Small-scale Fishers' Perceptions about the Performance of Seasonal Closures in the Commonwealth of Puerto Rico

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Abstract

The targeting of spawning aggregations is one of the most significant pressures facing coral reef ecosystems. The use of seasonal closures has been advanced for protecting aggregating fisheries for which managers have limited information on the location and timing of their reproductive events; however, few studies have examined the performance of these types of closures. This study assesses the perceptions of 150 fishers regarding the performance of seasonal closures in the Commonwealth of Puerto Rico.

Our results show that most fishers perceived that seasonal closures are effective fishery management measures. Across the six seasonal closures examined, fishers reported that these closures protected spawning aggregations and, to a lesser degree, increased fish abundance. These measures, however, did not always improve fishers' livelihoods nor result in their support for the seasonal closures. The loss of resource and market access during periods of high consumer demand and overlapping seasonal closures were the main causes of financial distress.

Fishers indicated that the performance of the seasonal closures could be improved by increasing investments in monitoring, control, and surveillance capabilities, and adjusting their timing to accommodate economic and local ecological considerations. Fishers argued that revisions were necessary because some species spawned year-round or outside closure windows. Some fishers also called for replacing seasonal closures with alternative management measures (e.g., area-time closures, marine protected areas, gear restrictions), conducting additional scientific research, and improving fisher education. This work exemplifies that beliefs about conservation and livelihood outcomes are closely linked to the quality of management, the importance of conducting periodic assessments, and engaging fishers in decision-making to increase accountability, transparency, and support for management interventions.

Key words: Seasonal closures, Puerto Rico, spawning aggregations, socio-economic.

1. Introduction

The directed fishing of spawning aggregations (spags) is one of the most significant threats to fish populations inhabiting coral reef ecosystems. Fishers frequently pursue spags because they form highly abundant, predictable aggregations in time and space, which makes them easy and lucrative targets (Sala et al., 2001; Sadovy and Domeier, 2005; García-Moliner and Sadovy, 2007; Graham et al., 2008). Species with gregarious reproductive strategies are particularly vulnerable because they often exhibit a hyperstable relationship between catch rates and population sizes, and this obscures signs of overfishing (Sadovy and Domeier, 2005; Sadovy de Mitcheson, et al. 2013; Grüss et al., 2014).[1] Hence, the persistent targeting of spags not only threatens their reproductive success, but also can lead to population collapse and local depletion (Sadovy and Erisman, 2012; Erisman et al., 2011; Russell et al., 2012; Kincaid et al., 2017). Moreover, directed fishing of spags has been linked to decreases in mean fish size, loss of genetic diversity, and disruption of population sex ratios (Graham et al., 2008).

Despite the increased awareness of the risks of fishing spags, progress continues to be slow due to the difficulties of balancing ecological and social needs (Russell et al., 2014). The Science and Conservation of Fish Aggregations (SCFRA) database reports that 26% of the known spags continue to decline, and another 4% have disappeared entirely (Russell et al., 2014). Moreover, only 35% of the SCFRA-documented aggregations have management protection.

To protect aggregating fisheries, the use of seasonal closures (hereafter closures unless otherwise noted) has been advanced as a potentially useful management measure because they can help minimize the risk of collapse when information on the location and timing of spawning events is partial (Russell et al., 2012; Grüss et al., 2014). This type of closure has also been proposed when area closures have been proven impractical because the number of aggregations is too large to be effective spatially.

[1] Hyperstability occurs when catch rates remain stable but the population is declining steeply or is close to collapsing (Erisman et al., 2011). In other words, the populations are dwindling without the overt signals of overfishing (Schärer-Umpierre et al., 2014).

Additionally, the use of these closures has been favored as a means of combating overfishing and declining numbers of spags. Moreover, previous research has shown that closures can be popular among fishers because they readily understand that successful reproduction is essential for stock conservation and livelihood continuity, in addition to the fact that closures continue to afford fishing opportunities outside the spawning period (Beets and Manuel, 2007; Karras and Agar, 2009). However, closures that significantly disrupt fishers' traditional annual rounds can face severe opposition (Halliday, 1988; Tonioli and Agar, 2009).

This paper investigates the perceptions of small-scale fishers regarding the performance of closures that take place during spawning seasons in the Commonwealth of Puerto Rico. We examine fishers' views regarding the efficacy of closures as a fishery management measure, as well as the specific performance of six closures with substantial commercial value: 1) red hind; 2) Grouper Units 4 and 5 (yellowfin, black, tiger, red, and yellowedge grouper); 3) Snapper Unit 1 (silk, vermilion, black, and blackfin snapper); 4) mutton and lane snapper; 5) mutton snapper (commonwealth only); and 6) queen conch (commonwealth only; Table 1). Most of the closures were established to protect aggregating spawning populations to enhance their reproductive output and help rebuild overexploited stocks (Aguilar-Perera et al., 2006; Ojeda-Serrano et al., 2007; Schärer-Umpierre et al., 2014), as closure dates correspond to known spawning periods. Table 2 shows that many of the closures have been in place for decades. On aggregate, the closures examined protect the spawning potential of species responsible for about 34% of the Commonwealth's dockside revenues. We also collected information on fishers' perceptions about the efficacy of area closures; however, for brevity we omit most of these results.

As van Overzee and Rijnsdorp (2015) argued, studies about the efficacy of management interventions can be extremely challenging, if not impossible, to carry out due to the difficulties of conducting replicated experiments in real fishery systems; therefore, alternative approaches are often used. The appraisal of perceptions has been shown to be a valuable policy-making tool because it enriches understanding of the experience and needs of user groups, informs decision-makers, and can help in the design and revisions of policy interventions (Pomeroy, 1995; Marshall, 2007; Pita et al., 2011a; Amigo-Dobaño et al., 2012; Leule et al., 2012; Garza-Gil and Varela-Lafuente, 2015; Bennett, 2016; Gelcich and O'Keeffe, 2016; Heinen et al., 2017). Favorable perceptions are indicative of the management actions deemed to be beneficial and equitable, which encourages compliance (Marshall, 2007; Pita et al., 2011b; Gelcich and O'Keeffe, 2016; Agar et al., 2019). On the other hand, opposing perceptions may signal the need to adjust the scale and scope of existing policies, improve their delivery, or abandon them altogether, as well as find novel solutions to failing policies (Marshall, 2007; Gelcich and O'Keeffe, 2016). Contrasting views may also indicate the need to enhance constituent knowledge and understanding, as well as improve stakeholder relations.

The aim of this paper is to contribute to the sparse literature regarding the perceived efficacy of spawning closures by providing insights into the strengths, weaknesses, and opportunities of this management measure. The rest of this article is structured as follows: Sections 2 and 3 introduce the study site and methods employed, respectively; Section 4 summarizes the results from the interviews; and Section 5 offers the main conclusions of this study and policy recommendations.

2. Fishery background

The Commonwealth of Puerto Rico is an archipelago consisting of the main island of Puerto Rico and several smaller islands and cays surrounded by the Atlantic Ocean to the north and the Caribbean Sea to the south (Suarez-Caabro, 1979). The archipelago has an area of 3,515 square miles and a coastline that extends for 311 miles. The main island of Puerto Rico is the smallest and easternmost of the Greater Antilles (Figure 1).

Puerto Rican commercial fisheries are small-scale in nature but are an important source of sustenance, income, employment, and cultural heritage to many coastal communities (Jarvis 1932;

Whiteleader, 1971; Gutierrez-Sanchez, 1982; Valdés-Pizzini, 1985; Griffith and Valdés-Pizzini, 2002; Perez, 2005; Griffith et al., 2007; Agar et al., 2008; Matos-Caraballo, D. 2009; Valdés-Pizzini, 2011). Puerto Rican fishers tend to control production by owning and operating their fishing craft and/or gear, and are highly dependent on fishing income to support their families (Perez, 2005). Matos-Caraballo and Agar (2011) report that about 85% of fishers derived 50% or more of their household income from fishing. Most fishing vessels are small with moderate levels of mechanization. The average vessel is 20-foot (ft) long and has an 80 horsepower (hp) engine (Matos-Caraballo and Agar, 2011). In contrast to artisanal fishers, who build their own rudimentary fishing gear and crude, homemade fishing craft, most Puerto Rican small-scale fishers tend to buy materials outside their communities to build their fishing gear (e.g., nets and fish traps) or acquire fiberglass for their fishing boats through government agencies (Perez, 2005). Local fisheries support about 1,200 fishers who use a number of gears such as hook-and-line, diving (including spears), traps, and nets to catch reef-fish, spiny lobster, queen conch, and miscellaneous coastal pelagic species (Matos-Caraballo and Agar, 2011). Between 2010 and 2015, fishers landed, on average, about 2.4 million pounds (1,089 metric tons) of finfish and shellfish with dockside revenues of US$8.6 million per year (NMFS, 2017). Regionally, the west coast is the most productive region, accounting for about 40% of the landings and revenues during the same period (NMFS, 2017). The south and east coasts generate about 25% and 20% of the landings, and 23% and 22% of the revenues, respectively. The north coast is the least productive region, producing 15% of the landings and 14% of the revenues.

Puerto Rican fisheries are managed by the Department of Natural and Environmental Resources (DNER) and the Caribbean Fishery Management Council (CFMC). DNER is responsible for managing fisheries out to 9 nautical miles (nmi) from the shore, and the CFMC is responsible for managing those fisheries in surrounding waters extending from 9 to 200 nmi. Most fisheries are under a regulated open access regime, with the exception of the limited entry deep-water snapper fishery (i.e., cardinal snapper, queen snapper). Fishery managers use a variety of management measures, including quotas, trip limits, gear restrictions, seasonal and area closures, size limits, and other miscellaneous restrictions. The Commonwealth also uses seasonal sales bans to prohibit trade of regulated species during spawning seasons. These usually begin shortly after a closure starts so that fishers and dealers can exhaust their inventories.

3. Materials and Methods

We conducted 150 in-person interviews, which is close to one-fifth (18.5%) of the fisher population that reports trip tickets to the DNER. The random sample was stratified by coastal area to capture the diversity of operations, and to make the data gathering easier and more economical.[2] Trained interviewers were instructed to set up meetings at times and places that were most convenient to fishers if current contact information was available. Otherwise, interviewers attempted to reach them at the local landing centers and/or facilities. The unadjusted response rate was 32.1% which was estimated by dividing the total number of completed interviews by the total number of fishes contacted.

The survey instrument had both open- and close-ended questions that inquired about demographics, fishing capital and practices, and views about the performance of seasonal and area closures. Fishers' opinions about whether seasonal and area closures were effective fisheries management measures were assessed using a 3-point scale: very effective, somewhat effective, and no effect. The survey also asked about the ability of closures to protect spags and increase fish abundance. Fishers appraised each closure's ability to meet these objectives using a five-point Likert scale that ranged from strongly disagree to strongly agree. Fishers were also asked about their initial and present support for each of the closures, as well as any hardships experienced because of them. The survey

[2] The Commonwealth of Puerto Rico was partitioned into four coastal regions: north, east, south, and west. The northern region extends from the municipalities of Isabella to Luquillo. The eastern region runs from the municipalities of Fajardo to Maunabo, including the islands of Vieques and Culebra, and the southern region stretches from the municipalities of Patillas to Lajas. The western region spans the municipalities of Cabo Rojo to Aguadilla.

concluded with an open-ended question soliciting recommendations for improving the efficacy of the closures. The survey instrument is available from the authors upon request.

Two sample t-tests and Wilcoxon rank sum tests (when distributional assumptions were not met) examined whether fishers' perceptions regarding the efficacy of seasonal and area closures as management tools (i.e., very and somewhat effective vs. no effect) differed by demographic, vessel, and municipality characteristics. Fisher's exact tests examined whether the efficacy of these management tools (i.e., very effective, somewhat effective, no effect, and DK/NA) differed by coastal region. Two sample t-tests and Wilcoxon rank sum tests (when appropriate) were also used to assess whether fishers' perceptions about the effectiveness of the individual closures to protect spags and augment abundance (strongly agree and agree vs. neutral, disagree and strongly disagree) differed by demographic, vessel, and municipality characteristics. McNemar's tests (with Holm-Bonferroni correction) were used to examine differences in pre- and post-closure hardship and support levels for the various closures (Holm, 1979).

In addition to surveying fishers, we interviewed key informants and used government reports and statistics to contextualize our findings. Key informants included three fishery managers, two port agents, and three professionals involved in research and outreach. Canvassing took place between June 2014 and January 2016; however, during this period, we simultaneously interviewed fishers who used hook-and-line, traps, and diving gear. The purpose of these attendant data collections was to provide socio-economic profiles of these fishing gears which has been reported in Agar and Shivlani, 2016; Agar and Shivlani, 2017; Agar et al., 2017.

4. Results and discussion

4.1. Profile of respondents

The majority of the fishers surveyed were seasoned, male fishers, who owned their vessel(s) and fished year-round. On average, respondents were 56 years old (22-89 range), and had about 30 years of fishing experience (1-80 range; Table 3). About 89% of the sample fell into the 40 years and over age bracket. Seventy percent of the respondents said that they fished on a full-time basis. Part-timers reported that they fished for income rather than for consumption (subsistence) purposes. Commercial fishing was a significant source of income to the household economy. On average, fishing income comprised about 66% of the household income (5-100% range; Table 3). About 71% of the respondents claimed that fishing income contributed 50% or more to their household income. The survey found that households had between 1 and 7 members (including the fisher), averaging three members, and fishers reported having lived in the same community for about 46 years on average.

Most respondents operated small-sized craft to pursue a variety of species. The average craft was 20 ft. in length (12-50 range), outfitted with a single, outboard, gasoline engine (Table 3). The average propulsion rate of the engines was 74 hp (9.5-450 range). Fishers valued their used vessel and engine(s) around $10,000 (500-60,000 range). Handlines, vertical lines, diving (SCUBA and skin), and fish and lobster traps were the most common gears used to target deep-water snappers and groupers, reef-fishes, spiny lobsters, queen conchs, and coastal migratory species, such as dolphinfishes, mackerels, and wahoos. Close to three-quarters of the respondents (71%) stated that most of their fishing took place in Commonwealth waters (≤9 nmi).

4.2. Seasonal closures as a management tool

Overwhelmingly, fishers believed that seasonal closures are an efficient fishery management tool, but they held slightly less favorable views about the efficacy of area closures (Table 4). Three-quarters of the respondents reported that seasonal closures are a very or somewhat effective fishery management tool, whereas 59% of them felt that area closures are very or somewhat effective. This suggests that fishers value both types of closures, but favor seasonal closures because the loss of fishing opportunities is only transient.

Views about the efficacy of seasonal and area closures were not affected by demographic, vessel, and municipality characteristics, but varied by coastal region. Two sample t-tests and Wilcoxon rank sum tests found no statistically significant relationship between efficacy beliefs and demographics (age, fishing experience, fishing income), vessel characteristics (engine propulsion, vessel length, vessel value), or municipality characteristics (unemployment rate, fishing revenue diversification).[3] On the other hand, Fisher's exact test showed that fishers' opinions about the efficacy of seasonal closures varied across coastal regions ($p=0.035$). Beliefs about seasonal closures being effective fishery management tools ranged from 64% on the north coast to 94% on the west coast. However, fishers on the east and north coasts tended to be more disbelieving about their efficacy relative to their counterparts. This may be because, on average, they are more reliant upon non-seasonally closed fisheries such as yellowtail snappers, spiny lobsters, and coastal migratory species (dolphinfishes, wahoos, mackerels).

Fisher's exact test also showed that fishers' views about the efficacy of area closures differed by coastal region ($p< 0.001$). While over 50% of respondents for each coastal region held favorable views about performance of the area closures, 40% in the south coast and 36% in the north coast were irresolute about their usefulness most likely because they were less familiar with area closures (Table 4). Interestingly, even though most area closures are found on the west coast, more than three-quarters of the east coast fishers surveyed believed that area closures were effective fishery management measures. Their beliefs may have been influenced by their awareness of the success of the US Virgin Islands red hind closure (Nemeth et al. 2005) and that most of the tagged fish at that aggregation returned toward eastern Puerto Rico (Nemeth et al. 2007).

[3] A Herfindahl-Hirschman index of landed revenue by municipality was used to proxy the level of diversification (or specialization). HHI scores range from close to zero (highly diversified) to 10,000 (highly specialized).

4.3. Assessment of individual seasonal closures

There was broad agreement that the closures studied successfully protected spags and, to a lesser degree, increased fish abundance. Favorable ratings regarding the protection of spags ranged from 62% for the Snapper Unit 1 closure to 77% for the queen conch closure (Table 5). T-tests and Wilcoxon rank sum tests found no statistically significant relationship between spag protection beliefs and demographics, vessel characteristics, or municipality characteristics, with the exception being diversification in the Grouper Unit 4 and 5 closure ($p=0.049$ with Holm-Bonferroni correction) and fishing experience in the queen conch closure ($p=0.050$ with Holm-Bonferroni correction). These favorable ratings were higher than from fishers in nearby islands. For instance, Karras and Agar (2009) found fishers from St. Croix, U.S. Virgin Islands were undecided about the efficacy of the Lang Bank red hind seasonal closure to protect spags (39% believed it was effective, 38% were unsure/neutral, and 23% dissented). Nemeth et al. (2006) suggested that poaching and fishing along the edges of the closure were the main reasons for the slow recovery of the red hind spags.

By contrast, positive views concerning the ability of seasonal closures to increase abundance were slightly lower, ranging from 50% for the Grouper Unit 4 and 5 closure to 69% for the Commonwealth's mutton snapper closure (Table 6). Fishers' less favorable views about grouper biomass increases were perhaps due to the combination of infrequent grouper catches, mostly as by-catch, after the implementation of the closures and the low recovery rates of these long-lived, slow growing, and late to mature species. T-tests and Wilcoxon rank sum tests found no statistically significant relationship between abundance augmentation beliefs and demographics, vessel characteristics, nor municipality characteristics, with the exception being diversification in the Snapper Unit 1 closure ($p=0.028$, with Holm-Bonferroni correction). Again, Puerto Rican fishers expressed more favorable views than those in neighboring islands. Karras and Agar (2009) report that 50% of the Crucian fishers surveyed were irresolute (did not know or neutral) about the ability of the Lang Bank red hind seasonal closure to increase fish abundance. Only 21% of the fishers surveyed agreed that it helped increase abundance outside the closure. Fishers argued that the fish caught in neighboring areas came from the adjacent grounds rather than from the closed area itself. They also complained that by the time the area was re-opened, red hind stocks had already spread out and were not accessible for the remainder of the year

Puerto Rican fishers' views regarding spags and fish abundance contrasted with the limited evidence from local biological assessments.[4] Most of these works did not establish causal relationships between the closures and the anticipated biological outcomes (Table 2). For instance, Marshak and Appeldoorn (2007) found that after the establishment of the red hind time-area closures on the west coast of Puerto Rico in 1996, there were sharp declines in fishing effort mainly during the spawning season, which briefly increased productivity (catch per unit of effort) throughout the platform and within the closed areas. As fishers substantially increased and redistributed their effort into previously unfished areas, and embraced technological advancements such as global positioning systems, earlier conservation benefits eroded. Marshak and Appeldoorn (2007) also noted that the observed increases in average fish sizes and the proportion of females immediately following the time-area closure were due to limited recruitment and contributions from remnant large females.[5]

Similarly, Baker et al. (2016) found that juvenile and adult queen conch densities were higher in federal waters around Puerto Rico, which are closed year-round. Juvenile queen conch densities rose from 2.3/ha in 1997 to 10/ha in 2013 in federal waters, whereas densities only rose from 4/ha to 6/ha in Commonwealth waters during the same period. The study also noted that even though surveys found

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[4] Griffith's et al. (2007) work on seven marine protected areas found that Puerto Rican fishers perceived that these were effective at protecting and/or maintaining spags (81% average, 67-86% range) and improving fish abundance outside the closed area (79% average, 63-86%range).

[5] It should be noted that the Marshak and Appeldoorn (2007) study was conducted at about the same time as the PR island-wide closure, which included a sales ban, regardless of where the fish was caught. It was following this regulation that there was a large drop in red hind landings, and so it is this measure that would have had the greatest impact on the stock. The Marshak and Appeldoorn study would not have seen this effect.

higher overall mean juvenile and adult queen conch densities in 2013 relative to 1997 and 2001, no improvements in mean density or size and age structure were detected after 2006.

Despite the anticipated conservation benefits of the closures, these measures can generate significant economic dislocations.[6] Although most fishers reported that they had overcome the economic obstacles triggered by the closures (with the exception of the Snapper Unit 1 closure), McNemar tests (with Holm-Bonferroni correction) showed that their progress was modest (Table 7). Statistically significant differences in pre- and post-closure hardship were only detected for the mutton snapper, red hind, and queen conch closures. Fishers recounted that their livelihoods were mostly impacted by the loss of resource and market access during periods of high demand, since most, if not all, of the landings are consumed locally rather than exported. They were most concerned about the queen conch closure and the overlapping Snapper Unit 1 (especially silk snapper) and red hind closures, which curtailed their sales during the summer and winter (especially Christmas) holiday seasons, respectively. One fisher, for example, claimed that the red hind closure alone had cost him between five and seven-thousand dollars.

Fishers explained that the disruption caused by the overlapping Snapper Unit 1 and red hind closures was frequently misunderstood because the closures were preceded by the months of September and October, known for inclement weather and rough seas, which curtail fishing activities; hence, they reasoned that these overlapping closures instead feel like one "five-month closure."

Regardless of these difficulties, most fishers stated that they adapted by targeting other species and/or switching to other gears. For instance, many queen conch divers switched to traps to catch spiny lobster, and others continued diving, but shifted to spiny lobster, lane snapper, and octopus. Similarly, fishers targeting silk snapper also reported shifting to other gears. Many switched to handlines to target yellowtail snapper, while others continued fishing with vertical lines, but targeted pelagic species such as dolphinfish, wahoo, king mackerel, and tuna. By contrast, few respondents moved to land-based jobs,

[6] Our percentage of fishers facing current hardships due to the seasonal closures (40% average, 33-47% range in Table 7) are in line with Griffith's et al. (2007) estimates of the percentage of Puerto Rican fishermen facing hardships due to marine protected areas (35% average, 32-46% range).

probably because there were few employment opportunities available to middle-aged men with limited formal education in the economically-distressed Commonwealth.

The ability of fishers to overcome the adverse consequences of the closures was also impacted by the local management context. In the case of the queen conch divers, fishers had recently benefited from revisions to the closure calendar. In 2012, the Commonwealth adjusted the closure dates from July 1 - September 30 to August 1 - October 31 to grant fishers greater access to the domestic tourist market during the summer season. In contrast, silk snapper fishers complained that they were shut out of the commercially valuable Snapper Unit 2 fishery (mainly queen and cardinal snappers), their mainstay fishery during the Snapper Unit 1 closure, because they did not qualify for the deep-water snapper fishery limited entry program, which started in 2013. Even those who qualified for the limited entry program stated that they had been negatively impacted from a number of early closures to redress Snapper Unit 2 quota overages in 2013 (September 21 - December 31) and again in 2016 (November 26 - December 31). Silk snapper fishers also objected to having to discard incidentally-caught deep-water species because the fish they caught were dead or not likely to survive after being released. This requirement was viewed as wasteful and ineffective.

Support for management actions usually increases the longer management actions have been in place (Pita et al., 2011a). For instance, Shivlani et al. (2008) document that commercial fishermen support for the establishment of the Florida Keys National Marine Sanctuary grew from 13% to 42% over a ten year span. However, our study found conflicting evidence that support for the closures grew over time. McNemar tests (with Holm-Bonferroni correction) showed statistically significant differences only for the mutton snapper and red hind closures (Table 8). Fishers recounted that their early support was rooted in the recognition that "*stocks needed an opportunity to rest up, spawn and grow*" and ensuring that "*fishing opportunities would remain available to them, their children and future generations,*" whereas the ensuing support stemmed from the perception that condition of the resource was improving. As one fisher noted "*I support the closures because I have seen first-hand silk snappers* *filled with roe during the closed season.*" Despite the growing approval of extant seasonal closures, most respondents objected to increasing the number of seasonal closures or extending their duration because of livelihood concerns.

Fishers who overcame their initial opposition to seasonal closures did so because they believed that the fishery had improved, they were able to adjust to the closures, or they simply gave in. Most fishers who remained opposed to the closures and those who withdrew their early support did so based on conservation and economic grounds. As one fisher succinctly put it: "*Seasonal closures do not work and only hurt fishers.*" These fishers continued to struggle to replace the lost income, and complained that the closed seasons were too lengthy. They felt that the closed seasons should be shortened (from 3 months to 1.5 months). Others felt that the seasonal closures should be completely eliminated because they understood that spawning occurred year-round or outside the closed season.

The survey concluded by soliciting advice on ways to further the performance of the closures. The most popular recommendation was to strengthen monitoring, control, and surveillance capabilities to reduce poaching and encourage compliance (30%). Also, fishers suggested stiffer fines and closer monitoring of recreational anglers, who they felt did not comply with regulations.

Although there were conflicting stances about the appropriate timing of the closures, slightly under a third of the respondents (29%) believed that the closure calendar needed to be revised based on socio-economic and local ecological knowledge considerations. Another 5% favored their elimination altogether. By contrast, about a quarter of the respondents felt that the timing of the closures should remain unchanged. Fishers seeking changes observed that spawning seasons differed around the island; therefore, the timing of the closures should be modified accordingly. For example, red hind fishers on the north coast argued that the timing of the closure was incorrectly set since they reasoned that red hind spawn in April. Another fisher argued that the red hind closure should be eliminated because he believed that red hind spawn year round. Similarly, silk snapper fishers on the north coast stated that silk snapper spawn earlier than the current closure, while others said that spawning occurred in the summer following the closure. Silk snapper fishers on the south coast argued that silk snapper spawned in September and October. A handful of fishers advocated for exploring the expansion of the queen conch closure due to the presence of egg bearing individuals in November (and even in January and February), as well as for the implementation of an octopus (and even a spiny lobster) seasonal closure. The majority of the fishers, however, said that additional seasonal closures were not warranted.

About 9% of the respondents suggested replacing the closures with other regulations such as time-area closures, marine protected areas (MPAs), gear restrictions, minimum sizes, net bans, and import restrictions, among others. Some of those who believed that the red hind, Snapper Unit 1, and mutton snapper closures had been effective said they preferred MPAs or rotating time-area closures because those management measures would afford them greater flexibility. Others suggested replacing the queen conch closure with size and depth restrictions (e.g., 120 ft.) and the mutton snapper closure with minimum sizes restrictions since they felt both species spawned year-round.[7] Additional suggestions included conducting more scientific research and improving fisher education (8%), and waiving discard requirements (or replacing them with gear-area restrictions, 3%). Fishers also felt that anthropogenic threats such as sedimentation and pollution should be addressed echoing similar concerns raised by fishers in the Ojeda-Serrano et al. (2007) study.

5. Conclusions

Despite the mounting interest in the use of seasonal closures to protect aggregating fisheries, few studies have examined the perceptions of fishers about closure performance. This study contributes to this sparse literature by focusing on the Puerto Rican experience with this management measure.

Our survey revealed that the majority of Puerto Rican fishers believed that closures were useful management measures for protecting spags and, to a lesser degree, increasing fish abundance. However,

[7] While these species may have protracted spawning seasons, studies by Appeldoorn et al. (2011) and Ojeda-Serrano et al. (2007) show that the vast majority of spawning occurs during a 3-4 month period.

fishers did not believe that these measures always improved their livelihoods, presumably because it can take a long period before the closures lead to increased spawning stock and enhanced recruitment. In other words, fishers believed that some of the anticipated conservation gains were lagging. Predictably, fisher support did not always increase after the adoption of the closures. The study showed that fishers had conflicting stances on the appropriate closure calendar based on economic and local ecological considerations. The study also found that fishers believed that the government needed to strengthen monitoring, control, and surveillance capabilities to reduce poaching and encourage compliance. This suggests that some fishers were conflicted between their normative preferences and economic well-being, which made them hesitant to refrain from fishing despite the potential for enduring benefits (McClanahan et al., 2014).

This work also underscores the importance of engaging fishers in decision-making. Fishers' beliefs about conservation and livelihood outcomes have been shown to be closely linked to their perceptions about management quality (Bennett and Dearden, 2004; Bennett, 2016). Moreover, fisher participation has been reported to increase accountability, transparency, legitimacy, support, and compliance with management interventions (Jentoft and McCay, 1995; Charles and Wilson, 2009; Pita et al., 2011b). Perhaps, a useful first step to promote participation would be to have fishers work closely with managers not only to define broad management goals, but also to set tangible, focused, and measurable objectives (targets). Without clear terms of reference, evaluations cannot conclusively determine whether management goals have been met (Agar et al., 2014). Agreed goals and objectives should take into account how life histories and environmental conditions affect recruitment, as well as how fishers will likely respond to regulations. Fishery scientists should also strive to better communicate the uncertainty surrounding their assessment results given the noisy and often partial data available and the simplifying assumptions used in assessment models (Cadrin, 2014). If evaluation results disagree with fisher observations, scientists should seek to understand the reasons why and be open to using other approaches (Cadrin, 2014).

While many of the concerns raised by fishers may not be placated, they may point to the need to devote additional resources to enhance our knowledge of spags and to be critical about past interventions. New investments may be necessary to conduct timely biological assessments of past management actions and periodically disseminate information on their performance. The use of passive acoustic methods may prove to be a valuable tool since they can monitor multiple spags simultaneously (Rowell et al., 2012). Additionally, managers should be amenable to a meaningful dialogue about the need to adjust the scale and scope of existing interventions. Otherwise, fishers may feel alienated from the management process, the ability of managers to develop meaningful management actions may be questioned, and the risk of non-compliance with rules and regulations may increase.

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Figure 1: Map of the Commonwealth of Puerto Rico.

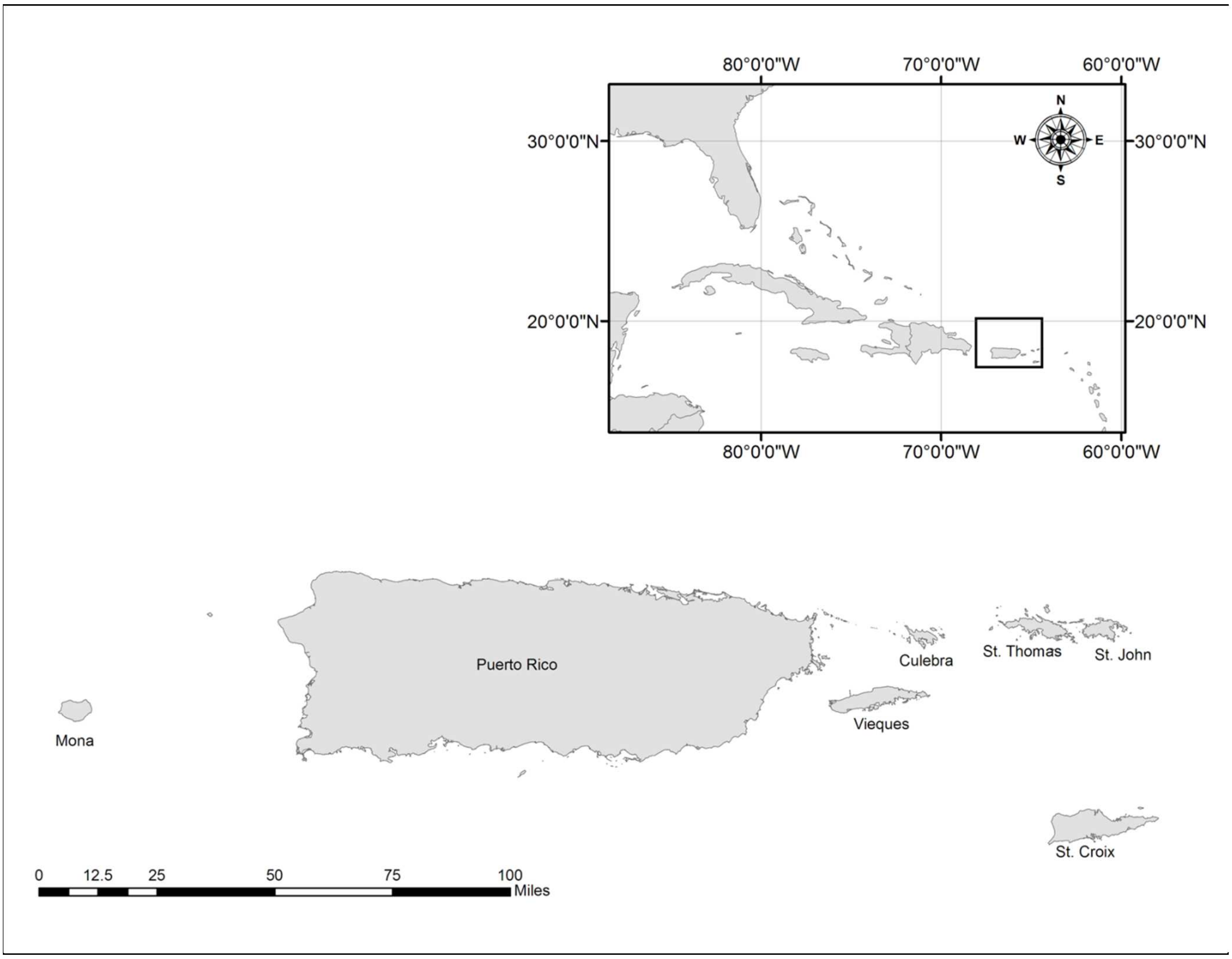

Table 1: Local and scientific finfish and shellfish names.

Common Name	Scientific Name
Grouper Unit 3 (Shallow-water)	
Coney	*Cephalopholis fulva*
Graysby	*Cephalopholis cruentata*
Red hind	*Epinephelus guttatus*
Rock hind	*Epinephelus adscensionis*
Grouper Unit 4 (Shallow and deep-water)	
Black grouper	*Mycteroperca bonaci*
Red grouper	Epinephelus morio
Tiger grouper	Mycteroperca tigris
Yellowfin grouper	Mycteroperca venenosa
Grouper Unit 5 (Deep-water)	
Misty grouper	*Epinephelus mystacinus*
Yellowedge grouper	*Hyporthodus flavolimbatus*
Snapper Unit 1 (Mostly shallow-water)	
Black snapper	*Apsilus dentatus*
Blackfin snapper	*Lutjanus buccanella*
Silk snapper	*Lutjanus vivanus*
Vermilion snapper	*Rhomboplites aurorubens*
Wenchman	*Pristipomoides aquilonaris*
Snapper Unit 2 (Deep-water)	
Cardinal snapper	*Pristipomoides macrophthalmus*
Queen snapper	*Etelis oculatus*
Snapper Unit 3 (Shallow-water)	
Dog snapper	*Lutjanus jocu*
Gray snapper	*Lutjanus griseus*
Lane snapper	*Lutjanus synargris*
Mahogany	*Lutjanus mahogoni*
Mutton snapper	*Lutjanus analis*
Schoolmaster	*Lutjanus apodus*
Snapper Unit 4 (Shallow-water)	
Yellowtail snapper	*Ocyurus chrysurus*
Coastal Pelagics	
Dolphinfish	*Coryphaena hippurus*
King Mackerel	*Scomberomorus cavalla*
Wahoo	*Acanthocybium solandri*
Other species	
Queen conch	*Lobatus gigas*
Spiny lobster	*Panulirus argus*

Table 2: Management experience with seasonal closures in the Commonwealth of Puerto Rico.

Seasonal closure	Jurisdiction	Year adopted	Outcomes	Comments	References
Mutton and lane snapper	Commonwealth (May 1-31, amended to Apr 1 – Jun 30 in 2007; mutton only) Federal (Apr 1 –Jun 30)	2004 2005	Unknown Mutton snapper aggregations heavily fished		CMFC (2009) as cited by Russell et al. (2012)
Red hind	Commonwealth 3 area-time closures, added island-wide seasonal closure in 2004 (Dec 1- last day of Feb) Federal (Dec 1- last day of Feb)	1993 2005	Landings and CPUE increased on west coast from 1996-1999	Possible positive effect but inconclusive.	Matos-Caraballo (2002), CFMC (2009) as cited by Russell et al. (2012), Marshak and Appeldoorn (2007)
Silk, vermilion, black and blackfin snapper	Federal (Oct 1 – Dec 31)	2005	Unknown		CFMC (2009) as cited by Russell et al. (2012)
Yellowfin Yellowfin, black, tiger, red and yellowedge grouper	Commonwealth (Feb 1- Apr. 30) Federal (Feb 1- Apr. 30)	2005 2005	Yellowfin grouper landings data show a substantial drop after 2005	Prior to closure, tiger grouper aggregations showed precipitous decline in landings and CPUE	Sadovy de Mitcheson and Erisman (2012)
Queen conch	Commonwealth (July 1– Sept. 30, amended to Aug. 1– Oct. 31 in 2012) Federal closed year-round	1997 1997	Marked increase (but still low) spawning stock evidenced by greater share of adults and presence older adult age-classes. Overall, higher mean juvenile and adult densities in 2013 relative to 1997 but no density improvements since 2006. Greater increase juvenile density in EEZ (relative to local waters) from 1997 to 2013	Biological gains influenced by other measures such as minimum size and shell-lip thickness restrictions.	Baker et al. (2016)

Adapted from Russell et al. (2012)

Table 3: Demographic and vessel characteristics (mean, median with standard deviation in parentheses).

	Coast				Commonwealth	N
	East	North	South	West		
Age (yrs)	53.2 53.5 (10.8)	58.3 59.5 (12.1)	56.6 58.0 (15.3)	54.3 55.0 (13.3)	55.7 56.5 (13.2)	150
Fishing experience (yrs)	24.5 20.0 (14.8)	26.3 28.0 (16.3)	33.3 32.5 (17.9)	32.0 30.0 (15.7)	29.6 30.0 (16.5)	150
Residence in community (yrs)	39.6 43.0 (20.0)	42.9 46.0 (19.4)	47.7 47.0 (21.5)	51.7 53.0 (16.6)	46.4 47.0 (19.6)	134
Household income from fishing (%)	61.2 65.0 (33.7)	58.9 50.0 (34.6)	71.1 87.5 (33.6)	71.1 80.0 (31.7)	66.4 75.0 (33.3)	147
Number of dependents	2.8 2.0 (1.5)	2.4 2.0 (1.2)	3.0 2.0 (1.5)	3.0 3.0 (1.4)	2.8 2.0 (1.4)	148
Time spent on fishing activities (hrs/wk)	31.5 34.5 (11.0)	31.2 30.0 (11.8)	35.2 36.0 (14.4)	35.8 35.0 (15.4)	33.9 35.0 (13.7)	144
Vessel length (ft)	23.0 20.5 (7.3)	20.2 20.0 (3.0)	19.6 20.0 (2.1)	19.6 19.0 (5.6)	20.4 20.0 (4.9)	148
Engine propulsion (hp)	91.6 60.0 (89.2)	85.1 60.0 (63.5)	61.2 60.0 (38.4)	67.6 50.0 (60.7)	74.3 60.0 (63.3)	147
Value of vessel and engine ($)	10,159.1 8,.000.0 (7,431.3)	16,908.6 12,000.0 (15,450.2)	7,117.6 6,250.0 (5,468.4)	7,070.5 4,750.0 (7,183.8)	10,136.3 6,500.0 (10,513.1)	135

Table 4: Do you believe that seasonal and area closures are effective fisheries management measures?

Views on efficacy (%)	Strongly Agree	Somewhat Agree	No impact	DK/NA	N
Seasonal closures					
West coast	70.0	14.0	16.0	-	50
South coast	65.8	13.2	15.8	5.3	38
East coast	34.6	34.6	26.9	3.9	26
North coast	41.7	22.2	30.6	5.6	36
Commonwealth	56.0	19.3	21.3	3.3	150
Area closures					
West coast	48.0	10.0	26.0	16.0	50
South coast	42.1	7.9	10.5	39.5	38
East coast	34.6	42.3	19.2	3.9	26
North coast	30.6	25.0	8.3	36.1	36
Commonwealth	40.0	18.7	16.7	24.7	150

Table 5: Do you believe that seasonal closures have been effective protecting spawning aggregations?

Protects spawning aggregations (%)	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	DK/NA	N
Mutton and lane snapper (Apr. 1 –Jun 30; Federal only)	57.5	10.0	5.0	7.5	15.0	5.0	40
Red hind (Dec 1- last day of Feb.)	57.0	9.3	8.1	8.1	17.4	-	86
Silk, vermilion, black and blackfin snapper (Oct. 1 – Dec. 31)	47.3	14.9	6.8	6.8	21.6	2.7	74
Yellowfin, black, tiger, red and yellowedge grouper (Feb 1- Apr. 30)	66.7	5.6	11.1	5.6	5.6	5.6	18
Mutton snapper (Apr. 1 – Jun. 30; Commonwealth only)	65.1	9.3	2.3	4.7	14.0	4.7	86
Queen conch (Aug 31 - Oct 31; Commonwealth only)	71.9	5.3	7.0	7.0	7.0	1.8	57

Table 6: Do you believe that seasonal closures have been effective increasing fish abundance?

Increases fish abundance	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree	DK/NA	N
Mutton and lane snapper (Apr. 1 –Jun 30; Federal only)	52.5	12.5	7.5	12.5	10.0	5.0	40
Red hind (Dec 1- last day of Feb.)	50.0	9.3	9.3	11.6	14.0	5.8	86
Silk, vermilion, black and blackfin snapper (Oct. 1 – Dec. 31)	41.9	9.5	16.2	12.2	16.2	4.1	74
Yellowfin, black, tiger, red and yellowedge grouper (Feb 1- Apr. 30)	44.4	5.6	33.3	11.1	-	5.6	18
Mutton snapper (Apr. 1 – Jun. 30; Commonwealth only)	61.6	7.0	7.0	8.1	9.3	7.0	86
Queen conch (Aug 31 - Oct 31; Commonwealth only)	59.7	5.3	14.0	8.8	10.5	1.8	57

Table 7: Fisher initial and current hardship status for individual seasonal closures.

Seasonal closure	Initial hardship (%)	Current hardship (%)	P-value	N	Notes
Mutton and lane snapper	53.9	38.5	0.0313	39	3 fishers initially unaware of closure
Red hind	53.5	40.7	0.0034*	86	4 fishers initially unaware of closure
Silk, vermilion, black, and blackfin snapper	40.6	46.4	0.6587	69	3 fishers initially unaware of closure
Yellowfin, black, tiger, red, and yellowedge grouper	55.6	33.3	0.1250	18	1 fisher initially unaware of closure
Mutton snapper (Commonwealth only)	56.0	34.5	<.0001*	84	7 fishers initially unaware of closure
Queen conch (Commonwealth only)	66.7	47.4	0.0010*	57	-

*Significant with Holm-Bonferroni correction ($\alpha_1 = 0.008$, $\alpha_2 = 0.010$, $\alpha_3 = 0.013$).

Table 8: Fisher initial and current closure support for individual seasonal closures.

Seasonal closure	Initial support for seasonal closure (%)	Present support for seasonal closure (%)	P-value	N	Notes
Mutton and lane snapper	54.3	68.6	0.0625	35	3 fishers initially unaware of closure
Red hind	41.5	65.9	<.0001*	82	4 fishers initially unaware of closure
Silk, vermilion, black, and blackfin snapper	41.4	54.3	0.0225	70	3 fishers initially unaware of closure
Yellowfin, black, tiger, red, and yellowedge grouper	47.1	47.1	1.0	17	1 fisher initially unaware of closure
Mutton snapper (Commonwealth only)	47.4	65.8	0.0001*	76	7 fishers initially unaware of closure
Queen conch (Commonwealth only)	51.8	66.1	0.0574	56	-

*Significant with Holm-Bonferroni correction ($\alpha_1 = 0.008$, $\alpha_2 = 0.010$, $\alpha_3 = 0.013$).