Evaluation of the Status of the *Panulirus argus* (Spiny Lobster) from 2004 through 2016 in the Turks and Caicos Islands

Evaluación del Estado del *Panulirus argus* (Langosta Espinosa) de 2004 a 2016 en las Islas Turcas y Caicos

Évaluation du Statut de *Panulirus argus* (Homard Épineux) de 2004 à 2016 dans les Îles Turques et Caïques

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ABSTRACT

With increasing anthropogenic pressures, the sustainable management of any fishery now requires an in-depth understanding of a species' biological attributes and the temporal and spatial scales by which they vary. *Panulirus argus* (*P. argus*) is the most commercially lucrative fishery of the Turks and Caicos Islands (TCI), yet few studies have addressed local trends in growth and reproduction. To examine how biological attributes of the *P. argus* vary in relation to both environmental and fisheries-dependent factors, carapace length, reproductive attributes, and sex ratio of *P. argus* landed at South Caicos processing facilities from 2004 - 2017 were assessed. The data of this study suggest that individual lobster as small as 76 mm carapace length (CL) are reproductively capable and that *P. argus* can be found reproducing year-round. Additional research from April through July (i.e. closed season) could provide assistance to determine if the current closed season is best for reproductive success.

Current trends of the fishery are examined through the biological, temporal, and spatial factors that affect *P. argus* CL. Data suggest that variations in CL are related to both yearly and seasonal fluctuations; and can be associated with local geographic differences throughout the Caicos Bank. The Eastside of South Caicos and Fish Cay exhibited a higher proportion of tar chested female *P. argus* than the areas near Ambergris Cay, Bush, and Sea Cays. However, commercial landings and environmental conditions in neighboring locations may impact the sustainability of the overall TCIs' *P. argus* fishery. Greater collaborations throughout the Caribbean would benefit the species and the TCIs monitoring initiatives could be designed to further investigate the fine-scale variation in *P. argus* reproductive biology observed in this study.

KEYWORDS: Lobster, reproduction, variations, spatial, Turks and Caicos

INTRODUCTION

Since the early 1970s, *Panulirus argus* (*P. argus*, Caribbean spiny lobster) has been the most profitable commercial fishery for the Turks and Caicos Islands (TCI) (Béné and Tewfik 2001, Lockhart 2007a) and many other nations in the wider Caribbean region, generating a regional estimated $450 million USD annually (CRFM 2013). Unfortunately, throughout the region, this fishery is susceptible to both exploitation and increasingly variable climate conditions (Puga et al. 2013). Declining catches have been reported throughout the Caribbean (Chávez 2009, Cochrane and Chakalall 2001, Ehrhardt and Fitchett 2010), with the five largest producing countries experiencing more than 5% reduction in catch since the 1990's (FAO June 6, 2016) (Table 1).

Commercial landings of the *P. argus* has fluctuated over the years in the TCI, yet there has been a limited number of publications on the recent status of the Turks and Caicos *P. argus* fishery. Status Information such as this can be most vital for countries throughout the regional to obtain perspective on how effective their landings are representing the fishery. Knowledge of size, reproductive viability and catch per unit effort (CPUE) can be attributed with both varying independent and dependent factors that can assist policymakers in making decisions that encourage reproductive potential, sustainable practices and thus improve the socio-ecological well-being of the TCI spiny lobster fishery and its dependents.

The TCI has placed sanctions or regulations to prevent unsustainable exploitation of *P. argus*. However, the current degree of acquisition within the TCI is unclear, as catch-per-unit effort has oscillated over the recent years and a full assessment on the stock parameters has not been recently conducted. The most recent in-depth assessment of the Turks and Caicos spiny lobster fishery was conducted in 2001. Using the Gordon-Schaefer and Thompson-Bell (Schaefer 1954) stock assessment techniques, the analysis indicated the *P. argus* fishery was operating near maximum sustainable yield, suggesting that increased fishing pressure may result in profit reductions, and unsustainable exploitation (Clerveaux et al. 2002). While lobster catches around the region were declining, by 2007 the annual catch in the TCI had risen to 336 MT (740,279 lbs.), having reached a peak of 446 MT (984,176 lbs.) in 2006/2007 fishing season (Figure 1).

Unfortunately a substantial decrease in landing in 2008 is believed to have been caused by two consecutive Category 4 and higher hurricanes, Hanna and Ike, which struck the TCI in late August and early September 2008 (Buesa 2011), dropping catches to 160 MT (353,000 lbs.) (Figure 1). Through anecdotal information from fishermen observations implied that important lobster habitats such as sea grass beds and dens were severely impacted. Such habitat degradation could in turn cause changes in reproduction, growth, natural mortality, and ultimately productivity (Ehrhardt et al. 2005).

Recovery of a population may be impeded by fishing activities above sustainable reproductive yields, closed season/ reproductive peak mismatches, illegal harvesting of undersize or berried females, regional recruitment reductions and foreign poaching (Butler 2015, Ehrhardt 2005, Puga et al. 2013). Whether the Turks and Caicos spiny lobster reproductive biology and seasonality matches that of the neighboring countries is unconfirmed. However, based on limited fishery-dependent data in the TCI, the spiny lobster fishery appears to be replenishing and rehabilitating by increased sizes of

Table 1. Average catch of *P. argus* for highly productive countries. * Countries with Production >1000 MT. (FAO 2016, 6 June)

COUNTRY	Average 1990	Average 2000	Average 2010-2014
Bahamas *	7623.1	8435.5	8123
Belize	482.7	542.6	693.4
Cuba *	9244.1	5995.4	4635.4
Dominican Republic	730.7	1235.9	2214
Haiti	851	795	280
Honduras *	3829.5	3818.9	4645.4
Jamaica	267.7	310.1	270
Mexico	773.1	749.8	573.4
Nicaragua *	2886.1	4114.3	4182.4
Turks and Caicos	320.8	309.5	197.6
United States *	2742.6	1903.1	2216.8

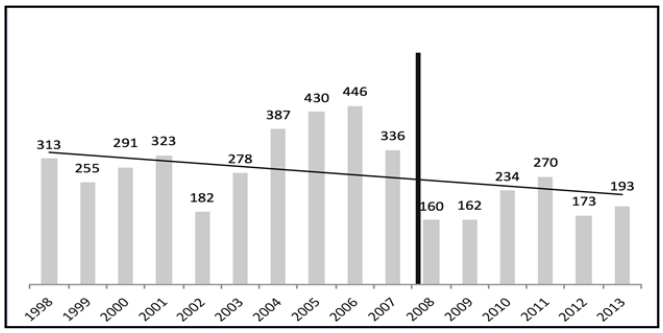

Figure 1. Column chart of *Panulirus argus* commercial catch weight metric tonnes (MT) each fishing year (August through March, inclusive) from 1998 through 2013, (black line) trendline of decreasing catch (unpublished: Department of Environment and Maritime Affairs) Thick black verticle line indicating timing of two category 4 hurricanes Hanna and Ike.

individuals, continued observation of reproductive females and an increase in catch-per-unit-effort (CPUE).

The replenishment and rehabilitation activities could be attributed to the TCI Government, Department of Environment and Coastal Resources (DECR) current and responsible management of the *P. argus* fishery through numerous restrictions: limited entry, a seasonal closure, area closures (marine protected areas) and a minimum CL size restriction of 83mm that has remained constant and enforced according to the Fisheries Protection Ordinance 1998. Restrictions also include the prohibition of harvesting molting lobster, lobster in the early stages of spawning (as indicated by a tar spot on the female), or lobsters visibly bearing eggs (berried females).

Within the Caicos Banks, intra-population variability in size and reproduction also needs further investigation. In this context, this study aims to provide a comprehensive evaluation of the recent growth and reproduction in the Turks and Caicos Islands *P. argus* fishery. Using fishery-dependent data collected at landing docks in both South Caicos and Providenciales, TCI, this study examines the change in carapace length (CL), sex ratio, sexual maturity of female lobster, and female reproductive activity of *P. argus* landings from 2004 - 2016. The results place the Turks and Caicos' lobster fishery within a regional context that can lead to discussion on the broader management implications of these localized trends in reproduction and growth.

MATERIALS AND METHODS

Study Area and Fishing Methods

The Turks and Caicos Islands has directly employ more than 360 commercial fishers each year for more than 10 years. Three Class A processing facilities in South Caicos obtain 80% of the *P. argus* landings. A fisher's day consists of 'day' trips throughout the Caicos Bank, but concentrated on the southern portion of the bank with high pressure fishing zones near Ambergris Cay, White & Seal Cays, Bush Cay, Fish Cay, and as well as a small location in the center of Caicos Bank (Hall and Close 2007) (Figure 2). The East side of South Caicos is also considered a location of high landing of *P. argus*.

The commercial fleet is comprised primarily of small retrofitted V-hull fiberglass boats ranging in length from 5.5 meters (18 feet) to 6.7 meters (22 feet) with 85 - 200 hp out board engines. Using only free diving methods or lobster traps, fishers harvest *P. argus* in depths ranging from 3 meters to 30 meters (Lockhart 2007b). TCI fishermen are often opportunistic in their catch, often working multiple fisheries at a time including queen conch, turtle and finfish, depending on the availability of the species at their current fishing location. The Catch-Per-Unit-Effort (CPUE) for this study is based on the catch each day dependent on the effort or boat-day, whether the species of intention for that day of fishing was *P. argus*.

Data Collection

In collaboration with TCI South Caicos fishermen, commercial processing facilities and the TCI Department of Environment and Coastal Resources (DECR), body weight, morphometric measurements, and maturity information of *P. argus* were collected by DECR and the School for Field Studies, Center for Marine Resource Studies (SFS CMRS) between 2004 - 2017 during the commercial fishing year (August - March, inclusive), with limited data collected for the month of April 2011 only. Data were collected from lobster landed at both licensed processing facilities and local artisanal sites on South

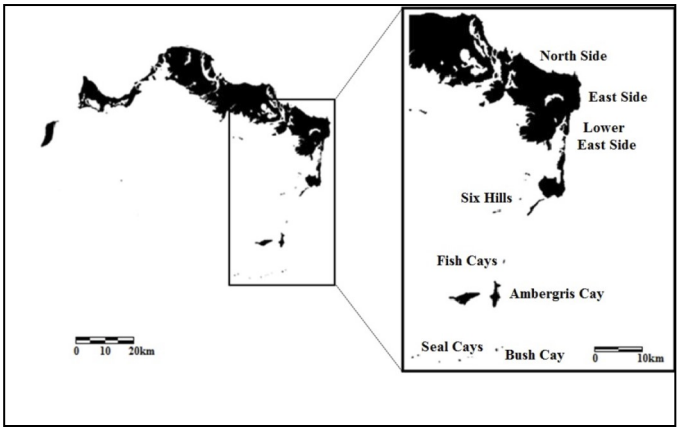

Figure 2. Map of the spatial distribution of the *P. argus* at key locations on the Caicos Bank.

Caicos and Providenciales prior to purchase. Fishermen were asked for their method of capture (free diving, trap), estimated depth and location of catch. Location information was given by either the locally accepted name of the general fishing location, which was transferred to a gridded map of the Caicos Bank. For this analysis, grid locations were then classified into general fishing locations for common areas, and left as unique locations when rarely visited.

A sub-set of the total catch from each vessel was extracted and for individual measurements. CL was measured with a Spi 2000 dial caliper (0.1 mm) and total weight measured with a 7000 g x 1g digital scale (0.1 g) versus the full catch weight by an industrial digital hanging scale (0.1 lbs). All female lobster were assigned a maturation class (immature, questionable, or mature) based on the absence or presence of setae on the inner set of pleopods (Chittleborough 1976), although there may be a delay between the appearance of setae on the pleopods and spawning (Jayakody 1989). Additionally, the presence of spermatophore, eggs, or obvious "scraping" or removal of eggs was collected and considered as indicators of recent breeding.

Statistical Analysis & Data Compilation

All statistical analyses were computed with the software package JMP Pro 10 (SAS Institute, Middleton, Massachusetts, USA). Temporal trends in CL, sex ratio and commercial catch were evaluated through general trend analysis in Microsoft Excel. Our full dataset included 7,556 lobster captured at 40 locations throughout the TCI. Data were collected from both commercial landings and artisanal landings; thus "closed season" months were not available for additional analysis. A Kolmogorov-Smirnov-Lilliefors (KSL) test of the full dataset determined that CL and maturity data was not a normal distribution so nonparametric statistics were used in these analyses. A Kruskal Wallis test was used to determine if there were differences in female sexual maturity among months of the fishing season as well as in the median length of adult female and male *P. argus* each month.

Additionally, to view and better understand potential underlying drivers of variability in overall *P. argus* CL, as well as in the breeding activity of mature females, basic trend analysis and description analysis was conducted. Based on these analyses eight of the most commonly surveyed fishing locations: North Side, East Side (including Phillip's Reef), Lower East Side, Bush Cay, Seal Cays, Fish Cays, Ambergris Cay, and Six Hills Cays (Figure 2) were evaluated based on CL size.

RESULTS

Preliminary Biological Attributes

The biological information was categorized through the Turks and Caicos Islands annual fishing year. This study spans from August 2004 through November 2016 during the open commercial fishing seasons only (August through March). A temporal examination of the carapace length from one fishing year to another was found to be significantly different (Kruskal Wallis, n = 7,556, $p < 0.0001$). In general, *P. argus* CL ranged from 60 – 185 mm and weight range, averaging 100.4 mm in CL and 879 g, respectively. Males were significantly larger (Kruskal Wallis, n = 7,556, $p < 0.0001$) than females with an average CL of 104.8 ± 21.8 mm and a weight of 971.8 ± 581.1 g as compared to the female average CL of 95.7 ± 16.3 mm and a weight of 782.9 ± 393.9 g. Females were also less prevalent in individuals over 115 mm CL (Figure 3).

A total of 7,556 individual spiny lobsters were measured, (3,730) 49.4% were female of which and (2,477) 66.4% were visibly sexually mature, as identified by the existence of small hairs on the pleopods. Sexually mature females were found to be landed throughout the year. However, the months with the highest landings of sexually mature females were during the months of March (48.6% ± 29.6%) and April (94.7% ± 0.0%) and then again in October (53.7% ± 31.9%). However a median value of 38.8% (IQR 36.8) was determined for sexually mature females across all months. There were no significant differences among numbers of sexually mature female by month (Kruskal-Wallis, df = 8, $p = 0.4331$; Figure 4).

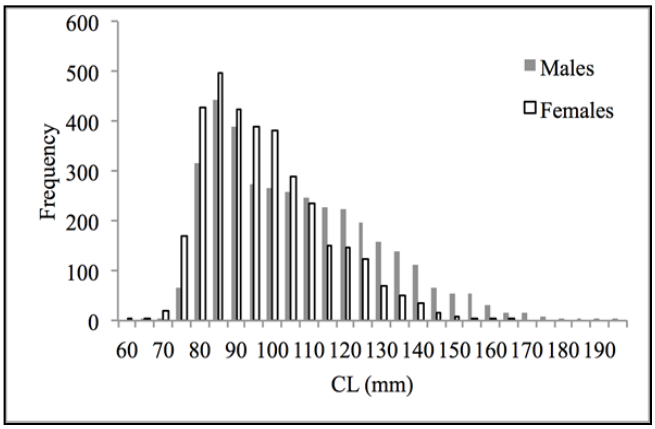

Figure 3. Histogram of carapace length (CL) of *P. argus* males (n = 3826) and females (n = 3730) measured throughout the commercial fishing season.

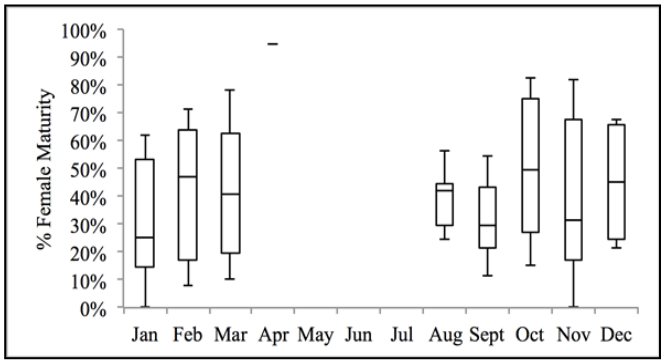

Figure 4. Boxplot of percent of mature female *P. argus* from 2004-2016 by month indicating no significant difference (Kruskal-Wallis, df = 8, $p = 0.4331$).

Comparing signs of recent mating by month of capture revealed general temporal patterns in the breeding activity of mature females. 66.6 % of mature females showed visual traits of reproduction such as long setae on the inner set of pleopods (Figure 5). The proportion of mature females to total females averaged 0.470 ± 0.191, while the proportion of "tar spot" and "egg-bearing" averaged 0.293 ± 0.199 and 0.027 ± 0.023, respectively. With an exclusion of the "closed season" months over the course of 13 years (2004 - 2016), negative trends can be found for both the proportion of female maturity and observable "tar-spot", with coefficients= -0.0062 and -0.0096, respectively. However, there is a slight positive trend found in the "egg bearing", coefficient = 0.0003. (Figure 6).

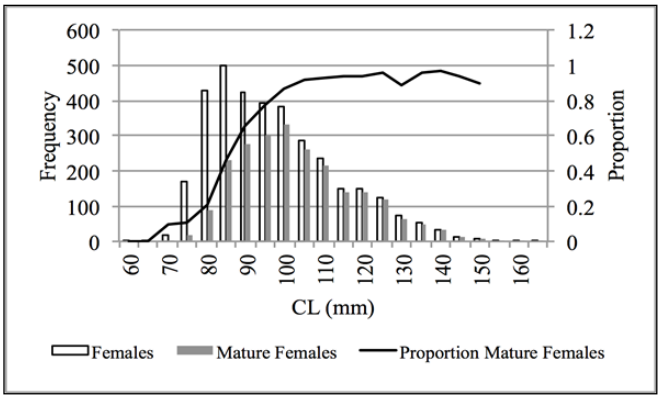

Figure 5. Histogram of carapace length (CL) of *P. argus* sexually mature females (n = 2484) and total females (n = 3730) measured throughout the commercial fishing season. The solid line represents the proportion of mature females.

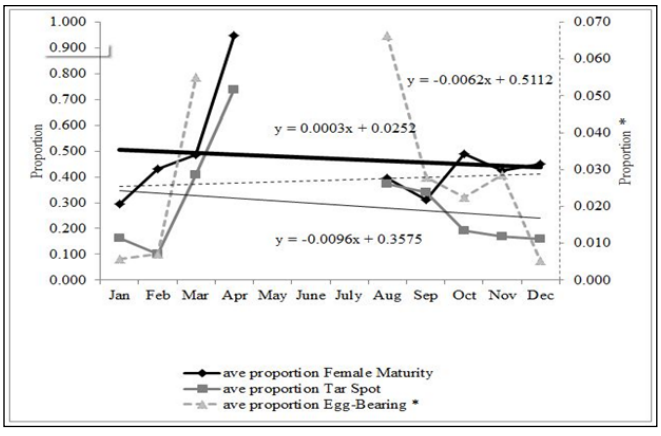

Figure 6. Line chart of the *P. argus* mean proportion of female maturity (y = -0.0062x + 0.5112), proportion of tar spot (y = -0.0096x + 0.3575) and proportion of egg bearing (y = 0.0003x + 0.0252) to female maturity from August through April for fishing years ranging from 2004 - 2016. Linear trends indicate a positive trend for egg-bearing and negative trends for both female maturity and tar spot.
(* indicates use of the 2nd y-axis).

Factors Affecting Carapace Length

The factors that could affect the variation in sizes over time could be attributed to biological or spatial differences. Through anecdotal information from local commercial fishermen, it would appear that some locations for capture are more desirable because larger lobsters are found at these locations. When comparing specific locations from the gridded map to the size in lobster there does appear to be a significant difference between locations (Kruskal Wallis, n = 7556, $p < 0.0001$). Depths of capture varied between sites. Unfortunately, it is subjective to suggest that depth alters the size of lobster, as depth information was collected on estimation from the commercial fishermen. However location of capture warranted addition investigation into the spatial distribution of carapace length. The grid system was further categorized into eight (8) general locations: North side, East Side, Lower East Side, Bush Cay, Seal Cays, Fish Cay, Ambergris Cays, and Six Hills Cays. When categorizing by sex, the spatial trends of the median CL size of either males or females were both found to vary significantly based on fishing locations (Kruskal-Wallis Test, $p < 0.0001$ (Figure 7). A final evaluation was conducted on the breeding capacity at each of the eight locations. No significant differences were found among the eight locations with regards to females percent of sexual maturity and percent egg bearing (Kruskal-Wallis Test, n = 3,730, $p > 0.05$). However there was a difference between the eight sites and the percent tar chested (Kruskal-Wallis Test, n = 3,730, $p < 0.05$) (Figure 8).

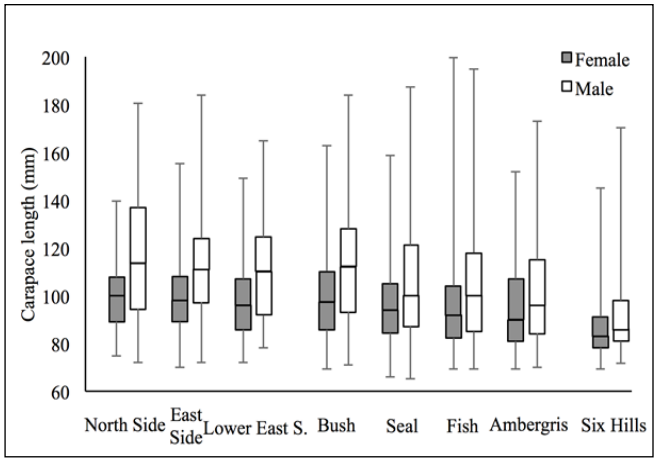

Figure 7. Box-whisker plot of the *P. argus* median carapace lengths (mm) of female (n = 3,730) and male (n= 3826) via location of capture on the Caicos Bank. Both female and male CL varied significantly by fishing location (Kruskal-Wallis test, both $p < 0.0001$).

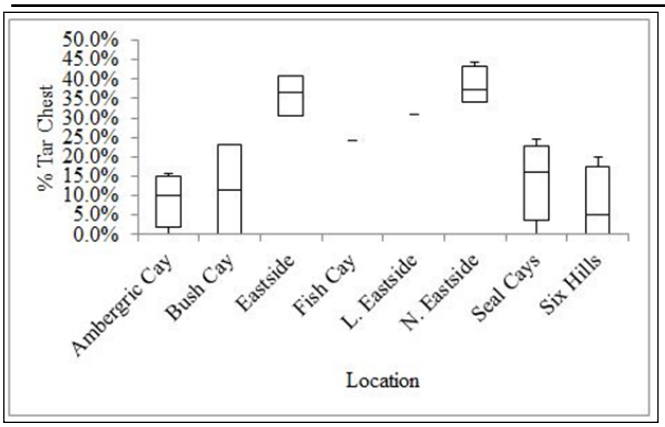

Figure 8. Box-whisker plot of the *P. argus* median percentage of tar chested females (n = 3730) via location of capture on the Caicos Bank. (Kruskal-Wallis test, $p < 0.05$).

DISCUSSION

The Turks and Caicos Islands has been in need of a current assessment of its *Panulirus argus*, Caribbean spiny lobster fishery. Using a fisher-dependent dataset of *P. argus* captured during the fishing seasons of 2004 - 2016, we provide the first preliminary review of temporal trends of TCI *P. argus* size and reproductive factors since the FAO report by Clerveaux et al. (2002). Local *P. argus* carapace length and the breeding activity of mature females were analyzed on a spatial scale, indicating that locations on the Caicos Bank contain larger and more reproductive individuals. These biological, temporal, and spatial relationships, when coupled with commercial catch information and local stakeholder knowledge, can help managers to assess the recent status of local stocks and optimize the future sustainability of the fishery.

The basic biological attributes of the Turks and Caicos *P. argus* fishery fall within the range of values previously found at other locations throughout the Caribbean. Over the course of the study period, the smallest reproductively active female lobster had a CL of 76 mm in August 2005. While CL at reproductive maturity has been found to vary from 40 mm (the Bahamas (Smith 1951)) up to 90 mm CL (Antigua and Barbuda (Peacock 1974)), our findings most closely match early data from *P. argus* in the Florida Keys, where reproductive maturity for females was also reported at 76 mm CL (Crawford and De Smidt 1922, Dawson and Idyll 1951). Although there were differences in the size and proportion of actively breeding females found at different fishing location, there was no clear relationship between these differences and location.

However, females found on the Caicos Bank were significantly smaller than males, with a 9 mm difference in overall average CLs. This finding is consistent with other fisheries throughout the region, which have shown male carapace length to be significantly larger than female carapace length at shallow depths (Cruz and Bertelsen 2008).

Temporal Variation in CL and Breeding Activity

Both the year and month of capture showed significant differences. However, variation in CL size may be better explained by the variation in year rather than month of capture. This may be related to policy changes, hurricanes, and changes to international recruitment, which likely have long term effects on the scale of years rather than oscillating monthly. However, the proportion of reproductively active females was not found to be of significant difference from one month to another. This finding was unexpected given the seasonality of lobster reproduction and the temporal scales by which the reproductive biology can change populations. It would be expected that the months of March through September would have a much larger prop oration of reproductively active female individuals. However, based on the limited dependent data for the month of April and no data for the months of May, June, and July, the data may not capture seasonal variations.

The significant differences in the CL over the years could be the possibility of both environmental factors as well as management incentives. The general trend in CL has increased since 2004. The trend of larger CL may be the result of increased enforcement and adherence to minimum size restrictions over the last decade. In terms of seasonal variation, carapace length was greater at the beginning of the open season when the primary efforts of fishermen are focused on the harvesting of spiny lobster instead of mixed catch. This time frame also corresponds with the end of the reproductive peak. This reduction of average CL may correspond to the timing with which young adults are recruited into the fishery.

Spatial Variation in Breeding Activity

Since the evaluation of male *P. argus* sexual maturity was difficult to determine, only the female lobster were examined by location. Locations were separated into eight specific locations that local commercial fishermen are found to fish. Of these eight locations, female sexual maturity and percent egg bearing were not found to show signs of difference. This could be attributed to the possibility of female lobster being sexually mature and bearing eggs throughout the Caicos Bank. This supports the local commercial fishermen views that *P. argus* are breeding throughout the Caicos Bank. Often larger *P. argus* are found at deeper depths as has been documented in Cuba, the Bahamas and the Florida Keys (Bertelsen and Cox 2001, Bertelsen and Matthews 2001, Cruz and León 1991, Cruz and Bertelsen 2008, Gregory et al. 1982, Lyons et al. 1981). Moreover, usually spatial patterns observed in carapace length are in part related to the depth profile, which would encourage larger female lobster the opportunity for breeding. The whole of Caicos Bank may serve as particularly suitable breeding grounds for *P. argus*, who have been shown to prefer deep areas (Cobb and Phillips 1980), this is supported by the significant difference in tar chested females.

In the TCI the Caicos Bank reefs may be located in more optimal reproductive areas, and thereby more important to self-recruitment within the TCI *P. argus* fishery.

Our findings in the TCI are consistent with the theory that the whole of the Caicos Bank is a highly productive location and with the close proximity to ocean currents allows for larval dispersal which are selected as breeding locations (Cruz and Bertelzen 2008, Ehrhardt 2005, Kough et al. 2013, Lipcius and Cobb 1994).

Management Implications

Size Restrictions — Although there are oscillations in total size of commercial catch from 2004 - 2016, there is a decline in the observable catch per unit effort (CPUE) from 1998 through 2012. Concurrently, a positive relationship exists between CL of measured *P. argus* between 2004 and 2016, indicating lobster with increasing size are consistently landed at South Caicos processing facilities each year. This is likely related to an adherence to the catch restrictions that have been instated by the TCI Government including the enforcement of the local minimum size restriction. Historical individual morphometric measurements of spiny lobster collected by the TCI government at Turks and Caicos dock landings from 1989 through 1998, suggested approximately 41.3% of the lobster landed annually were undersized (Clerveaux et al. 2002). To increase compliance, the Government of Turks and Caicos enacted a "Zero Tolerance" Policy in 2003, which gave conservation officer the power to prosecute offenders for harvesting of lobster below the minimum CL of 83 mm. In 2004 the morphometric sampling was re-established. It was determined that 29.0% of fishermen's catch were below the minimum legal length during the 2005 - 2006 fishing season (FAO 2006), which is a decrease of more than 10% from the previous 1998 estimation. From 2004 - 2011 the proportion of undersized catch changed from 29% to 20.4%. Morphometric parameters are not currently recorded, however, should be included in future analysis based on this trend. The reduction in the proportion of undersized catch through 2012 is likely related to increased enforcement efforts over the last decade as well as change in data collection methodology. The proportion of undersized lobster may vary throughout the year, as the average CLs of young adults are recruited into the fishery.

Closed Season — Like the use of size restrictions, a closed season is another method by which nations protect the viability of breeding *P. argus* populations (Maxwell et al. 2013, Miller et al. 2011, Cox and Hunt 2005). The closed summer season in the Turks and Caicos Islands was originally set with this principle in mind and has been shifted by a month in an effort to better protect breeding females. Without data from the closed season (including April/May through July) we can only be assumed that females are highly sexually reproductive throughout this time.

With regards to the reproductive activity of the *P. argus* and the establishment of a closed season, it has been well documented that the frequency of multiple spawning has been found to vary with female size (Birkeland and Dayton 2005, Cruz and Bertelsen 2008) and with latitudinal range (MacDiarmid and Kittaka 2000). Such spatial variation in reproductive biology is likely related to differences in water temperature (Kanciruk 1980), habitat quality (Marx and Hernkind 1985) and proximity to ocean current systems (Gregory et al. 1982). In the Bahamas, Florida Keys, and the north-east coast of Cuba, spawning peaks during the spring and summer months (April - June), with a second peak occurring anywhere from August - October (Arce and de Leo´n 2001, Bertelsen and Cox 2001, Cruz et al. 2001b, Cruz et al. 2007, Ehrhardt and Fitchett 2010, Gregory et al. 1982;). Unlike the direct relationship of larger females producing more eggs, a reverse relationship between sizes and spawning has been found in the Florida Keys (Bertelsen and Matthews 2001).

One of the primary goals of establishing a closed season is to protect reproductive individuals during the peak breeding times. With year-around *P. argus* breeding the start and end dates of seasonal closure is a contentious issue in the Turks and Caicos Islands. Although peak reproduction is assumed to occur during the summer (April - August), a secondary peak may also occur in the late spring or early fall (October - November). The Fisheries Ordinance of 1998 established a closed season from April 1st – July 31st, of each year, similar to both the United States and Bahama's seasonal closer dates. In collaboration with local stakeholders views, DECR has adjusted the start and end dates. The current closed season in TCI is similar to that of the Bahamas and Honduras, with Jamaica also beginning their closed season on April 1st, while other countries such as Cuba, Belize, Mexico, and the Dominican Republic have chosen earlier start dates.

Unfortunately, the changes to the TCI *P. argus* closed season is a bit arbitrary, as this study suggests that there is constant reproduction activity throughout the fishing year. However, since there is little data available during the "closed season", there should be a continued evaluation of the fishery during both the open and closed season to collect independent data.

Although it is illegal to capture females that exhibit signs of breeding, local fishermen have noted the difficulty of detecting signs of recent breeding until after lobsters are captured. An optimal closed season can successfully reduce the likelihood of capturing breeding females (Cox and Hunt 2005, Forcucci et al. 1994, Quackenbush and Herrkind 1981 and 1983). Systematic sampling of breeding activity during the closed season as well as in February, March and August through October, would support the TCI seasonal closure dates established to protect *P. argus* breeding as well as fisher needs. The analysis of variation in the breeding activity of mature females suggests that peak breeding may change on fine temporal and spatial scales as environmental and fisher-dependent factors are not static influences (Rudorff et al. 2009). Regular data collection can help inform dynamic ocean management decisions such as optimal closures.

For many artisanal fisheries around the world, local adherence to size restrictions or seasonal closures has led to increases in fish biomass or contributed to the sustainability of stock levels (Miller et al. 2011, Quackenbush and Herrkind 1981 and 1983). Notably, the relationship between the protection of breeding stocks and future catch sizes is more complicated for species with long-term dispersive larval stages such as *P. argus* (Kough 2012). Although size restrictions and seasonal closures can assist in self-recruitment into the TCI fishery, some *P. argus* larvae initially bred in the TCI may be recruited into the fisheries of neighboring countries. Meanwhile, previous biophysical modeling of Caribbean-wide *P. argus* larval dispersal predict that although the Turks and Caicos lobster fishery is replenished through self-recruitment, it relies heavily on larval imports that transcend its national boundaries

(Kough et al. 2013). Fluctuations in hydrodynamic conditions (Hill et al. 1997), changes in food availability (Tuck et al. 1997), and the sustainability of catches throughout the wider Caribbean ultimately affect any local *P. argus* fishery. Greater collaboration with neighboring countries such as the Bahamas, Dominican Republic, and Cuba can only assist in improving our understanding of recruitment to the lobster fishery of the Turks and Caicos Islands and the development of holistic management strategies. Concurrently, researchers can continue to explore the fine-scale variation in *P. argus* reproductive activity originally noted by local fishermen, and detected in this study.

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