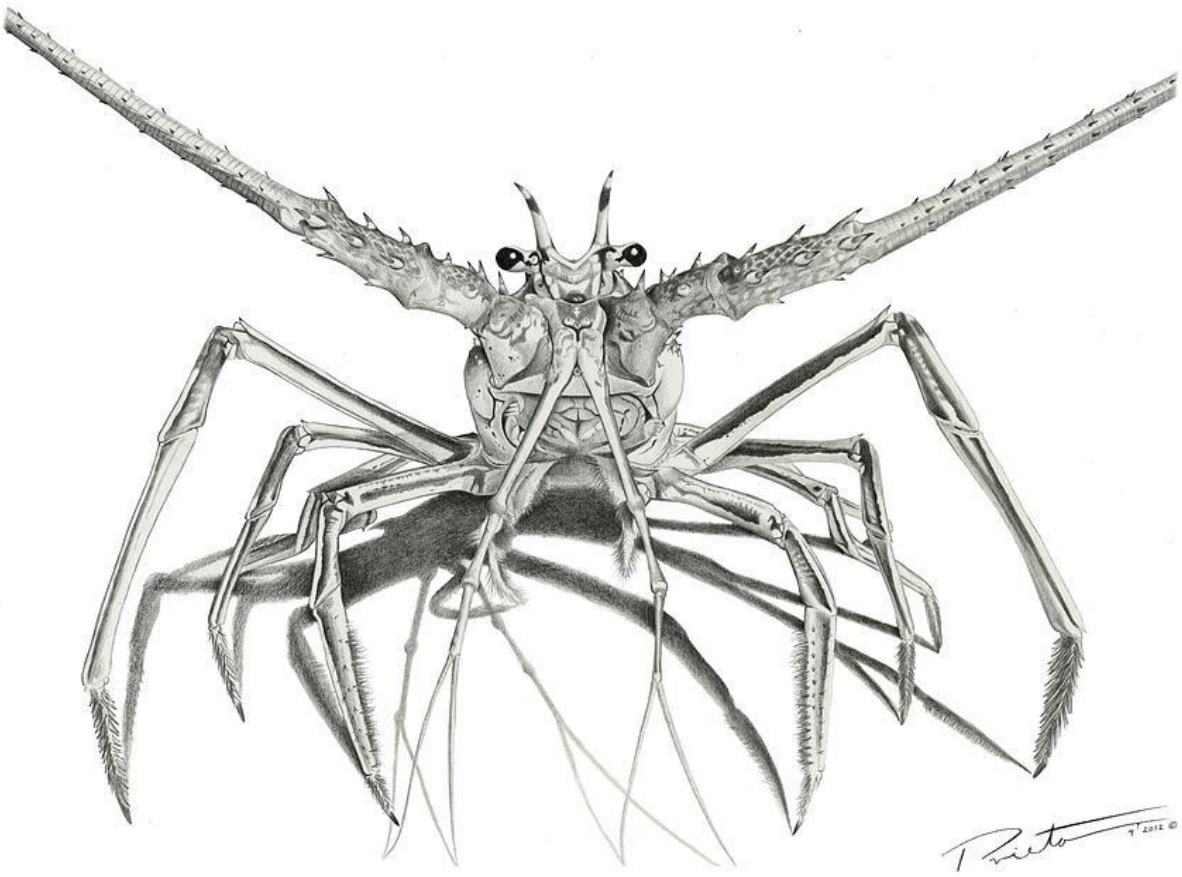
Size at maturity, breeding seasons and fishery selectivity of *Panulirus guttatus* in Anguilla, British West Indies



Department of Fisheries and Marine Resources

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SUMMARY

The Spotted Spiny Lobster (*Panulirus guttatus*), known locally in Anguilla as the Crayfish, is a recognised fishery and concerns exist about its sustainability. It is currently managed in Anguilla through legislation that applies also to the Caribbean Spiny Lobster (*Panulirus argus*) and generic fish pot minimum mesh size regulations that applies to all trap fisheries. In order to manage this fishery sustainably it will be necessary to establish species specific legislation as already exists to a limited extent for *P. argus* (minimum landing size, but no current closed seasons). This report presents the results from an assessment of the Crayfish fishery that took place during 2004 and later during 2007 and 2008, and makes recommendations for management measures that may promote its future prosperity.

It was found that size at maturity for male Crayfish occurred at 51.3 mm carapace length (CL), whereas females matured at approximately 46 mm CL. Peaks in female reproductive activity occurred between December and April, with highest levels between January and March. Crayfish of smaller sizes were seen to be less active on the reef than larger individuals, and the mean minimum Crayfish retention size of traps with legal mesh was calculated as 47.4 mm CL. Crayfish landed via traps were significantly larger than those landed via the hand capture method that is also common in Anguilla.

These results suggest that the Crayfish trap fishery will likely only capture a small number of immature individuals. The hand capture fishery is able to target such Crayfish however so it is recommended to introduce a minimum landing size to mitigate against this. Based on size at maturity results it is suggested that the minimum landing size be set at 52 mm. This will be unlikely to affect the livelihood of trap fishers who have made considerable financial investments to pursue this way of life.

Although trap fishing does not target immature individuals it does inevitably capture egg-bearing females. Furthermore hand fishers often have to capture a Crayfish before they can assess whether it is an egg-bearing female. Crayfish are known to be relatively frail once they have been physically removed from their natural habitat, and although egg-bearing females are by law returned to the sea, little is known as to how this displacement affects the success of their brood. It is feared that egg-bearing females who go through the trauma of being landed and thrown back into the sea suffer increased mortality and their eggs damaged by stressed abdomen contractions. Thus it is recommended that in conjunction with a minimum landing size, a closed season be implemented during the peak breeding season that occurs between January and March each year. Although this will impact local livelihoods to a certain extent the effect will be minimal because at this time of year sea conditions (ground seas) often make fishing problematic. Furthermore, the long-term benefits of these measures have the potential to adequately compensate for short term losses.

1. INTRODUCTION

The Spotted Spiny Lobster (*Panulirus guttatus*), known locally in Anguilla as the Crayfish, is a fishery in its own right with a small number of dedicated fishers relying on it as a livelihood. It commands high prices at tourist restaurants and is a lucrative business, a fact that draws other more opportunistic fishers to target it by hand at night while snorkelling. Although catches are still relatively healthy fishers are known to avoid certain areas that only a few years ago proved productive, suggesting sustainability of this fishery may be in question. Indeed, some fishers have also recently diversified into less lucrative but presumably more productive fisheries, and for others it has become a secondary source of income, choosing instead to become more directly involved in the tourism sector. This change however may be in part due to increasing fuel cost offsetting profit margins, and as such the intensity of labour needed to reap reduced benefits no longer deemed worth it.

Although a small fishery, it is intensive (see section 3.1) and largely unregulated. Legislation does prohibit the possession of berried (egg-bearing) females; the striping of eggs from a berried female; the possession of a moulted Crayfish or one possessing tar-spots (spermatophores); or the taking of a Crayfish by way of a spear gun that would thus prohibit its return should it prove to be berried. This legislation is however not specifically designed for *P. guttatus*, being equally relevant to *P. argus*, in a similar way to trap mesh-size legislation that relates to all fish-traps operated in Anguillian waters (minimum width 42 mm). *P. argus* is also regulated by a minimum landing size, and there is the possibility of introducing a closed season during peak spawning times to protect recruiting populations from excessive interference or law breaking. Although a minimum size is more important for *P. argus* because immature individuals of this larger species are more likely to be trapped than the smaller *P. guttatus*, hand-fishing for this latter species has become a popular activity and attractive source of income for many islanders. This activity requires very little financial investment and as such is practiced opportunistically by an unknown number of people, with the technique allowing any sized individual to be captured. Hence, a minimum landing size for *P. guttatus* is likely advisable, especially in light of results by Wynne (2004), where larger individuals appear to be becoming less common in areas of higher fishing intensity. If this perpetuates demand for smaller individuals may increase to a level where immature individuals dominate hand-landed catch and trap fishing for *P. guttatus* is no longer economically viable.

Furthermore, handling of lobsters has been documented to cause varying levels of mortality (DiNardo *et al.,* 2002), and because the effect handling and discarding berried females has on offspring survival is unknown, the precautionary approach with regards to sustaining this important fishery is advisable. As such a closed season during peak breeding periods would be prudent to minimise the potential effects from this.

This study has been undertaken because breeding peaks and size of maturity appear to vary across the geographic range of *P. guttatus*, based on the available scientific literature. For example it was reported by Briones-Fourzán & Contreras-Ortiz (1997) that breeding

occurs year round in the Mexican Caribbean and that peaks in reproductive activity vary inter-annually. They did note though that the greatest percentage of egg-bearing females occurred from winter through to spring with highest reproductive activity in November-May, and reducing in summer. Similarly, in a paper from a study in Glover's Reef Atoll (Belize), Acosta & Robertson (2003) infer that it is during the summer months that the lowest percentage occurs, although temporal variations in this were not quantified. In contrast Robertson & Butler (2003) recorded peak reproductive activity between March to June in Florida, with Evans et al. (1995) recording a similar situation in Bermuda. Such geographic variation in the western part of the Caribbean, and no known studies conducted in or around the Eastern Islands have lead to a knowledge gaP. To ensure that any new fishery regulations in Anguilla complement the natural regime it is essential that the relevant studies are carried out.

A similar situation is also apparent when considering size at maturity, with variations even occurring in the same geographic region. For example, Briones-Fourzán & Contreras-Ortiz (Mexico - 1997) estimate the size for 50 % mature females was 56.4 mm CL, whereas Robertson & Butler (Florida Keys - 2003) estimated it as 32 mm CL. For males, Sharp et al. (Florida Keys - 1997) estimated size at maturity at 48 mm CL, whereas Robertson & Butler estimated it at 36 mm CL, and Chitty (Florida Keys -1973) observed that males with 40 mm CL had viable sperm in their testes. Thus, although a study was conducted in Anguilla (Wynne, 2004) that recorded a size at 50% maturity for females of 47.6 mm carapace length (CL – see method), with male size at maturity being estimated as 51.3 mm via the onset of allometric leg growth, it was felt wise to build on this study by increasing sample sizes and thus the validity of results before making management decisions that will potentially affect local livelihoods.

2. METHODS

Nine fishing trips were undertaken with local fishers between March 2007 and July 2008. It was originally intended for the study to cover a two year period, but bad weather in the latter half of 2008 and other logistical problems meant that this was not possible. Data from this work were also combined with those obtained from a previous study in Anguilla (Wynne, 2004) that looked at ecological aspects of *P. guttatus* which included size at maturity estimations.

During the fishing trips all *P. guttatus* were sexed and, if female, assessed for reproductive activity. They were categorised as either: Berried; tar-spotted; with egg or tar spot remains; or showing no signs of reproductive activity. Irrelevant of the sex, the carapace length was measured as was the length of the second segment of the second walking leg. The carapace length (CL) is defined as the distance from in-between the two rostral horns to the posterior edge of the cephlothorax, and is the measurement that is used in this study when describing *P. guttatus* size. The second segment of the second walking leg is used to

establish male size at maturity, as when maturity is reached the two frontal pairs of legs begin to grow at a faster rate in relation to their carapace, referred to as the period of allometric growth (Robertson & Butler, 2003). The extra leg length increases the ability of males to mount receptive females and deposit their spermatophores. The measurements were made by callipers to the nearest millimetre, as more precise measures were seen unrealistic while at sea in a small fishing vessel. Although females do not exhibit this growth pattern similar measures were taken as a comparison. Female size at maturity is classically defined as when 50% of the population of a certain size exhibit reproductive activity, and it is this measure that was used in this study.

Breeding seasons were assessed by again looking at female reproductive activity, however, it was only the presence of eggs that were considered significant activity as tar spots could have been placed by a male weeks or months before, and tar spot or egg remains again could have persisted for some time. Furthermore, it is the presence of eggs that is the main impetus for conducting this work.

Information relating to selectivity within the *P. guttatus* fishery came from studies conducted in 2004 that compared the size of trap caught individuals with those caught by hand and those from natural populations. Trap selectivity was determined by correlating carapace length with carapace width, and stating that the carapace width was equal to the size of trap mesh a particular individual could escape through. Although this is likely a little simplistic as the lobsters legs will probably hinder escape, it provides a bench mark when discussing the results later. Also during this period nocturnal snorkelling surveys were conducted to assess *P. guttatus* populations on a variety of reef areas as detailed in Wynne (2004), where carapace sizes were estimated to the nearest 5 mm and the activity exhibited by the individual noted (either foraging in the open or hiding in a protective recess). Fishing pressure at the sites where natural populations were sampled was assessed by asking fishers to give the sites a score based on their knowledge of fishing intensity in the area.

3. RESULTS

3.1 Fishery Description

Of the three main fishery target groups in Anguilla spiny lobsters are, by fresh weight, the most valuable of all, with *P. guttatus* commanding the highest prices within this grouP. Although it is a relatively small fishery in terms of trapping, with approximately five boats targeting the species island wide, it can also be caught by hand at night and is hence a valued opportunistic income for many islanders. This also means it is one of the more unregulated fisheries on the island. *P. guttatus* cannot be kept in water based storage boxes as *P. argus* can because they suffer more rapid mortality once out of the water and are usually inactive and near death by the time they arrive on land. Those captured by hand suffer less stress and thus could potentially be stored alive, but the threat of mortality

usually leads to all fishers freezing their catch or delivering them directly to restaurants. Again, because of this direct sale it is increasingly difficult to assess landing volumes, although as Anguilla lacks a formal fish market this problem exists for almost all other fisheries.

Trap Capture Fishery

The *P. guttatus* trap fishery has been in existence for c.25 years since the beginning of the luxury tourist industry which drives demand. Prior to the 1980's *P. guttatus* by-catch was given away by fishers and generally considered a 'trash food'. It is estimated that there are now approximately 1000 'Antillean arrowhead' traps in Anguillian waters targeting *P. guttatus* that are hauled and set approximately three times a week. It is estimated that approximately 10% of traps are out of the water at any one time for repairs. Traps are baited with a mixture of cowhide and reef fish. Reef fish are cut up and added to the bait box each time the traps are set, with the more robust cowhide only being added when needed. The reef fish used as bait are obtained from three sources: By-catch from the hauled *P. guttatus* traps; by-catch from offshore fishers kept for sale as bait; caught through spear fishing, either directly from the fishing boat or by visiting coastal locations the evening before. This latter source is a damaging and wasteful practice, as although less valuable, many of these reef fish would provide a greater volume of food if eaten directly. Stoplight Parrotfish (*Sparisoma viride*) are the preferred reef fish to use as bait because they reportedly yield a better catch. During the 2004 study fishers would spear fish directly from the boat on the main offshore reef and return with a sackful of reef fish, mainly this species or other parrotfish. During the 2007/2008 study this practice had ceased because it took too long to fill the sack. Instead, other areas were visited when bait could not be obtained from other fishers.

Hand Capture Fishery

An unspecified number of persons undertake this activity, from fishers attempting to fill a big restaurant order; enterprising residents with relatives or other contacts in the restaurant business; to recreational catches undertaken to fill the family weekend grill. The most popular method of capture is by snorkelling with gloves and a v-shaped prong, together with a mesh bag and float to transport the catch. The activity occurs at night while *P. guttatus* are active, and once spotted the fisher pins them down with the prong and quickly slides their gloved hand down the prong shaft to capture the creature. It takes a little practice but once mastered is an almost foolproof way to catch *P. guttatus*. The concern exists that while trap fishing allows small individuals to escape, this more efficient method will lead to ever smaller individuals being targeted as the larger individuals are removed, especially if trap fishing one day becomes inefficient due to depleting stocks. Such depletions are already being reported with fishers seldom visiting the main Seal Island Reef because of diminishing catches. It is therefore possible that any new legislation designed to manage stocks of *P. guttatus* will affect the hand capture fishers more than those involved solely with traps.

It should be noted that traps were not always equally baited, and soak times varied. It was unreliable to get soak times from fishers as when asked more than once on the same fishing trip their response often varied. Also sometimes fishers appeared to be in a hurry which meant traps were not baited and just thrown back into the water in an almost random fashion. On other occasions each and every trap was carefully baited and set by hand using snorkelling equipment. Also, if bad weather was known to be approaching traps would be placed in less favourable but sheltered fishing spots to avoid losses. It is likely these spots have been historically overfished and hence why they are less favourable, as the more favourable areas were all in exposed, hard to reach reef regions. The end result of these variations mean those data presented in table 1 are a representative snapshot of *P.* guttatus fishing yields in the Island Harbour community, but that practices may vary in other communities making landings vs effort difficult to predict. It also means that these results can not be used to make estimates of population changes by conducting rigorous trapping exercises.

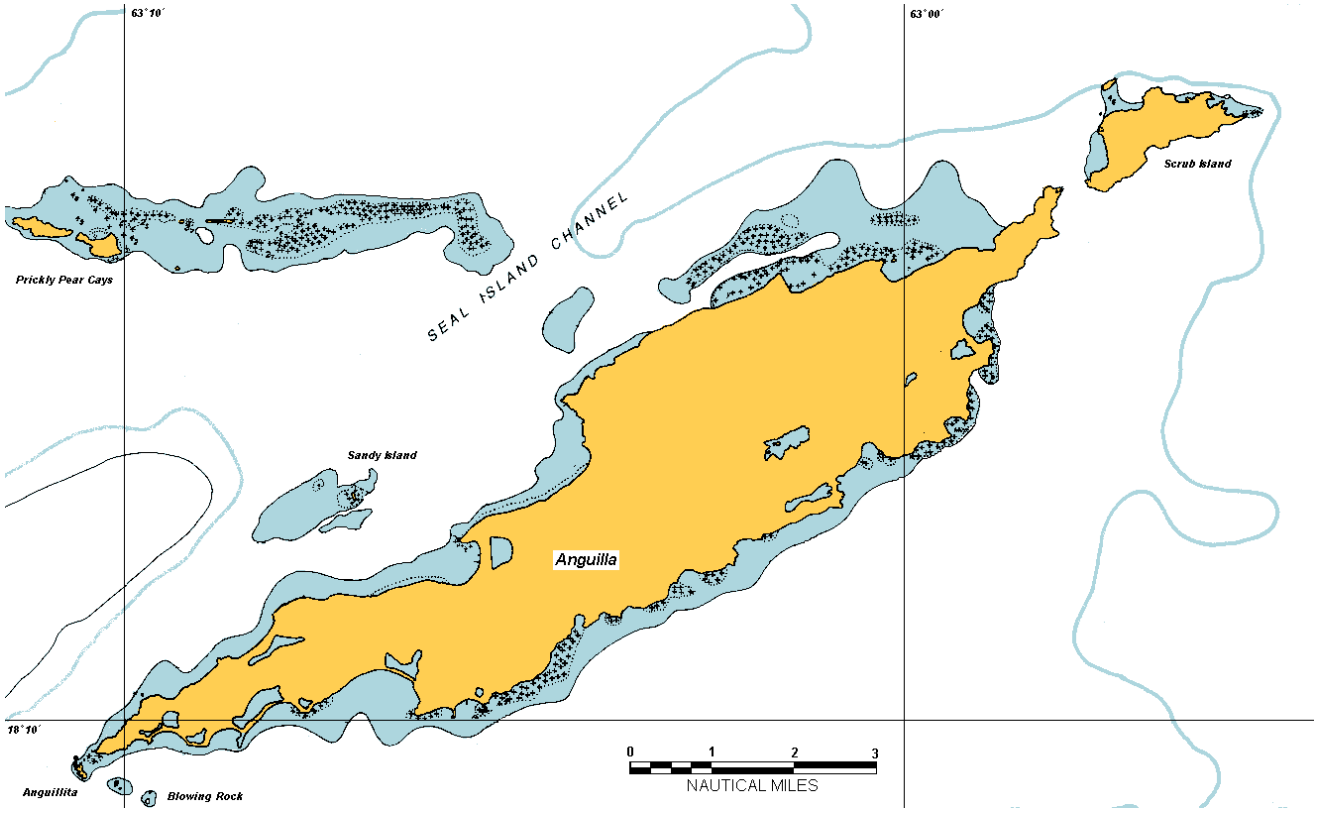

Figure 1 – Map illustrating the main regions where *P. guttatus* traps are set (blue areas with black dots). Note that only the northern areas were studied during this work, with the information from southern coast areas coming from historical records.

During the fishing trips a small amount of by-catch was noted. This consisted of Caribbean Spiny Lobsters (*Panulirus argus*), Spanish Lobsters – known locally as the Sea Louse (*Scyllarides aequinoctialis*), Batwing Coral Crabs (*Carpilius corallinus*) and a variety of reef fish. All crustaceans were landed, as were most of the larger reef fish. Smaller reef fish and Nurse Sharks (*Ginglymostoma cirratum*) were all used as bait. Stoplight Parrotfish (*Sparisoma viride*) were used as bait irrespective of their size as they apparently yield better catches.

Table 1 - Summary of data collected during 2007 & 2008 illustrating a snapshot of the *P. guttatus* fishery catch statistics represented as mean value per fishing triP.

Number of traps hauled	70
Total catch (including those suffering predation)	95
Number suffering predation in traps	13
Total captured alive	82
Number returned to sea (berried females)	18
Total landed catch	64
Number of confirmed males (including those suffering predation)	59
Number of confirmed females (including those suffering predation)	31
Number not sexed due to predation damage	5
Percentage suffering predation	13%
Percentage of live catch male	66%
Percentage of live catch female	34%
Percentage of female with signs of reproductive activity	82%
Percentage of females with eggs (berried)	58%
Percentage of females with egg or tar spot remains	24%
Percentage of female with intact tar spots	1%
Percentage of female with no sign of reproductive activity	18%
Mean number caught per trap (total)	1.62
Mean number caught per trap (live)	1.43
Mean number caught per trap (landed)	1.13
Average *P. guttatus* size (CL mm)	61.35

3.2 Size at Maturity

As described in the methodology section the means of determining size at maturity differs between the sexes. For males it is generally agreed among scientists that maturity has been reached when allometric leg growth begins. Even though viable sperm is present in smaller individuals they will be less likely to successfully mount receptive females and more likely to be dismounted by larger males. Female size at maturity on the other hand is generally agreed to be the size at which 50% of the female population is exhibiting reproductive activity.

Male Size at Maturity

239 male *P. guttatus* were measured during the 2004 study, with a further 491 measured during 2007 & 2008. Data from both studies yielded almost identical results for the offset of allometric growth (at c.65 mm CL with a 70 mm leg length), and regression equations for the latter two growth phases also yielded almost identical results. However, because the 2004 dataset encompassed individuals during the pre-allometric growth phase, it is these presented in figure 2. From this figure the start of allometric growth and therefore size at maturity is concluded to be 51.3 mm CL.

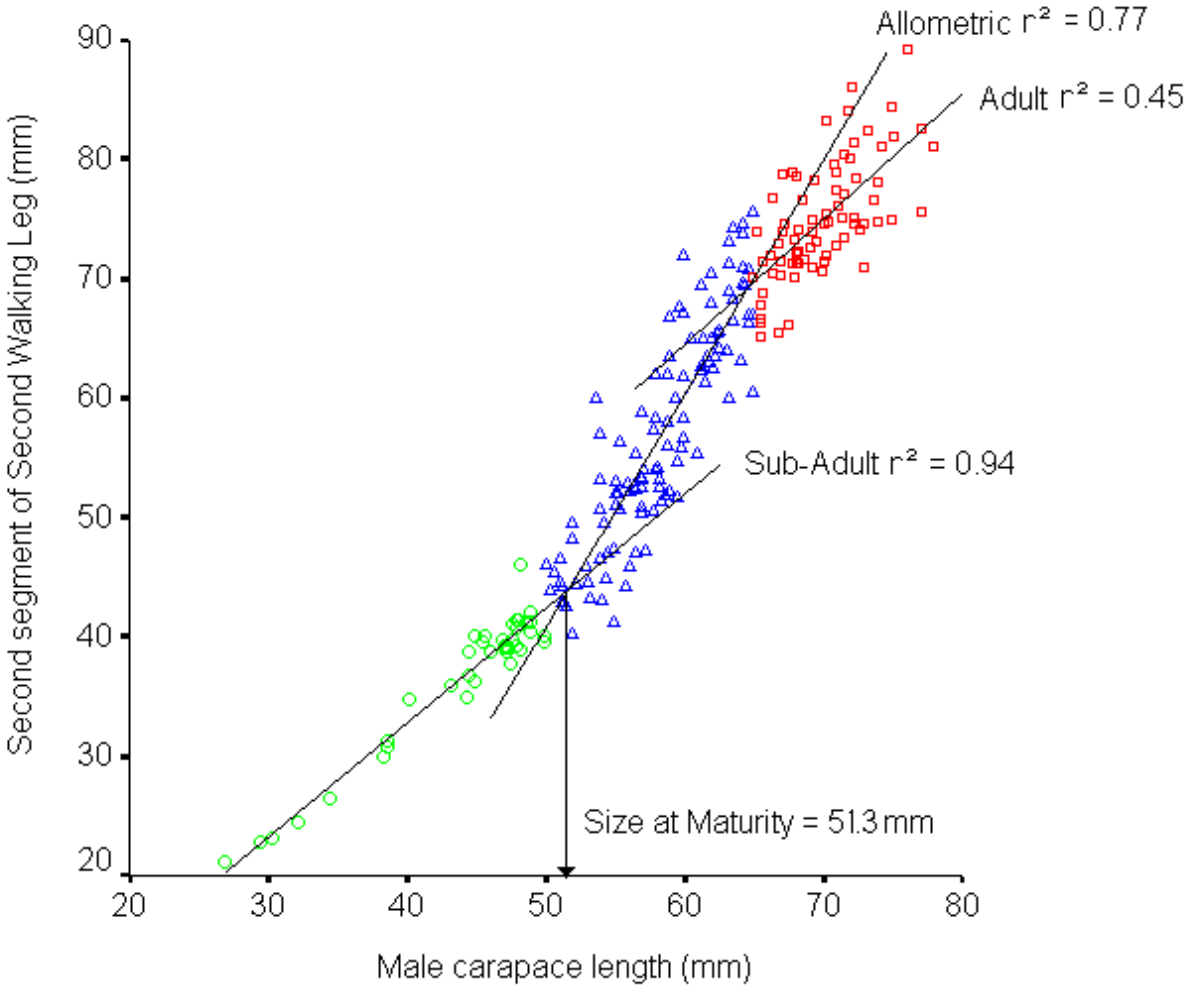

Figure 2 - The relationship between male *P. guttatus* leg growth rates in relation to carapace length. Three regression equations are obtained: Subadult (circles) y = 0.959x – 5.574, p < 0.001; Allometric (triangles) y = 1.949x – 56.467, p < 0.001; Adult (squares) y = 0.894x + 12.028, p < 0.001. These equations can be solved in pairs simultaneously to give intersect values for either variable. For example: Subadult and Allometric gives and intersect value on the x axis (CL) of 51.3 mm.

Female Size at Maturity

Results from 277 females measured and assessed during fishing trips as part of the 2007/2008 study were combined with 207 females measured and assessed as part of the 2004 study. Mean percentages of females exhibiting reproductive activity are presented in figure 3 below.

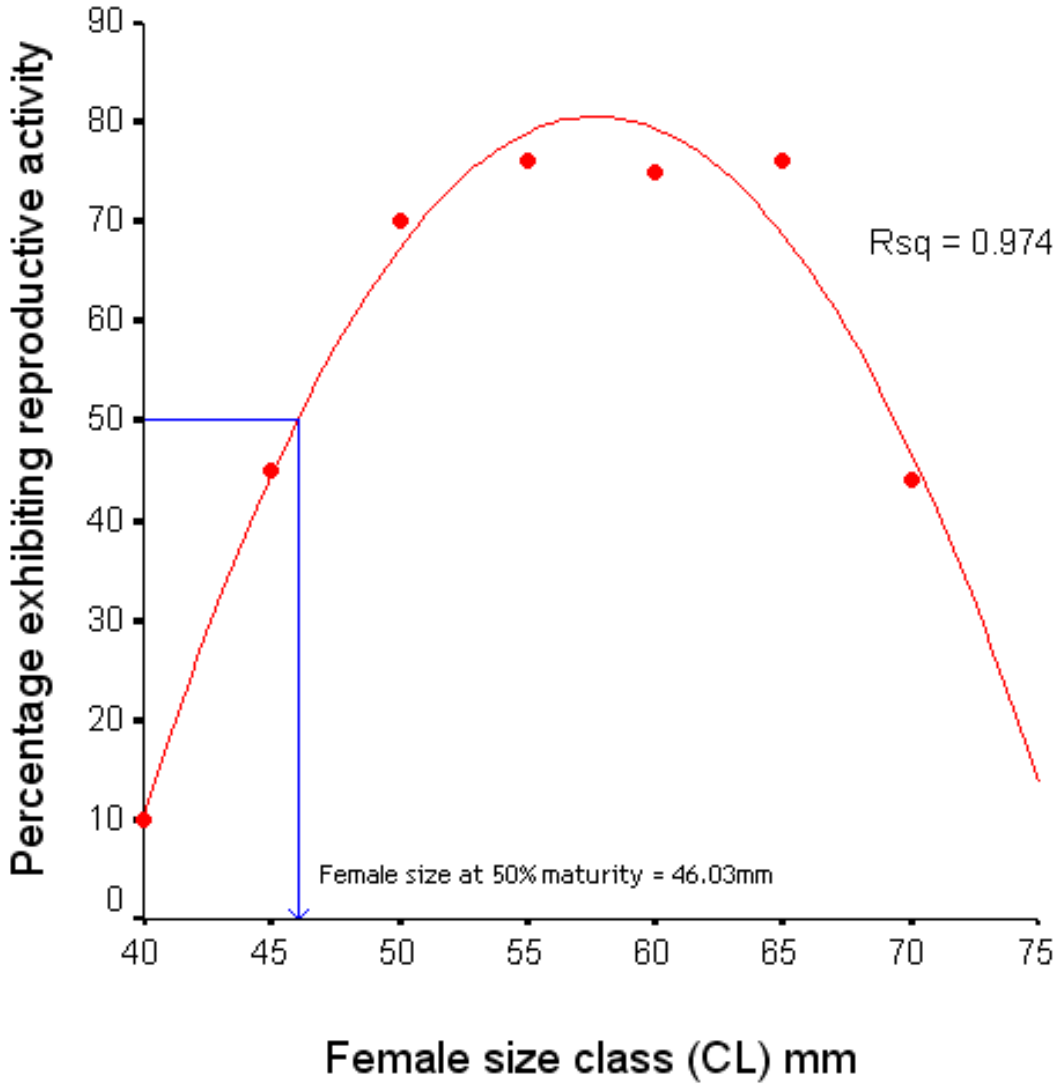

Figure 3 – Figure 7. Percentage of female *P. guttatus* exhibiting reproductive activity plotted against median carapace length of each size class. Solving the quadratic regression equation $y = 25.77x - 0.2233x^2 - 663.07$ ($p < 0.001$) when $y = 50$ gives a value of 46.03 mm (CL).

3.3 Breeding Seasons

277 females were assessed for reproductive activity during the 2007/2008 study. A peak in female reproductive activity was found to occur in February each year (figure 4), with high levels of activity between December and April. Variations in the catch percentage of females also varied throughout the year, with an inverse relationship to breeding activity, peaking in August (figure 5). Data from 2004 were not used in either figures because they were unrepresentative in terms of temporal spread.

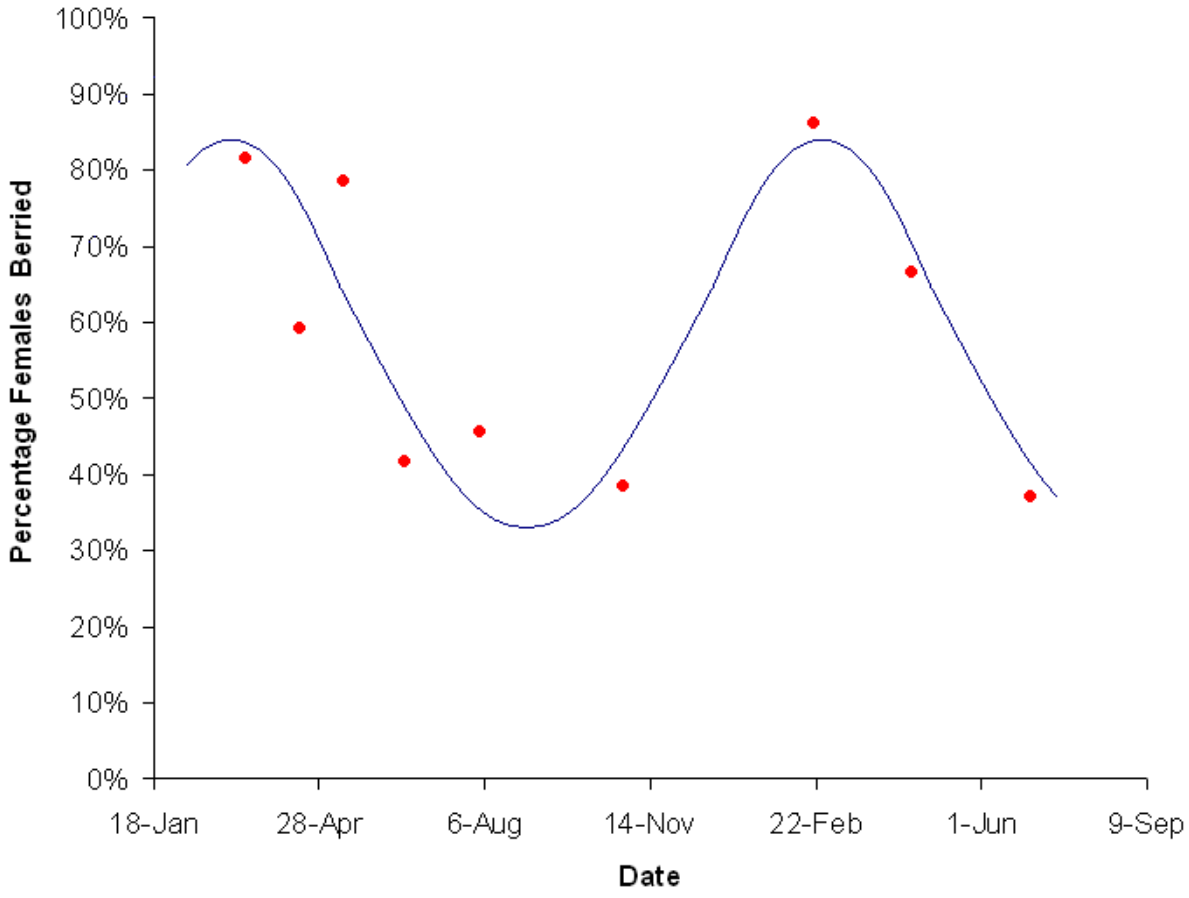

Figure 4 – The percentage of females that were berried from each fishing trip. It is interesting to note that a graph plotted for percentage of females that were exhibiting any reproductive activity produces similar peaks and troughs. There is no mathematical formula provided for the oscillation curve as it was plotted manually by attempting to obtain minimal residuals.

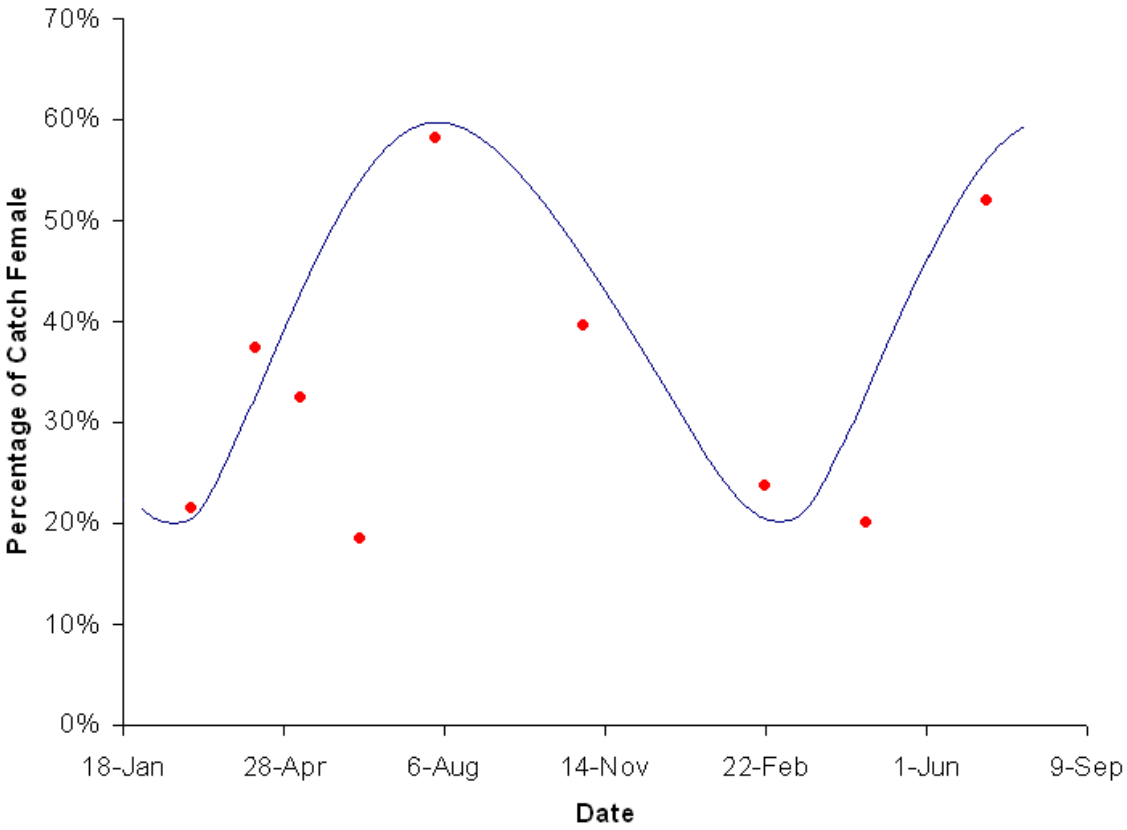

Figure 5 – The percentage of catch during each fishing trip that was female. There is no mathematical formula provided for the oscillation curve as it was plotted manually by attempting to obtain minimal residuals.

3.4 Fishery Selectivity

The majority of fishers were observed to use legal mesh size, although this reportedly depends on the mesh readily available for purchase on Anguilla. 65 *P. guttatus* were measured and their carapace width correlated with carapace length. This gave an estimated trap retention size of 47.4 mm (see figure 6).

440 *P. guttatus* were observed during nocturnal snorkelling surveys, 237 (54 %) males and 173 (39 %) females and 30 unidentified (7 %), and categorised as to whether they were foraging in the open or hiding within a protective recess (figure 7). In total 256 individuals (58 %) were seen within protective recesses and 184 (42 %) foraging out in the open. Female P. guttatus began foraging out in the open at a significantly larger size than males ($t_{181} = -2.778$, $p = 0.001$). 86 % of all P. guttatus < 45 mm were seen in a recess compared with 38 % > 45 mm. Males found in a recess were significantly smaller than those foraging in the open ($t_{235} = 12.270$, $p < 0.001$), as were females ($t_{171} = 4.568$, $p <$

0.001). Of the 833 *P. guttatus* sampled during 2004 the size class structure of those captured by trap was significantly larger than for both hand captures (t_{444} = -9.264, $p < 0.001$) and those observed during nocturnal snorkeling surveys (t_{652} = -15.921, $p < 0.001$) see figure 8. Sites with low fishing pressure had larger size classes present than sites with high fishing pressure although the results were not significant.

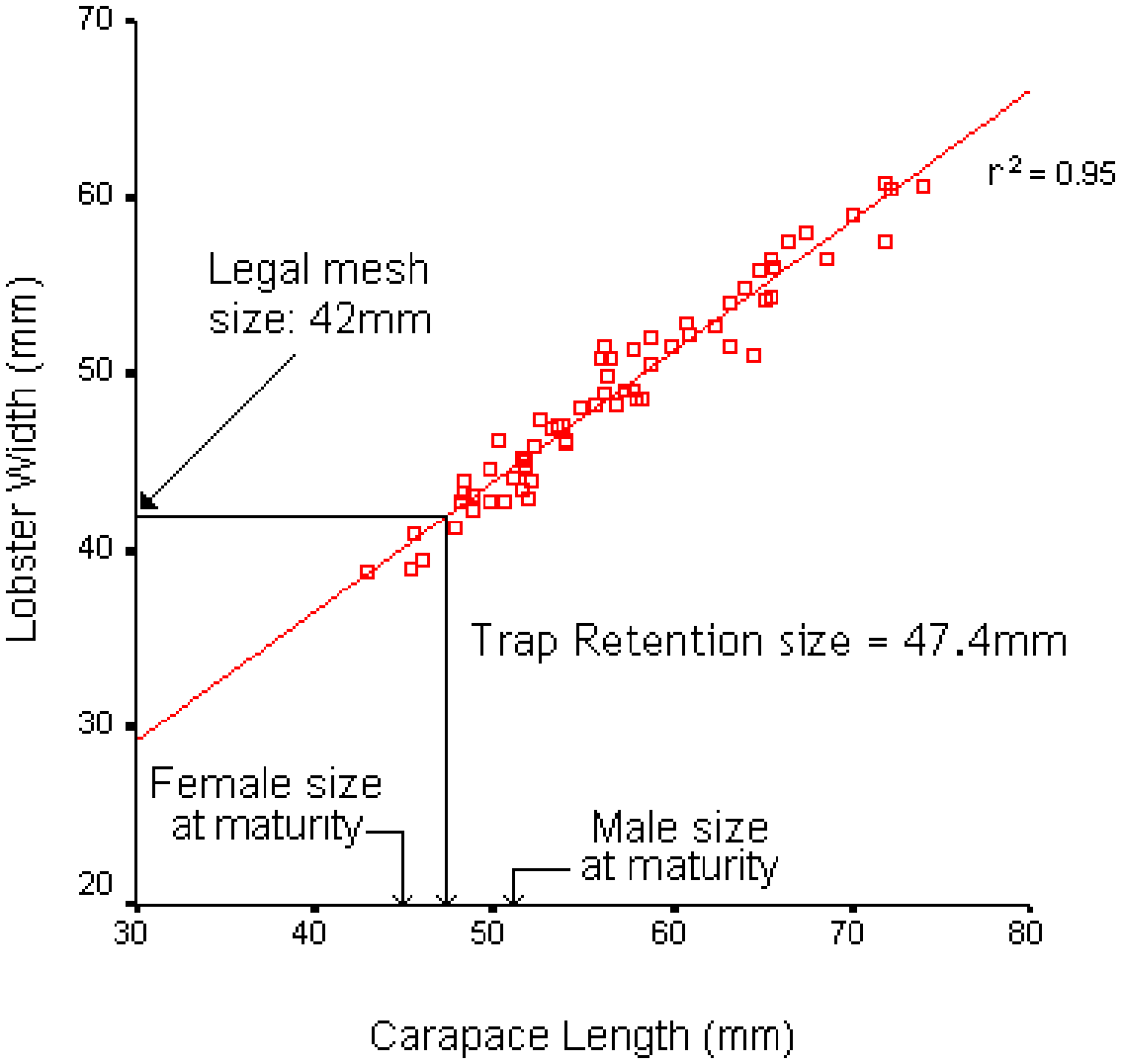

Figure 6 – The correlation between *P. guttatus* carapace width and carapace length. The regression equation y = 0.737x + 7.071 ($p < 0.001$) can be solved for a lobster width (equated with lobster trap mesh size) of 42 mm to give a retention size of 47.4 mm CL. The size will likely be slightly larger though due to leg entanglement. The graph also illustrates male size at maturity (51.3 mm CL) and female size at maturity (46.03 mm). This result relates quite closely to Evans & Evans (1995) who calculated a 1.5 inch (c.40 mm) mesh to have a mean retention size of 50 mm CL.

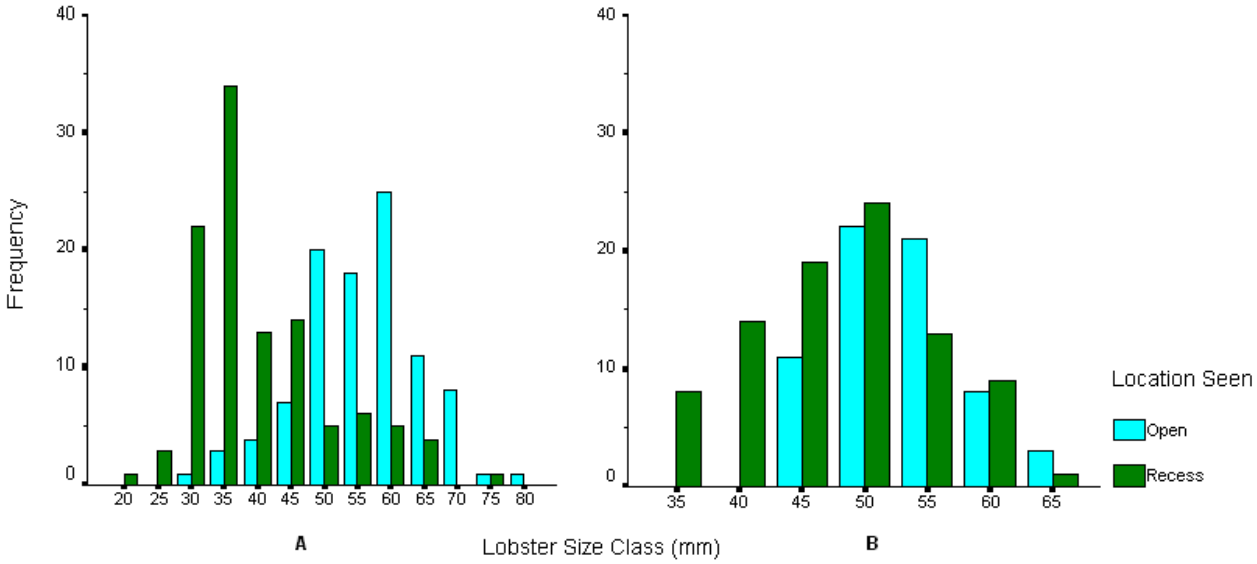

Figure 7 – Male (A) and female (B) *P. guttatus* activity during nocturnal snorkelling surveys, split into whether individuals were seen foraging in the open or hiding in protective recess.

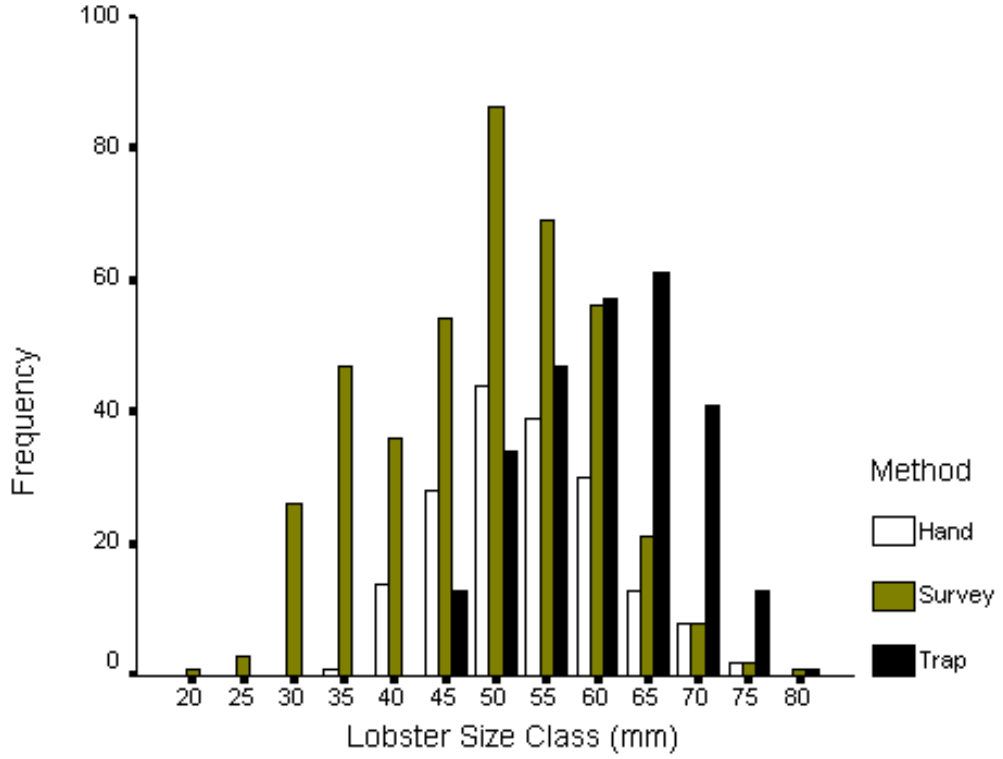

Figure 8 – Frequency of different *P. guttatus* size classes: Whether caught using traps; by hand; or those observed during nocturnal snorkelling surveys. Note how the hand capture method yields a proportionally similar size class structure to that seen during surveys, where as the trap caught size class structure is skewed towards the larger individuals.

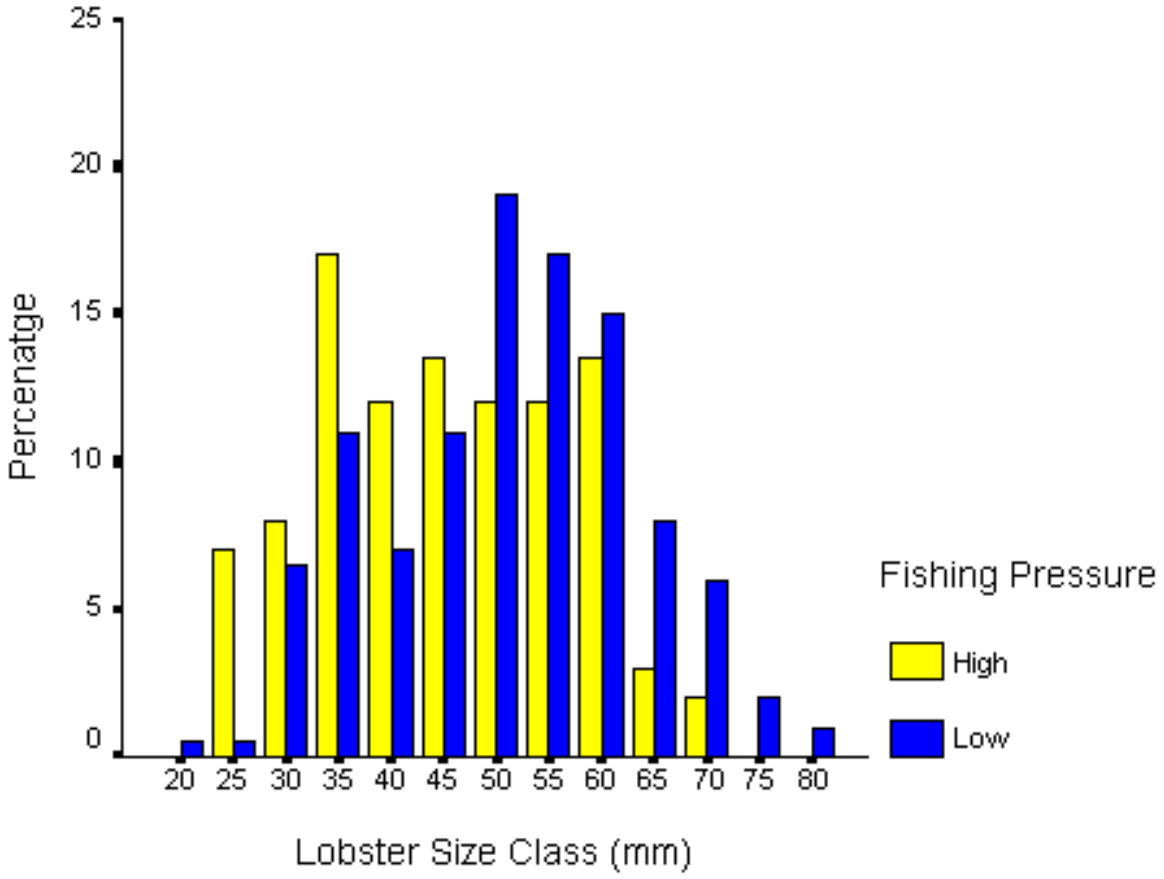

Figure 9 – Percentage size class distributions across sites with high fishing pressure and low fishing pressure as assessed during nocturnal snorkelling surveys in 2004.

As a final note relating to fishery selectivity, during experimental trap treatments where small (1cm) mesh was used, there were no significant differences seen between the size lobster captured and the size captured by traps with legal mesh size (Wynne 2004).

4. DISCUSSION

From the results it seems clear that fishing *P. guttatus* solely via traps, if as intensive as it is in Anguilla, will remove the larger individuals from a population, an effect observed by Wynne 2004. It is however unlikely that it will remove all reproductively active individuals as maturity begins in size ranges that are very rarely caught. Although the trap retention size does point to the fact that this is due to the mesh size allowing smaller individuals to escape, experiments done with smaller mesh sizes (Wynne 2004) seem to indicate other factors. It is known from the scientific literature on *P. guttatus* that they are cryptic and that

the smaller size classes are seldom seen (Robertson 1994). Furthermore, the smaller individuals that are sighted are usually found hiding in recesses or other protected locations, such as under the spines of *Diadema antillarum* (Wynne, pers. Obs.). Smaller individuals were rarely seen venturing away from such locations in the same way the larger sizes frequently were. It is suggested here that their reclusive nature will aid their sustainability in a trap fishery because the smaller individuals are usually not trappable, aside from the occasional outgoing adventurer.

This does not mean that no legislation is recommended to protect this fishery from detrimental exploitation. On the contrary, the fact that hand fishing allows the catching of smaller often immature individuals that remain close to protective recesses, means that such legislation would be beneficial to the future of the fishery. Furthermore, because it may become unprofitable to continue trap fishing as stocks of larger individuals become depleted, hand fishing may become the dominant form of obtaining *P. guttatus*. With fewer larger individuals, smaller individuals will become more acceptable for consumption than they currently are and thus become more actively targeted. This will ultimately lead to a change in perception of what the 'normal size' of *P. guttatus* is, and gradually smaller and smaller individuals will be sought after until immature individuals make up the bulk of the catch. This is a situation to avoid at all costs as it will lead to recruitment over fishing and collapsing stocks.

Not only this, but where in the past hand fishing was largely limited to coastal regions, or involved camping on an offshore cay, fishers are becoming bolder and willing to make boat trips at night to areas they used to target with traps (Wynne, pers. obs.). On consultation the fishers said with reducing catches it was now more efficient to take the risk and visit these areas at night. This potentially means that eventually the only populations that will survive will be those inaccessible shallow reefs that are populated by *D.antillarum* as Wynne (2004) suggested. These spots will remain as seeding areas however and be able to repopulate depleted regions in the long-term.

Another consideration relating to fishery sustainability is that *P. guttatus* rapidly becomes inactive and dies once landed (Wynne, pers. obs.). This suggests that this species is particularly susceptible to stress and raises the question of impacts on breeding individuals that when landed are required by law to be returned to the water. Although during fishing trips fishers diligently returned berried females to the sea, no studies exist to suggest that these individuals return to their dens and spawn successfully. Indeed, by the time they are returned to the water the fishing boat has moved on some distance which may in itself disorientate them, although it has been demonstrated that they do have a limited homing and orientation ability (Lozano-Álvarez 2002). However, being disorientated may cause stresses which, combined with damage sustained while being removed from the trap (leg loss was observed to be common) likely leads to increased mortality risk. Not only this, but berried females rapidly flick their tails while being handled which often dislodges and also likely damages those that remain in place. Also worth consideration is that when *P. guttatus* were measured in restaurants a number of the females looked as if they had been

tampered with, potentially having their eggs removed (Wynne, pers. obs.). Disturbingly, the head chef reported that the Crayfish in question had been purchased from fishers who had been observed by the author returning berried females to the sea only days previously, suggesting that behaviour was purely because a surveyor was on board. All these points highlight the need to protect breeding stock from mortality.

As an interesting side note, figure 5 illustrates how a smaller percentage of females are caught during peak breeding season and a larger one is caught during the lull in breeding activity. This suggests that males are proportionally more active during the breeding season and less active in the lull. This likely due to the fact that females, once egg bearing become more inactive to avoid predation or other damage to their eggs, and likely forage near their dens, moving further a field only if food supplies dictate. Similarly, this relationship is also likely affected by the fact that males become more active during the breeding season while seeking out receptive females. The fact that overall catches did not vary throughout the year suggests increases in male activity offsets decreases in female activity, and thus the results don't represent and increase or decrease in the activity of only one sex.

From these discussions it is clear that the *P. guttatus* fishery would benefit from two separate management measures: An enforced minimum landing size to avoid hand potential future recruitment over fishing; a closed season to restrict the molestation of berried females. It is however important to balance these with the understanding that a number of Anguillans earn their livelihood from this fishery and so any regulations have to balance sustainability with this.

As very few *P. guttatus* are caught smaller than 50 mm while trap fishing (less than 2.5% of the catch in the 2007/2008 study), and because individuals smaller than this are currently considered unattractive to tourist restaurants (Straw Hat, pers. comm.), setting this as a minimum landing size can be justified in terms of both livelihood issues and species maturity. However, even though males of less than this size have viable sperm, their ability to mate is drawn into question because they lack the leg length that is thought to aid mounting a receptive female and depositing their spermatophores. In fact, fecundity has been seen to be positively related to the size of both sexes (Robertson 1994). Furthermore, as fisheries management rounds up landed catch measurements to the nearest five millimetres, setting the limit at 50 mm CL would lead to a 46 mm CL individual being legal, which is not recommended in light of the results here. Therefore a limit of 52 mm is instead suggested as it encompasses the onset of male allometric leg growth but also means no individuals smaller than 50 mm are legal if landed. At the same time, as mentioned above, this will have minimal impact to socioeconomic aspects of the trap fishery as individuals 52 mm or smaller account for less than 5% of the current trap fishery.

These results seem to vary from some of the other studies mentioned, but corroborate others. These variations are likely caused by the different methodologies used. For example, Robertson & Butler (2003) captured their specimens by hand and found the female size at 50% maturity to be 36 mm. Because the present study relied on trap caught specimens,

and as such no specimens of this size were assessed, the resulting estimate is understandably higher. However, Sharp *et al* (1997) estimated the *onset* of female maturity to be between 32 and 38 mm CL, with a size at 50% maturity calculated as 48 mm CL. Sharp *et al.* also used traps, and hence arrived at the same 50% figure, although even with Robertson & Butlers small 50% figure, the smallest ovigerous female they found was 32 mm, thus their result also corroborates that of sharp, which as stated was the same as that obtained in the present study. Furthermore by using the quadratic regression equation presented in figure 3, the onset of sexual maturity can be estimated as c.39 mm, which again is very similar to the result suggested by Sharp *et al*.

The peak of the breeding season was found to be between December and April, although closing the *P. guttatus* fishery for such a long period would likely cause much local resentment. For this reason it is suggested that a closed season be best implemented between January and March. This encompasses the period of peak activity, without unreasonable length. Furthermore during this period Anguilla is effected by 'Ground Seas' - a period of high swells caused by storms off the eastern coast of the United States that stir up sediment and turn coastal waters murky. Fishing is often more sporadic during these times even though the tourist season and therefore catch demand is higher. As *P. guttatus* are virtually always sold to restaurants frozen because of their very short 'shelf life', it is not unrealistic to imagine fishers stocking their freezers prior to the closed season during which time tourism and therefore tourist demand is low. At the present time many fishers remove their traps from the water between September and November for repairs (coinciding with hurricane season), so the closed season would merely involve a slight change to their annual schedule. Hurricane risk has been greatly reduced over recent years by advances in weather modelling, and as such fishers would be given plenty of warning to remove their traps from the water or move them to safe locations should a hurricane threaten.

Another factor in favour of having a closed season is the capacity of Government departments to carry out surveillance and enforcement. It is far easier for the only suitable vessel owned by the Department of Fisheries and Marine Resources to ensure closed season status is respected than it is to ensure all berried female *P. guttatus* are returned to the water. Not only this, but by the time berried females are discovered it will be too late to return them to the water, and it is unlikely fines or other deterrents would be enforced over such a minor violation. It is much more likely that penalties would be applied to those flouting the closed season, with the added likelihood that fellow fishers would 'enforce' the legislation on a local level though peer pressure.

Although results from Florida & Bermuda put the breeding season between March and June, the results here corroborate those attained in Mexico and Belize. It has been suggested that egg production begins to increase above the constant yet low background production level when sea temperatures reach their annual minimum and that levels once again begin to drop as temperatures increase (Briones-Fourzán & Contreras-Ortiz 1997). From the results here this seems to also be the case in Anguilla, and suggests that the breeding season for this species, and maybe all *Panulirus sp.* can be ascertained by looking

at sea temperatures rather than undertaking in-depth studies. This certainly seems to be the case because in Florida and Bermuda *P. argus* reproductive activity also peaks from March to June (Evans *et al.,* 1995), whereas across the Caribbean the main peak for *P. argus* is again during the spring months. Lacking water temperature records for Florida and Bermuda it is not clear however if the peaks reported there are due to temperature minimums, but the fact that in the Caribbean there is a secondary, smaller peak for *P. argus* during September-October, suggests other seasonal factors may be in play.

5. CONCLUSIONS

- Life history characteristics combined with a minimum mesh size of 42 mm mean the *P. guttatus* trap fishery will not likely lead to recruitment over-fishing, although it will likely lead to the removal of larger size classes from fished populations.

- As larger size classes diminish it is possible that the trap fishery will no longer be economically sustainable, and all *P. guttatus* landings will occur via the already popular hand-fishing method.

- Hand-fishing can and does target smaller individuals than those caught through trapping, and thus as population size classes continue to diminish landed size classes will follow suit.

- Based on size at maturity for both sexes a minimum landing size of 52 mm is recommended that will have little livelihood impact on trap fishers but will protect immature individuals that can be targeted by hand fishing.

- As *P. guttatus* is suspected to be sensitive to external stresses and because it is difficult to police the landing of berried/tar spotted females, a closed season is also suggested to promote the fishery's sustainability. To best protect spawning populations, and also to minimise livelihood impacts, this closed season is suggested to occur between January 1st and March 31st each year.

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