Investigation of the Nassau grouper (*Epinephelus striatus*) Fishery in the Turks and Caicos Islands: Implications for Conservation and Management

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ABSTRACT

Nassau grouper (*Epinephelus striatus*) fishing pressure is still moderate in the Turks and Caicos Islands (TCI) and population densities encountered are amongst the highest within the Caribbean. Nevertheless, as tourism grows in the country, increased demand on local finfish stocks, particularly on the endangered Nassau grouper, may result. Because of their life history traits, Nassau grouper are particularly vulnerable to over-fishing and warrant necessary protection. Currently, the TCI has no restrictions on Nassau grouper harvest. Dockside monitoring, fishermen surveys, GIS technology, and restaurant phone interviews were used to collect data on (1) size distributions, (2) geographical distribution of fishing effort, (3) CPUE, and (4) restaurant demand. Mean total length (TL) and weight (kg) of all Nassau grouper (n = 79) measured in dock landings was 55.4 cm $\pm$ 3.6 cm S.E. and 3.6 kg $\pm$ 0.4 kg S.E., respectively. Most Nassau grouper (n = 54) were harvested from one region known as "the Lakes." Twenty-eight Nassau grouper with a mean TL of 68.4 cm $\pm$ 13.0 cm S.E. were caught in deep water compared to 39 caught in shallow water with a mean TL of 45.5 cm $\pm$ 7.3 cm S.E. The average CPUE was calculated as 0.44 fish/fisherman/hour and 2.18 kg/spear/hour. Twenty-nine restaurants were phoned and 67% cited customer preference as the main reason for serving Nassau grouper. Based on the findings of this study, proactive management advices are suggested such as size limits, closed seasons, and/or quotas. The implementation of those restrictions in conjunction with co-management will protect the Nassau grouper fishery from over-harvest.

KEY WORDS: Nassau grouper, CPUE, fisheries

Pesquería del Mero de Nassau (*Epinephelus stratus*) en Tursk and Caicos Islands:

La presión de la pesca del mero de Nassau (*Epinephelus striatus*) es todavía moderada en Turks and Caicos Islands (TCI) y las densidades de población encontradas están entre las mayores en el Caribe. Sin embargo el crecimiento del turismo en el país, puede resultar en un incremento de la demanda sobre las reservas locales de peces de aleta, especialmente en sobre el mero de Nassau, el que se encuentra en peligro. Por los rasgos de su historia de vida, los meros de Nassau son particularmente vulnerables a una sobre pesca y justifica una necesaria protección. Actualmente, TCI no tiene restricciones en la recolección del mero de Nassau. Monitoreos en el muelle, encuestas a los Pescadores, tecnología de GIS y entrevistas telefónicas a los restaurantes fueron usadas para recolectar los datos en (1) tamaño de las distribuciones, (2) distribución geográfica del esfuerzo de pesca, (3) CPUE, y (4) demanda de los restaurantes. El promedio de largo total (TL) y peso (kg) de todos los meros de Nassau (n = 79) medidos en el muelle fue de 55.4 cm $\pm$ 3.6 cm S.E. y 3.6 kg $\pm$ 0.4 kg S.E. respectivamente. CPUE fue calculado como 0.44 pez/pescador/hora y 2.18 kg/lanza/hora. Veintinueve restaurantes fueron telefoneados y 67% citaron la preferencia de los clientes como la principal razón para servir mero de Nassau. Basado en las conclusiones de este estudio, consejos para una gestión proactiva son sugeridos como limitaciones en el tamaño, temporadas de veda, y/o cuotas. La implementación de dichas restricciones junto con una co gestión protegerán la pesquería del mero de Nassau de una sobre-pesca.

PALABRAS CLAVES: Mero de Nassau, CPUE, pesquería

Les Pêcheries de Mérous (*Epinehephlus striatus*) dans le Îles Turks et Caicos (ITC): Implication pour la Conservation et le Mangement

La pression de pêche du mérou ((*Epinephlus striatus*) est encore assez modérée dans les ITC et les densités de population rencontrées sont parmi les plus élevées dans les Caraïbes. Néanmoins, avec le tourisme grandissant, la demande de poissons locaux, et particulièrement de mérous, pourrait augmenter. A cause des ces caractéristiques de vie, le mérou est particulièrement vulnérable à la surpêche. Pour le moment, les ITC n'ont pas de restriction pour la pêche des mérous. Des monitorings des docks, des enquêtes auprès des pêcheurs, des SIG et des interviews téléphoniques aux restaurants, ont été utilisés pour collecter des données sur (1) la distribution des tailles, (2) la distribution de l'effort de pêche, (3) le CPUE, (4) la demande des restaurants. La longueur totale (TL) et le poids (kg) de tous les mérous (n=79) mesuré aux docks était 55.4 cm + 16.3 cm et 3.64 kg + 2.72 kg respectivement. La plupart (n = 54) des mérous ont été pêché dans une région connue comme "the Lakes." 28 mérous avec une TL de 68.4 cm + 8.25 cm ont été captures dans des eaux profondes et 39 dans des eaux peu profondes avec un TL de 45.5 cm + 14.0 cm. CPUE a été calculé étant 0.59 poisson/pêcheur/heure et 2.15 kg/lance/heure. Vingt-neuf restaurants ont été appelés et 67% citent la préférence des clients comme étant la raison principale pour servir du mérou. En se basant sur les résultats de cette étude, des conseils de gestion proactive sont suggérés, comme une taille limite, une saison fermée à la pêche et/ou l'établissement de quotas. L'implémentation de ces restrictions en conjonction avec un co-management protégera les pêcheries de mérous de la surpêche

MOTS CLÉS: Mérou, CPUE, Pêcheries

INTRODUCTION

The economy of the Turks and Caicos Islands (TCI) is based on offshore banking, tourism, and its fisheries. The TCI's tourism industry continues to grow as evidenced by a 41% growth rate in the number of tourist arrivals and between 2005 and 2006 (DEPS 2008). The hub of this industry is centered on the island of Providenciales, but commercial developments are expanding to several other islands in the archipelago. However, investing so heavily in the tourism industry is risky since it is highly dependent on other countries' economic statuses. In order to maintain economic resilience, it is important for countries to diversify their involvement in alternative financial activities (Robards and Greenberg 2007). The fisheries industry comprises the third most important economic sector for the TCI, particularly the spiny lobster, *Panulirus argus*, and queen conch, *Strombas gigas*, fisheries. The exploitation of these two species began in the mid-1800s and early 1900s respectively (Rudd 2003).

Historically, catch-per-unit-effort (CPUE) for the conch fishery has varied greatly, but has risen steadily since 1988 (Rudd 2003). The lobster fishery, however, has seen a decreasing trend in CPUE in recent years along with a decrease in landings (Rudd 2003, TCI Government 2004). While the TCI Department of Environment and Coastal Resources (DECR) believes the conch fishery is healthy, fishing effort for the more profitable lobsters may be nearing an unsustainable level (TCI Government 2004). In 1999, the DECR estimated roughly 40% of the lobster landings were undersized individuals (Hall and Close 2007), and Rudd *et al.* (2001) estimated 95% of lobsters landed in certain fishing grounds were below the minimum carapace length limit of 8.3 cm.

The demand for local finfish, particularly grouper has occurred due in part to the decline in lobster landings as well as the recent tourism boom and 40% seafood import tax has (MPA News 2001, Rudd 2001). The finfish fishery is believed to be underutilized and stock densities considered high compared to other areas in the Caribbean (Rudd 2003, TCI Government 2004) making this alternative business venture an excellent candidate for facilitating economic expansion. In the TCI, the Nassau grouper, *Epinephelus striatus*, has been a traditionally targeted finfish for domestic consumption (Olsen 1985, Rudd 2003), and is recently receiving more attention from restaurants as tourism demand for this species increases (Rudd 2001). As a result, *E. striatus* may begin receiving increased fishing pressure (Rudd 2001, Tupper and Rudd 2002, MPA News 2001), making them susceptible to overfishing. At present, the Nassau grouper's population is believed to be greater than 10,000 reproductively active individuals. This marks a 60% stock decline in the last three decades (IUCN 2008). At one time, the Nassau grouper was the most commonly caught fish species in the Caribbean (Sadovy and Domeier 2005). Today, however, in many parts of its range the Nassau grouper is considered commercially extinct (Sadovy and Eklund 1999).

Historically, minimum size limits, temporal and spatial restrictions during the spawning season, total fishing bans, and marine protected areas (MPAs) have all been used in an effort to conserve and protect Nassau grouper stocks (Sluka and Sullivan 1998, Sadovy and Eklund 1999, Tupper and Rudd 2002, IUCN 2007). However, illegal fishing (Chiappone *et al.* 2000), ineffective size limits (Sadovy and Eklund 1999), movement outside of protected areas (Tupper and Rudd 2002), and lack of enforcement (Sluka *et al.* 1997) have contributed to management failure and caused exploitation to continue. Currently, there exist few regulations protecting finfish in the TCI beyond gear restrictions and a ban on fishing in some MPAs.

Proper management is paramount if the TCI stands to gain any long-term economic benefits from the Nassau grouper fishery. This study aims to investigate the characteristics of the fishery by:

i) Examining size distributions of Nassau grouper landed,
ii) Revealing patterns of fishing pressure using GIS technology and detailed maps,
iii) Calculating CPUE for Nassau grouper, and
iv) Ascertaining current consumer demand using restaurant phone interviews.

These data are used to describe suitable approaches to management for Nassau grouper in the TCI.

METHODS

Species

The Nassau grouper's lifespan can stretch some 29 years during which they can grow to weights upwards of 27 kg and total lengths of 122 cm (Sadovy and Eklund 1999). *E. striatus* reach sexual maturity between 45-55 cm total length, and age at sexual maturity ranges between four and eight years (Sadovy and Eklund 1999). Food preferences are variable and include crustaceans, fish, and occasionally sea turtles (Randall 1967). Juvenile Nassau grouper prefer shallow, macroalgae habitat (Eggleston 1995) before shifting to reef habitats as adults (Sadovy and Eklund 1999, Tupper 2000). *E. striatus* spawn in aggregations between December and April, often coinciding with the full moon (Thompson and Munro 1978, Colin 1992, Sadovy and Eklund 1999).

Study Site

The Turks and Caicos Islands are located on the southern tip of the Bahamian Archipelago and consist of eight inhabited islands and 41 cays (Hall and Close 2007). The shallow Caicos Bank and Turks Bank as well as the deeper, completely submerged Mouchoir Bank comprise the majority of fishing grounds in the TCI (Figure 1). South Caicos is home to the majority of commercial fishermen in the archipelago (Rudd 2003). Fishermen typically operate in groups of three fishing from fiberglass

boats generally 4 - 5 m in length and powered by 70 - 110 horsepower motors. These small vessels can reach fishing areas up to 40 km from port (Rudd 2003). Toward mid to late afternoon, fishermen return to the docks where they unload their catch at one of three processing plants on the island.

Data Collection and Analysis

Dockside monitoring occurred on South Caicos between April 11 and April 28, 2008. Total length (TL) was recorded to the nearest tenth of a centimeter from all finfish, including Nassau grouper, brought to the docks. For each set of groupers returned to the dock, fishermen were asked to complete a short questionnaire (Table 1) detailing their catches and asked to either verbally describe catch locations or point to locations on a map. Catch-per-unit-effort (CPUE) was calculated two ways: (1) total number of Nassau grouper caught per fishermen per hour and (2) sum weight of catch per number of spears per hour. Though weights were not collected during sampling because fish were gutted at sea to preserve the quality of meat, they were extrapolated using a length-weight calculator provided by FishBase (2008). Furthermore, two additional sampling periods – spring 2006 (March 8th to April 30th) and fall 2007 (November 19th to December 5th) – were used to create a more robust size distribution analysis. We compared the effect of gear use on size distributions (TL) for the harvest methods that yielded the most Nassau grouper catches in the fall 2007 (traps) and this study's spring 2008 (Hawaiian sling) sampling period. In addition, we compared size distributions of harvests from "shallow" (0 - 6 m) and "deep" (15+ m) water. Each catch location was entered into the GIS software ArcView 9.0 (ESRI) to show distributions of fishing pressure (Hall and Close 2007). Lastly, in order to determine demand for this species, restaurants on Providenciales were phoned and asked their preferences for serving Nassau grouper to their customers. Since the majority of the TCI's tourism takes place on Providenciales, only restaurants on this island were phoned.

All data were analyzed in Microsoft® Excel (2003) and graphs created in Sigma Plot 10.0. T-tests were used to determine statistical significance between depth and mean length (TL) of catch as well as for mean lengths (TL) of grouper caught by trap and Hawaiian sling in fall 2007 and spring 2008, respectively.

Table 1. 10 question fisherman survey.

Date:	Boat Name:
Time Out:	Registration #:
Time In:	Fisherman:

1. Where did you fish?
2. Why did you pick this location? Be specific.
3. How deep is it at this location?
4. Can you describe the ocean bottom at this location?
5. What method did you use to fish?
6. How many lines/hooks/spears?
7. How long were you fishing today (specifically for finfish)?
8. How many people are on your boat?
9. How many people fished for finfish

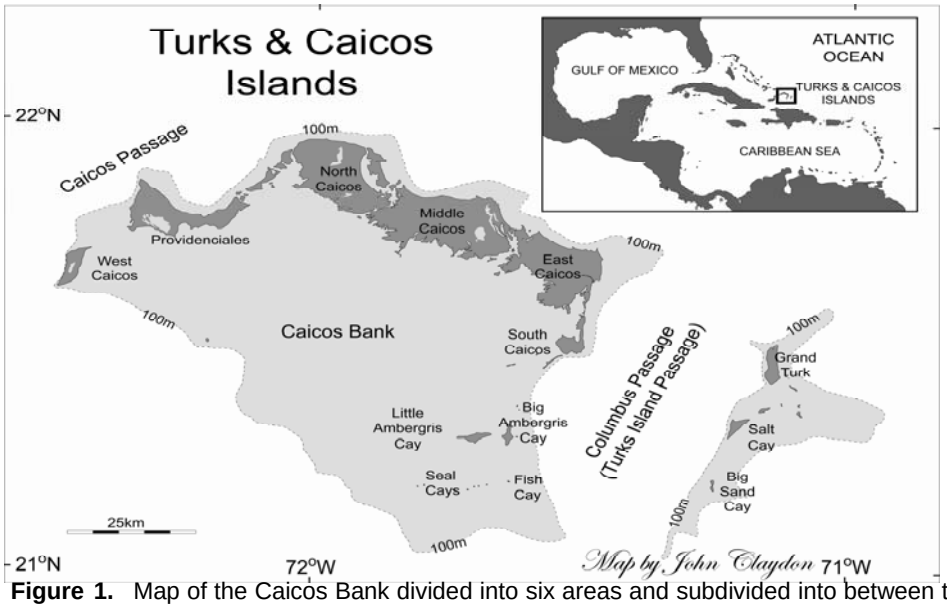

Figure 1. Map of the Caicos Bank divided into six areas and subdivided into between two and seven sub-zones.

RESULTS

Of the 1,321 finfish returned to the landing docks during our sampling period, 79 were Nassau grouper (6.0%). Sizes ranged from 25 cm TL to 84.4 cm (Figure 4), and mean TL was 55.4 cm ± 3.6 cm S.E. Also, mean weights were 3.6 kg ± 0.4 kg S.E. (Figure 2). Mean TL distributions for the spring 2006 (n = 26) sampling period were 48.7 ± 9.6 cm S.E. and for fall 2007 (n = 115) were 54.4 ± 5.1 cm S.E.

Furthermore, 91.1% (n = 72) were harvested using Hawaiian slings with a mean total length of 54.1 cm ± 6.4 cm S.E, compared to traps that caught for 8.8% (n = 7) of Nassau grouper harvested and yielded a mean total length of 68.8 cm ± 26.0 cm S.E. Comparison of harvest methods that yielded the most Nassau grouper catches for fall 2007 (lobster traps) and spring 2008 (Hawaiian slings) showed traps (n = 74) produced a mean total lengths of 42.7 cm ± 5.0 cm S.E. and 54.1 ± 6.4 cm S.E. for Hawaiian slings (n = 72) (Table 3), creating a significant difference in the size of harvested grouper between the two methods ($t = 1.98$, $p < 0.001$).

The majority of Nassau grouper (n = 54) were taken from a region dubbed "the Lakes" that consists of Ambergris Cays, Fish Cays, Six Hills Cays, and Long Cay (Figure 3). Of the 13 boats sampled, only three boats specifically targeted finfish both for sale and personal consumption, and only two returned with Nassau grouper. Duration of each trip for these two boats ranged from one to eight hours, with boats typically returning mid-late afternoon. Boats operate in teams of three: two fishermen diving and the third fishermen stationed in the boat in case of emergency.

Divers fished as deep as 27 m, but typically fished water 6 m or less. The results of a two sample, equal variance t-test showed a highly significant difference between size variations at different depths ($t = 2.00$, $p < 0.001$). Mean total length was greater (n = 28; 68.4 cm ± 13.0 cm S.E.) in deep water than in shallow water (n = 39; 45.5 cm ± 7.3 cm S.E.) (Table 4).

Seventy-one of the 79 Nassau grouper sampled were used to calculate CPUE. Seven Nassau grouper were sold to a middle man who did not know details of the catches aside from the method used (trap). One boat sold all but one fish from their day's catch to a resort on Ambergris Cay. This single fish was not counted because it did not accurately represent the day's catch. Two boats made nine fishing trips during the study's duration. CPUE for these trips was 0.44 fish/fisherman/hour and 2.18 kg/spear/hour (Table 2).

Of the 32 restaurants phoned on Providenciales a total of 29 restaurants responded to inquiries regarding serving preference of Nassau grouper, and were categorized as follows:

i) No greater value compared to other fish (21%),
ii) Customer preference (67%), and
iii) Chef preference (12%).

Table 2. Individual and mean Nassau grouper CPUE values calculated using total number Nassau grouper/total number fishermen/total fishing hours (A), and sum weight (kg)/total number spears/total fishing hours (B).

Method	Mean # Nassau Grouper	Mean # Fishermen	Mean # Hours	Mean CPUE	CPUE Range
A	7.89	2.89	6.23	0.44	0.19-1.57
B	27.17	2	6.23	2.18	0.28-4.70

Table 3. Size distribution comparison of primary harvest methods from data collected in fall 2007 and spring 2008.

Gear Type	Year	Sample Size (n)	Mean (cm)	S.E. (cm)	Range (cm)
Hawaiian Sling	2008	72	54.1	6.4	25-84.40
Traps	2007	74	42.7	5.0	21.9-62.6

Table 4. Size distribution comparison of Nassau grouper harvested from shallow water (0-6 m) and deep water (>15 m).

Depth	Sample Size (n)	Mean (cm)	S.E. (cm)	Range (cm)
Shallow (0-6 m)	39	45.5	7.3	25-73.5
Deep (>15 m)	28	68.4	12.9	53.6-84.4

DISCUSSION

TCI Nassau Grouper Status

The size distributions for *E. striatus* were bimodal, showing peaks between 30 - 44.9 cm TL and another at 60 - 74.9 cm TL. The peak of larger sizes could be explained by one boat that typically pursued Nassau grouper only in deeper water (15 - 30 m) where bigger adults are known to be found (Thompson and Munro 1978). The peak of smaller sizes may be explained by one boat who typically sought various finfish species, including Nassau grouper, in shallower water (0 - 6 m) where juvenile *E. striatus* are known to inhabit (Sluka *et al.* 1994, Eggleston 1995). Furthermore, since the upper limit of size at sexual maturity is around 55 cm TL (Sadovy and Eklund 1999), the amount of juvenile harvest (n = 34, 43%) could be problematic. To examine this potential problem, additional data from past collection periods during spring 2006 and fall 2007 (School for Field Studies Unpubl. data) were analyzed. One-hundred and fifteen Nassau grouper were collected in fall 2007 with 51.3% (n = 59) below 55 cm, and 26 Nassau grouper were sampled in spring 2006 with 65.4% (n = 17) below 55 cm TL (Figure 4). While good numbers of sexually mature Nassau grouper are harvested, there is still cause for concern that the more accessible juveniles will continue to be harvested at a rate that may eventually be unsustainable.

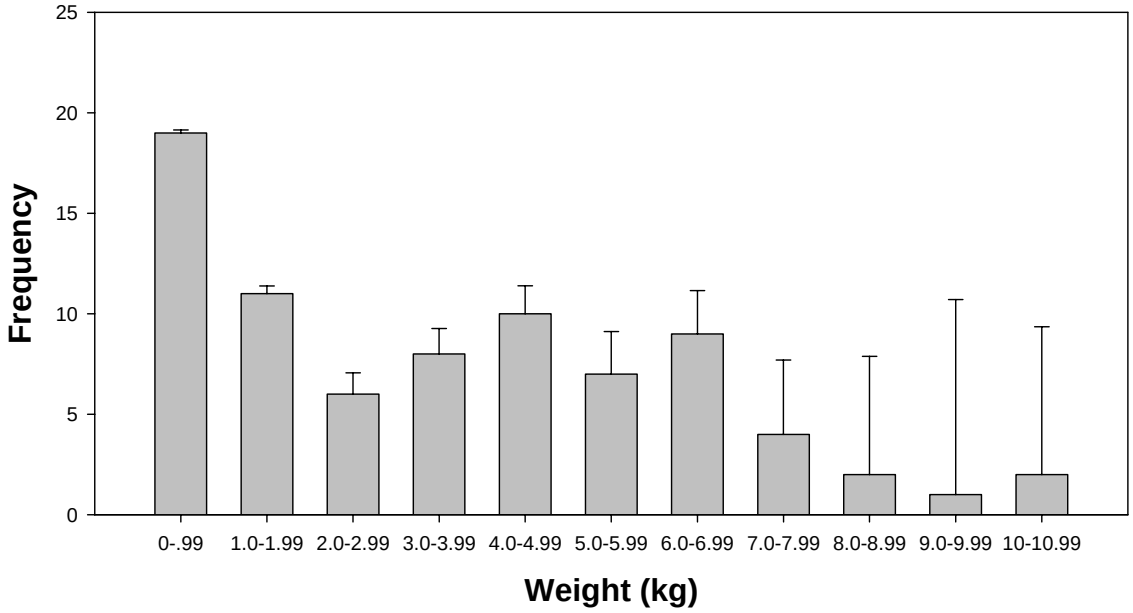

Figure 2. Frequency distribution of Nassau grouper weights (kg) (n=79; mean 3.6 kg ± 0.4 kg S.E.) from harvests in 2008.

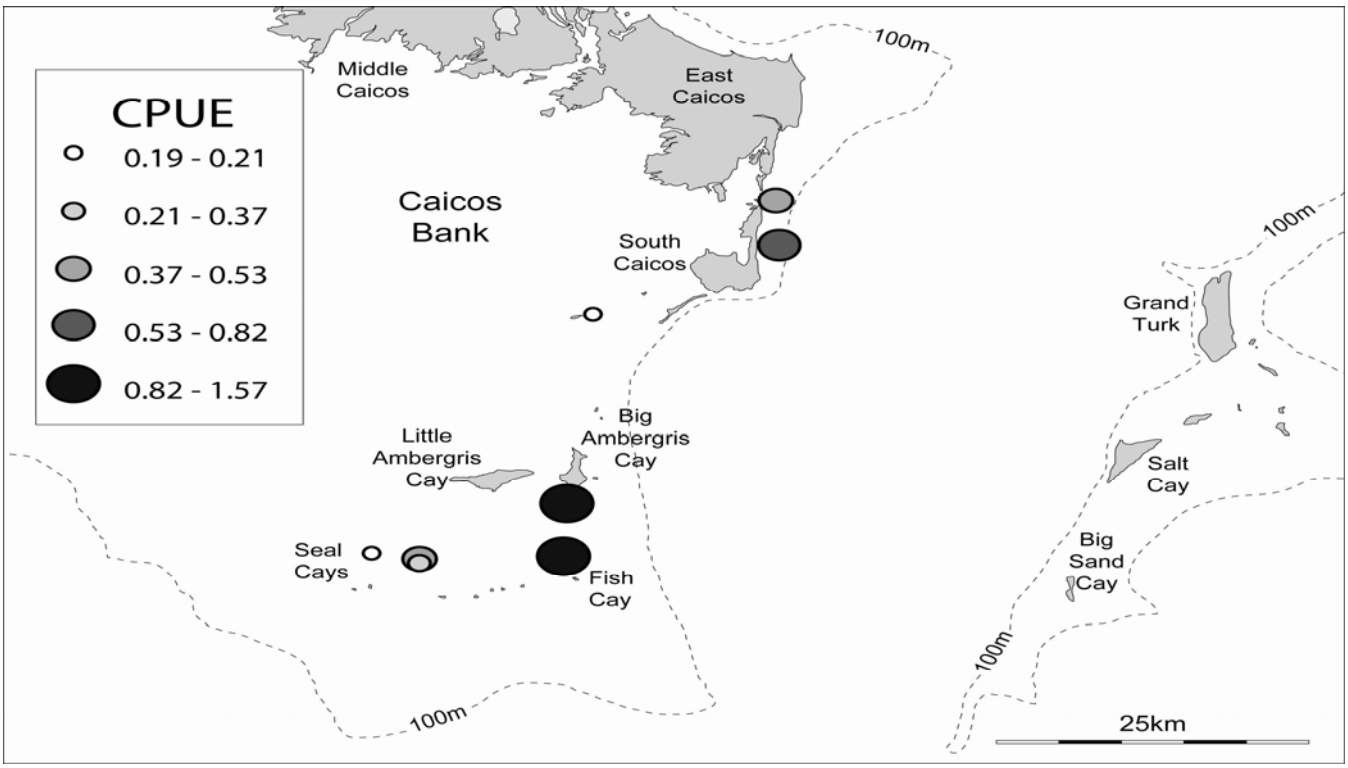

Figure 3. GIS based map of the Turks and Caicos Islands with 2008 Nassau grouper harvest locations and corresponding CPUE values. Increasing circle size denotes greater CPUE at those locations, and vice versa.

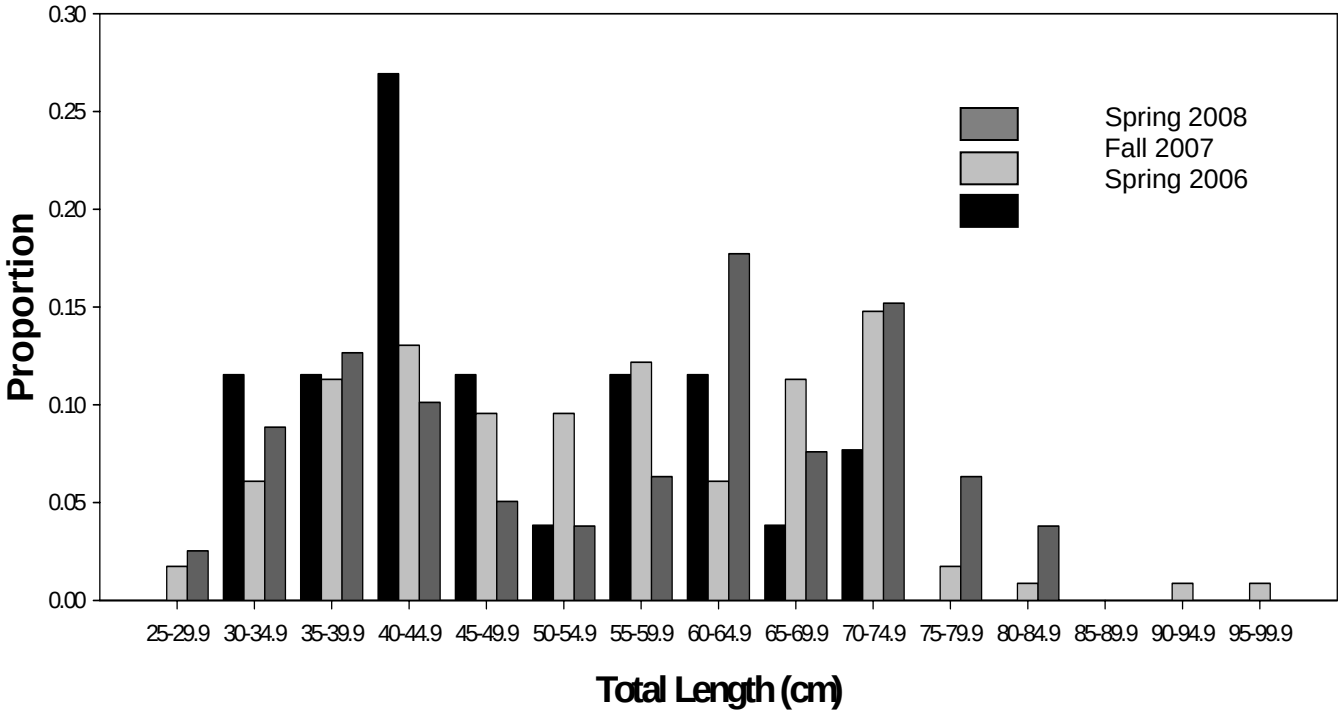

Figure 4. Proportion of Nassau grouper total lengths from individuals harvested in spring 2006 (n = 26; 48.7 cm ± 9.6 cm S.E.), fall 2007 (n = 115; 54.4 cm ± 5.1 cm S.E.), and spring 2008 (n = 79; 55.4 cm ± 6.2 cm S.E.).

One consequence of using lobster traps is their tendency to select for smaller fish, including Nassau grouper. Currently, there is a 10 inch trap aperture size that may be selecting for juvenile grouper. Of the 74 Nassau grouper harvested by traps in 2007, only 20% (n = 15) were above 55 cm total length. Vo (2008) reported 32% of Nassau grouper caught in lobster traps were sexually immature. Removing juveniles from a population results in lost opportunities for those individuals to reproduce. Furthermore, should the harvest of large, sexually mature individuals continue and progress towards unsustainable rates, the loss of juveniles may result in the population's inability to recover from over-exploitation.

Loss of juveniles due to using Hawaiian slings appears to be less of a concern. In the TCI, commercial license holders are permitted to use Hawaiian slings as long as the spear does not exceed five feet in length and the elastic bands not exceed 18 inches in length by one-half inch in width (TCI Amendments 1998). Spear fishing enables a person to select the exact individual they want to harvest. As a result, there should be, theoretically, no by-catch (Nevill 2004). In some scenarios, harvest by spear may be more efficient, both in terms of energy and time, than traditional hook and line (Nevill 2004). Comparing Hawaiian sling harvests in 2008 to trap harvests in 2007 shows a near 10 cm increase in total length for fish harvested. Since fishermen are paid by the weight of their catch, it is to their advantage to harvest the largest individuals possible. This, however, is a slippery slope since removing too many large, more fecund individuals may prevent necessary population growth to compensate for increased harvest and could, ultimately, lead to severe population declines.

CPUE for Nassau grouper was 0.44 fish/fisherman/hour and 2.18 kg/fisherman/hour. CPUE is considered to be relatively low throughout the Nassau grouper's range (Sadovy and Eklund 1999), and the values calculated in this study are comparatively high. CPUE for weight was based on weight/spear/hour, but the array of fishing gear used makes it difficult to compare to other CPUE values. However, since the Hawaiian sling appears to be an extremely important method of harvest in the TCI this CPUE value may be important for fisheries managers to use to compare the health of the Nassau grouper fishery in the future. Furthermore, Sadovy and Eklund (1999) suggest that there are not many Nassau grouper fisheries outside of aggregation exploitation, but these CPUE values may be an indication that a non-aggregation associated fishery is developing.

In addition to the Nassau grouper fishery in the TCI, it is possible that a misty grouper, *Epinephelus mystacinus*, deep-sea fishery is emerging. During the collection period, we sampled two deep-sea fishing boats. The vast majority of species landed were snapper, but a number of misty grouper were also harvested (n = 69). These are known to inhabit very deep water from 100 - 400 m, reach a

maximum length of 160 cm TL, and weigh in excess of 107 kg. Mean TL for *E. mystacinus* collected was 73 cm ± 7.8 cm S.E. Little is known, however, about reproduction, growth rates, and age (FishBase 2008). Therefore, future studies should seek to enhance the knowledge base of the Misty grouper and further evaluate its viability as a commercial fish species.

Implications for Management

Customer preference for Nassau grouper constituted 67% of all responses given during phone surveys. Therefore, as tourism infrastructure grows and the number of tourists per annum increases throughout the TCI, an increase in demand for Nassau grouper is expected to follow suit. This is likely to result in increased fishing effort for Nassau grouper. Unfortunately, this species does not appear resilient to high fishing pressure and dramatic declines in populations have followed almost all commercial fisheries throughout its range (Sadovy and Eklund 1999).

It is imperative that the TCI government regulate the Nassau grouper fishery proactively. The largest factor leading to over-exploitation of *E.striatus* appears to be concentrating fishing effort, both spatially and temporally, around its spawning aggregations, either fishing the aggregation itself or fishing migration routes (Aguilar-Perera and Aguilar-Dávila 1996, Sala *et al.* 2001). Top priority should be the establishment of a closed season between December 1st and March 1st that protects the species during these vulnerable activities. A complete moratorium on fishing during this period may also make enforcement easier since prohibiting fishing specific spawning aggregations can be difficult to enforce given their remote locations (Colin 1992).

One step in improving the overall knowledge base of this species' presence in the TCI is to perform a comprehensive stock assessment. Depending on the conclusions of the assessment, it may be beneficial for fisheries managers to enact a total allowable catch (TAC) in conjunction with a seasonal closure. This may be an effective way to protect the resource, as has previously been recommended by Tupper and Rudd (2002). Fishermen can still harvest the highly profitable spiny lobster and minimize income loss during the Nassau grouper seasonal closure. It is recommended that a precautionary approach be taken to establish a Nassau grouper TAC because this species is particularly vulnerable to over-fishing. Restaurant and processing plant compliance is vital, thus it should also be required that these businesses log any Nassau grouper purchased within the TCI. One major advantage to this output control is that it can be easily monitored from shore, thereby greatly reducing on-water enforcement costs (Tupper and Rudd 2002).

Continued removal of juveniles from the current stock may, over time, reduce the number of recruits entering a population thereby slowly causing population declines (Sadovy and Eklund 1999) and reducing a population's ability to rebound from rampant overexploitation. Therefore, it is highly recommended that a minimum size limit of 55 cm TL, representing size at sexual maturity, be created to prevent growth over-fishing. Size limits should, however, not be created without considering the needs of fishermen. Our data for spring 2008 show that slightly more than half of the fish harvested would fall above the proposed 55 cm TL size limit and thus could legally be harvested. Since fishermen are paid by weight, prohibiting taking of smaller juveniles versus larger adults should translate to less money lost if this management technique is employed. Whilst a maximum size limit would assist in maintaining a high egg production from the population, this may be ill-favored by fishermen as this would exclude the most profitable individuals from being harvested. Also of note, however, is the great number of sexually immature grouper taken in lobster traps as by-catch. This is likely caused by a small aperture size (3.9 cm) that selects for smaller fish and excludes larger individuals. Based on 55 cm size at sexual maturity, data from fall 2007 (School for Field Studies Unpubl. data) reveal juvenile Nassau grouper trap catches comprised 79% of the total trap catches. Therefore, a regulation increasing trap aperture size to allow greater proportion of juvenile Nassau grouper to escape should be considered.

Encouraging anecdotal evidence noted by Vo (2008) suggests local fishermen recognize that small, juvenile fish are needed in order to sustain a fishery. Often, these small fish are removed from the traps and released. During this study, conversations with Hawaiian sling fishermen revealed they will often pass on the opportunity to harvest smaller individuals even when the opportunity arises. In both instances, fishermen cite increased profit from larger individuals as the driving force behind their actions. Also, since each individual fish when using Hawaiian slings is visually identified before harvesting there is greater potential for spear fishermen to select only individuals above 55 cm TL, assuming the fishermen have the ability to correctly estimate sizes underwater. This evidence suggests regulation conformity could potentially be high.

Fisherman compliance is critical for the true effectiveness of any regulations to be realized. Co-management is fast becoming a popular fisheries management approach in which all stakeholders, including those previously excluded from the decision-making process, are given a voice in managing their collective resources (Jentoft 2004). In particular, fishermen included in management planning are more likely to comply and support regulations if they help create them (Jentoft *et al.* 1998). More importantly, co-management leads to empowerment by including the community in the decision making process (Torre 1986; Jentoft 2004). Not only does this motivate and empower the community, but participation in management often leads to increased stewardship of resources (Schumann 2007). Therefore, it is highly recommended that commu-

nity members, especially fishermen, be included in management planning, stock assessments, and monitoring programs.

CONCLUSION

While this study revealed key data on the Nassau grouper fishery, including CPUE and size distributions, it also showed a distinct concentration of fishing effort in specific locations. This shift in fishing pressure, combined with both increasing demand from tourism and the unique biological aspects of the Nassau grouper, necessitate immediate managerial action. The data from this and past studies have been used to create managerial recommendations that could be employed to conserve this economic and ecologically important species.

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