>222</td>
<td>704</td>
<td>1023</td>
<td>110</td>
<td>819</td>
<td>922</td>
<td>827</td>
<td>2349</td>
<td>1900</td>
<td>2584</td>
</tr>
<tr>
<td>Total catch weight (kg)</td>
<td>762</td>
<td>2234</td>
<td>3958</td>
<td>382</td>
<td>2165</td>
<td>2355</td>
<td>2725</td>
<td>4500</td>
<td>5202</td>
<td>7034</td>
</tr>
<tr>
<td>CPUE (kg “boat-d-fishing”$^{-1}$)</td>
<td>58.6</td>
<td>139.6</td>
<td>94.2</td>
<td>28.4</td>
<td>98.4</td>
<td>50.1</td>
<td>61.9</td>
<td>54.9</td>
<td>83.9</td>
<td>96.4</td>
</tr>
<tr>
<td>Sex ratios (M:F)</td>
<td>0.9:1</td>
<td>1.2:1</td>
<td>1.2:1</td>
<td>1.3:1</td>
<td>1.3:1</td>
<td>1.2:1</td>
<td>1.1:1</td>
<td>1.2:1</td>
<td>1.2:1</td>
<td>1.3:1</td>
</tr>
</tbody>
</table>

Between 1999 and 2011, fishing effort, catch, and CPUE fluctuated with a stabilizing trend during the last years (Table 1 and Fig. 3). CPUE in 2011 was significantly higher than in 1999, 2003, and 2007 (posterior PERMANOVA pair-wise tests: $p < 0.03$) and did not differ significantly from the peak observed at the beginning of the decade, in 2000 (posterior PERMANOVA pair-wise test: $p = 0.62$) (Fig. 3). A significant decrease was observed between 2001 and 2003, followed by an immediate significant increase between 2003 and 2004 (posterior PERMANOVA pair-wise tests: $p < 0.005$). The low CPUE detected in 2003 (Fig. 3) coincided with the low fishing effort and low catches recorded for that year (Table 1). This drop in CPUE occurred the year after Hurricane Iris hit the area. Hurricane Iris was a Category-4 tropical storm (Saffir-Simpson Hurricane Scale) that made landfall in October 2001, exactly between Monkey River and Placencia (see Avila, 2001). The aftermath of Iris was one of the most severe in the hurricane history of the area and it took considerable time to the fishing villages that were devastated to recover and rebuild (Alexander, 2008; Gray, 2009).

The frequency distributions of TL and TW, as well as M:F sex ratios of landed mutton snapper were maintained between 1999 and 2011 (Table 1 and Fig. 4). Sex ratios (M:F) averaged 1.2:1, with little annual variation (Table 1). Individual median lengths ranged from 490 to 570 mm TL (Fig. 4A). Median TW ranged from 2.72 to 3.63 kg (Fig. 4B). The largest mutton snapper recorded was a male of 905 mm TL and 11.8 kg TW, caught in May 2011. More than 50% of all the mutton snapper in analyses had TW that ranged between 4 and 6 kg. No significant changes were detected in median TL or TW among years (one-way PERMANOVAs: pseudo-$F < 1.9$, df $= 9$ and 59, $p > 0.10$).

### 4. Discussion

This study illustrates the history of the mutton snapper fishery at Gladden Spit in relation to key socioeconomic and environmental factors. After undergoing subsistence use in the 1950s (Craig, 1966), the fishery became more commercially oriented in the 1970s, when the Placencia Fishing Cooperative started generating electricity and producing ice that allowed better preservation of catches (Key, 2002). Mutton snapper landings probably surged in the early 1980s with the introduction of motorized Mexican-style skiffs to the Placencia Peninsula (Gray, 2009). Despite limitations in quantitative historical fishery data, we were able to reconstruct catches retrospectively and to capture a time, 24 years back, when fishing effort and the fishery yields were higher than recent times. The decrease in historical catches for the late 1980s and early 1990s is consistent with the findings of Graham et al. (2008) who used information from interviews with fishers. However, the interpretation of the declining trend is not simple and cannot be explained as a sole

![Fig. 3. Inter-annual trends (1999–2011) in daily estimates of catch per unit effort (CPUE) of mutton snapper (Lutjanus analis) landed in May at Buttonwood Caye, Belize. Sample size (d) is indicated in parentheses at the top of the figure. Data were not available for years 2002, 2005, and 2010. Within-year means are denoted by diamonds (●) in Whisker box plots. Annual changes in CPUE estimates were tested using one-way PERMANOVA routines: significant changes between successive years are indicated by solid lines ($p < 0.05$). In posterior pairwise comparisons, the lack of at least one letter in common (i.e., A, B, C, and D) indicates significantly different means between any pair of years.](image-url)
result of overexploitation since it occurred simultaneously with a
decline in fishing effort and a shift in occupations and livelihoods of
many fishers during the rapid development of the tourism industry in the area, described in the results. Our analyses for the years
between 1999 and 2011 show relatively stable CPUE, sustained values of individual sizes that are also concordant with the biological
variables of the species (see Allen, 1985; Claro and Lindeman, 2004;
Froese and Pauly, 2012), and continued preservation of M:F sex
ratios. These data all suggest persistence of the fishery over this time period. Graham et al. (2008) also analyzed CPUE changes
between 2000 and 2002, and concluded that the fishery was in decline. Nevertheless, as more years of data were available to us,
we found that the only significant decline in the whole decade was between 2001 and 2003 and that the fishery did not continue on a
declining trend.

Persistent mutton snapper fisheries have been documented in
Cuba and the Southeastern United States (Claro et al., 2001, 2009;
Claro and Lindeman, 2003; SEDAR, 2008). Individual fisheries show
a range of resilience to fishing pressure, depending on various factors including the intensity and nature of the fishing activity, the biology and life-history strategies of the species, the oceanography and meteorology of the fishing grounds, and the effectiveness
of fisheries management (Pauly et al., 1996; Ault et al., 1998; Claro
et al., 2009). In contrast to other reef fish, mutton snapper are eu-
topic fish that tolerate wide ranges of environmental conditions
throughout their ontogenic development (Allen, 1985; Watanabe,
2001; Claro and Lindeman, 2004). Among the most important factors explaining the persistence of the mutton snapper fishery in Cuba were their advantageous life-history strategies (Claro et al., 2009). Compared to other snappers and groupers of Cuba, mutton
snapper use a large number of spawning sites (Claro, 1981; García-Cagide et al., 2001; Claro and Lindeman, 2003) and the
species aggregates to spawn in relatively deep waters (Claro and Lindeman, 2004; Claro et al., 2009). Further, large feeding areas

Fig. 4. Inter-annual trends (1999–2011) in individual (A) total length and (B) total weight of mutton snapper (Lutjanus analis) landed in May at Buttonwood Caye, Belize. Female and male data are combined in whisker box plots. Sample size (number of individuals) is indicated at the bottom of the figure. Data were not available for years 2002, 2005, and 2010. Within-year means are denoted by diamonds (♦). No significant changes among years were detected in individual total lengths and total weights (one-way PERMANOVAs: pseudo-F ≤ 1.9, df = 9 and 59, p ≥ 0.10).
are often located close to spawning sites (Claro et al., 2009). Cuban mutton snapper fisheries also persist since they are targeted with hand lines, a more selective and less destructive fishing gear than seines, set nets, and bottom trawls used for other species. Since all the factors favoring the persistence of mutton snapper fisheries in Cuba are present in our study area, we can only hypothesize that they also play a role in the persistence of the fishery at Gladden Spit. Fishers have traditionally used hand lines at the site, which are considered the least destructive fishing gear across the Caribbean (Munro, 1983). Gladden Spit is one of the other four protected sites (Caye Bokel, Glover’s Long Caye, Seal Caye, and Rise and Fall Bank; Fig. 1) where mutton snapper aggregate to spawn along the Belize Reef (Heyman and Requena, 2002; Kobara and Heyman, 2010). Furthermore, fishing in these other four sites is presently banned throughout the year, as they are managed as permanent NTZ (Government of Belize, 2003b). At Gladden Spit, fishing is banned outside of the season (March–June). Finally, mutton snapper aggregate to spawn at Gladden Spit between March and September every year and similar to the conspicious aggregations from Cuba, mutton snapper also spawn at relatively deeper waters than the other species that also use the site (Heyman and Kjerfve, 2008).

It is generally agreed that reef fish spawning aggregation fisheries are likely to be sustainable only at limited, subsistence harvest levels (Sadovy and Domeier, 2005; Sadovy De Mithcheson et al., 2008). Only a complete stock assessment of the mutton snapper fishery at Gladden Spit and surrounding areas, that includes estimation of age-specific mortality rates and growth parameters, could project effective sustainable harvest levels. It is also important to mention that, since the relationship between a fishery’s CPUE and its population size is non-linear and disproportional (Beverton and Holt, 1957; Hilborn and Walters, 1992; Arreguín-Sánchez, 1996), the evaluation of fishery status using catch-based data such as the variables estimated for this study, should always be interpreted with caution. The most commonly assumed situation of disproportionality for aggregating fisheries is when estimates of CPUE can remain high even if the abundance of the exploited stock declines, a situation known as “hyperstability” (Hilborn and Walters, 1992). Although empirical support is still needed, tropical reef fish spawning aggregation fisheries are considered to exhibit hyperstability because of the highly dense fish concentrations that recurrently yield high catches in relatively short amounts of time at specific sites (Monroy-García et al., 1996; Sadovy and Domeier, 2005; Erazo et al., 2011; Russell et al., 2012).

Fishery regulations established with the declaration of GSSCMR effectively closed the multi-species spawning aggregation to fishing except for allowing fishers to fish the spawning aggregation only between March and June every year and only during daylight hours. While allowing fishing for mutton snapper, therefore, the regulations provided protection for other snapper species, such as cubera snapper (Lutjanus cyanopterus, Lutjanidae) that typically spawn around sunset (Heyman et al., 2005) and groupers, such as Nassau grouper (Epinephelus striatus, Epinephelidae), that spawn between December and March at Gladden Spit (see Heyman and Kjerfve, 2008). Management measures aimed at directly limiting the number of fishers at Gladden Spit during the spawning season were established in 2003 (Government of Belize, 2003a, b), and implemented in the field in 2006. The measure consisted of issuing “special licenses” only to traditional fishers but the legal definition is still vague and no maximum number of access licenses has been established. Nonetheless, enforcement increased after 2006 when co-managers had more resources available for patrols and monitoring of the reserve’s spawning aggregations, including landings surveys and underwater visual censuses. Our data showed an increase in fishing effort and landings after 2007. Faced with the limitations for projecting sustainable harvest rates, and in the best interest of the fishery and its management objectives, it is imperative that the granting process of special licenses be reviewed and updated and that intensive data collection and analysis be continued to closely monitor the fishery and guide management.

We consider that the current co-management structure of GSSCMR presents assets for successful fisheries management and the persistence of the mutton snapper fishery at Gladden Spit, so long as strong fishers’ involvement, stakeholder representation, and the cooperation and support from local governments and fishery and conservation policy makers are maintained. The platform exists for cooperation among co-managers, fishers, and rest of stakeholders in resource monitoring, evaluation, and decision making. Fishers, community leaders, and other stakeholders have representation in the advisory committee that develops the regulations for GSSCMR (see Government of Belize, 2003a) and these are regularly discussed during participatory consultations held at local communities throughout the year. Indeed, fishers played an important role in lobbying for the declaration of GSSCMR (Heyman and Graham, 2000; Heyman, 2011) and even before its declaration, fishers have continuously and actively participated in the landings surveys of the mutton snapper fishery. Stakeholder-centered approaches to marine resources conservation and management, with strong local leadership, effective self-enforcement by local stakeholders, and empowerment from the broader community can be more successful than reserves with top-down mandated preservation (Aburto-Oropeza et al., 2011; Berkes, 2012; Cinner et al., 2012). This approach is considered key in the management of reef fish spawning aggregations (Russell et al., 2012) and the most viable in rural settings where the food and economic securities of people rely directly on local natural resources (Gutiérrez et al., 2011; Frédou et al., 2009), such as within the Gulf of Honduras and Belize (Heyman and Granados-Dieseldorf, 2012).

Acknowledgments

This study originated from a volunteer research internship of PGD in the Science Program of the Southern Environmental Association (SEA) as part of the curriculum in the Applied Biodiversity Science NSF-IGERT Doctoral Program (ABS) at Texas A&M University (TAMU) (ABS-SEA Internship Agreement 08/01/2010). We thank SEA for encouraging and facilitating the execution of the internship, particularly A.B. Hagan, R. Castro, N. Catzim, S. Cawich, L. Garbutt, J.R. Finch, and W. Muschamp. The research was conducted under the Belize Fisheries Department marine scientific research permit #000015-11. The field research of PGD was supported in part by the ABS NSF-IGERT Doctoral Program of TAMU, the American Fisheries Society Steven Berkeley Fellowship in Marine Conservation, the Association of American Geographers Doctoral Research Grants Program, the TAMU Department of Geography Graduate Enhancement Fund, and funds from the McDaniel Charitable Foundation Chair Award to J.R. Rooker. We are especially grateful to the artisanal fishers from Placencia, Independence, and Monkey River based at Buttonwood Caye between March and June 2011 for their kind hospitality and collaboration in the field. We also thank S. Betancourt, E. Bowden, R. Castro, S. Coleman, L. Jacobs, and V. Noralez for assistance in the field. Finally, we appreciate thorough reviews on the manuscript by A. Baumgarten, Associate Editor K.A. Rose, and two anonymous reviewers.

References


Alexander, S.E., 2008. The resilience of vulnerable households: adjusting to a newly constructed ecotourism in the aftermath of Hurricane Iris. In: Gunewardena, N.,


SEDAR, 2008. SEDAR (Southeast Data, Assessment, and Review) 15A Complete stock assessment report: South Atlantic and Gulf of Mexico mutton snapper.