USVI Caribbean Spiny Lobster Assessment

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INTRODUCTION

Spiny lobsters (Palinuridae) are among the most economically important crustaceans in the world (Olsen *et al.* 1975). Spiny lobster catches in the greater Caribbean region accounted for 17% of the world's lobster production from 1978-1991, and is the species of highest commercial value in countries such as Cuba, Brazil, Bahamas, and Florida (CARICOM 1996). Florida, for example, commercially harvested approximately 2,721,088 kg annually over the last 20 years, and 907,029 kg annually in recreational landings (Bertelsen and Matthews 2001). The Caribbean Spiny lobster, *Panulirus argus*, also supports an important commercial and recreational fishery in the U.S. Virgin Islands (USVI).

Understanding adult populations of *P. argus* includes studying trends in settlement and recruitment. A degree of variance in recruitment is characteristic of most invertebrate fisheries. Thus, settlement and early post-settlement processes that influence recruitment demand great attention (Butler and Herrnkind 1997). Witham collectors give a measure of the relative abundance of pueruli in an area and have been used to make general comparisons across areas (Witham *et al.* 1968). Similar devices have been used in Australia to correlate postlarvae abundance with commercial catches several years later (Cruz *et al.* 1995). Butler and Herrnkind (1997) used this relationship to predict maximum sustainable yield of the western rock lobster, *Panulirus cygnus*. Long term monitoring can detect trends and changes in populations over time, thereby revealing information about spiny lobster stocks and sustainability of harvests. Nevertheless, it is not enough to only study trends in settlement and recruitment, juvenile habitat requirements must also be identified.

Over the last decade Witham collectors have been used in the US Virgin Islands for repeated sampling at selected sites to explore temporal trends in *P. argus* pueruli settlement and abundance (for 1992-93 see Quinn and Kojis 1997; and for 1997-98 see Kojis *et al.* 2003). These studies were done around St. Thomas both inside and outside the Cas Cay/Mangrove Lagoon and Great St. James Marine Reserves.

Juvenile and adult *P. argus* use a variety of benthic marine habitats (Herrnkind and Butler 1986; Butler *et al.* 1997; Herrnkind *et al.* 1997; and Acosta and Butler 1997). However, the affect of habitat characteristics on juvenile dispersal is unclear. The availability of refuge structures are thought to strongly influence survival, distribution and abundance of small benthic crustaceans (Caddy 1986). Crevices and other interstices for evading predators are especially important to vulnerable early benthic stages of spiny lobster (Herrnkind and Butler 1986). Specifically, insufficient sheltering structure is thought to limit early recruitment in some areas (Wahle and Steneck 1991).

According to Andree (1981), postalgal phase juveniles move out of vegetated areas and seek refuge crevices when they reach 15-20 mm CL. Soca-Cordero *et al.* (1998) reported that artificial shelters placed in benthic habitats deprived of hardbottom (natural shelter) enhanced juvenile populations. According to Bolden (2001) and Mateo and Tobias (2001), the USVI lobster fishery may be in decline. Therefore, besides surveying pueruli lobster in this study, an effort was made to investigate artificial shelters for juvenile *P. argus* in areas devoid of appropriate juvenile habitat.

Study Objectives

The main objectives of this study were: (1) to examine spatial and temporal variations in *P. argus* pueruli settlement and relative abundance within marine reserve habitats located on the east end of St. Thomas, USVI; (2) compare trends in relative abundance and settlement of pueruli between 1992-93, 1997-98, and 2002-03; and (3) to evaluate the use of artificial habitat enhancement structures on juvenile lobster occupancy or abundance.

MATERIALS, METHODS, AND STUDY SITES

Pueruli Settlement and Abundance

1. Modified Witham Collectors

Pueruli collectors (see Figure 1) were modified from the original design used by Witham *et al.* (1968). Collector frames were made from 1.90 cm diameter closed PVC pipes that measured 40.5 cm x 40.5 cm, and were comprised of four crossbars connected by 90° elbows. For each collector, four "hogs hair" air-conditioning filters were cut into 40.5 cm x 61 cm pieces. They were then folded lengthwise with the webbed backing material to the inside, slipped over each crossbar on the PVC ladder frame, and secured with plastic tie-straps. Each collector was anchored by ½ inch diameter polypropylene rope to two concrete building blocks (40 x 20 x 15 cm each). Block sets were bounded together with rubber hose collars around ½ inch polypropylene rope. A sub-surface buoy was used to suspend each collector at each site.

2. Study Sites and Collector Deployment

Using a WAAS GPS study sites (Figure 2 and Appendix 1) were located from previous studies by Quinn and Kojis (1997) and Kojis *et al.* (2003). In 1997-98 sampled sites included Mangrove Lagoon, Cas Cay, Nazareth Bay, northwest Great St. James and southwest Great St. James (Kojis *et al.* 2003). In 1992-93 however, Quinn and Kojis (1997) only sampled the Mangrove Lagoon and southwest Great St. James Island sites.

On 4 June 2002, two pueruli collectors each were deployed at five selected sites within the Cas Cay/Mangrove Lagoon and Great St. James Marine Reserves on the southeast side of St. Thomas (Figure 2). A subsurface buoy was used to suspend each collector at each site. If vessel traffic at a site was low, then a surface buoy was used to facilitate locating the site.

The Mangrove Lagoon site (18° 18.333'N, 64° 52.474'W) was located in a protected shallow channel in the Inner Mangrove Lagoon Marine Reserve (see Figure 2). The inner lagoon is enclosed and experiences limited flushing and water currents. This site is a mangrove habitat with a dense algal plain over fine sand and mud. The dominant vegetation was low canopy macroalgae consisting of *Halimeda* spp., *Penicillus* spp., *Udotea* spp., and cyanobacteria. The Witham collectors at this site were anchored approximately 1m below the surface in water about 2.0 m deep and placed about

8 to10 m apart from each other.

The Cas Cay site (18° 18.548'N, 64° 52.118'W) was located in the Cas Cay/ Mangrove Lagoon Marine Reserve (see Figure 2). Collectors were set just below the surface in water approximately 1.5 m deep, and placed within a halo of sand surrounded by a dense seagrass bed of *Thallasia testudium* and *Syrigodium filiformi*. This site was adjacent to the north shoreline of Cas Cay. These collectors were placed about 10 m apart and were exposed to constant trade winds from the south and southeast, as well as associated wave action.

The collectors at Nazareth Bay (18° 19.069'N, 64° 51.416'W) were located in the St. James Marine Reserve and were positioned over a sparse homogeneous seagrass bed (*Syrigodium filiformi*), approximately 100 m from the rocky shoreline of St. Thomas (see Figure 2). The Nazareth Bay collectors were suspended 3 m below the sea surface in approximately 6 m of water. Collectors were 10 m apart.

The northwest side of Great St. James (18°18.794'N, 64°49.075'W), located in the St. James Marine Reserve, was patchy coral reef/sand habitat (see Figure 2). This site was adjacent to (~20 m away from) the rocky shoreline and Current Cut Passage, which experiences moderate to strong tidal currents. The collectors at this site were set 3 m below the surface in water that was approximately 8 m deep. The collectors here were placed 10 m apart.

The last site, southwest Great St. James (18°18.403'N, 64° 50.140'W), also located in the St. James Marine Reserve, was a patchy mixed algal and seagrass/sand habitat (see Figure 2). Heavy water movement and current occurred along this side of the bay. Collectors at this site were set 3 m below the surface and were deployed in approximately 11 m of water. The collectors were set about 15 m apart.

3. Sampling

Collectors were sampled every two weeks over a 12 month period (from June 18, 2002 to June 17, 2003). The collectors were sampled by snorkellers at all sites. Prior to bringing a collector to the surface, it was enclosed in a 1 square meter mesh bag with 1 mm square mesh. Once covered by the bag, the collector was then unclipped and the bag and collector were brought on board a boat for inspection. All lobster pueruli and juveniles were counted and returned unharmed at each site. Pueruli were staged as follows: transparent, semi-pigmented, pigmented, and algal-phase juvenile (see Bannerot *et al.* 1992; CARICOM 1996; and Butler and Herrnkind 1997; see also Appendix 2 for definitions). Damaged, lost, or heavily encrusted collectors were replaced immediately after inspection. Each sample period represented a 14 to 16 day settlement period.

4. Data Analysis

Paried T-tests were used initially to test for differences between collectors at each site. No difference was detected in pueruli abundance between collectors within a site ($P>0.05$) in all cases except Cas Cay. Collectors at Cas Cay often broke and were lost, therefore, the samples were unbalanced and classical t-tests could not be used. For this reason, the data at Cas Cay was log(x+1) transformed and an one way ANOVA was conducted to test for differences between the Cas Cay collectors. The results of the one way ANOVA on the transformed data was marginal ($F_{1,52}$=3.826, P=0.056) between collectors. Therefore, it was decided that rather than disregard the Cas Cay site, CPUE should be used to make comparisons between sites, since the formula used for CPUE accommodates missing samples and a disproportionate number of days between sample periods. Catch per unit effort (CPUE) was calculated by dividing the total catch for each site by the number of days between sample periods then dividing this by the number of collectors at that site (usually 2). Thus, unless otherwise specified, CPUE = (total catch/ number of days between sample periods)/number of collectors. CPUE calculations included first stage juveniles (dark pigmented body; ~5-15 mm CL) as well as pueruli. Samples that had missing or detached collectors were not included in the data analysis (Cas Cay site for example). Standard one-way ANOVA was then used to test for differences in catch per unit effort between sample sites.

Timing in settlement was examined graphically, and by month and site. Lunar phase (new moon, first quarter, full moon, last quarter) was defined for each sample date. Sample dates without a distinct/obvious lunar phase were assigned to the nearest lunar phase.

Comparison between years was by graphical comparison of CPUE and by using ANOVA to test for differences between years. Catch per unit effort data from previous project studies (Quinn and Kojis 1997 and Kojis *et al.* 2003) were standardized for direct comparison to 2002-2003 data. The northwest St. James and southwest St. James sites in 2002-2003 were combined to allow comparison to the 1992-1993 and 1997-1998 data sets.

Juvenile Lobster Artificial Shelters

1. Artificial Shelter Construction

In an effort to study the status of the lobster fishery and the efficiency of artificial shelters, CARICOM (1996) recommended that a standard shelter be deployed at 20 m and monitored on a regional level. Therefore, ten sets of lobster shelters were constructed after the model suggested by the CARICOM (1996). Each shelter consisted of 16 large concrete cement blocks (40 x 20 x 15 cm each) with three square holes per block. The 16 blocks were arranged in a two-level quadrangular structure with an open central area (see Figure 3).

2. Artificial Shelters Study Site and Installation

The study area selected for shelter installation was located east southeast of Cow and Calf Rocks and south of Great St. James (start of shelters: 18° 17.986'N, 64° 50.230'W; end of shelters: 18° 17.998'N, 64° 50.375'W; see Figure 2 and Appendix 3). It was an area approximately 20 m deep with a relatively flat sandy bottom and sparse algae plain. The prominent algae were *Halimeda* spp., *Penicillus* spp., *Udotea* spp., and *Caulerpa* spp., along with sparsely scattered sessile invertebrates.

On 11 June 2002, ten sets of block shelters were deployed. Each set of shelter blocks were first lowered from a surface vessel and spaced approximately 30 m apart. These were later arranged underwater by divers. Each of the ten shelters was marked by a guide rope 1-2 m away from the juvenile shelters for divers to follow. Sub-surface marker buoys were deployed at each end of the artificial shelter sites. Because only one juvenile lobster was encountered from July to October 2002, at the October 2002 Southeastern Area Monitoring and Assessment Program Caribbean (SEAMAP-C) meeting; it was decided that half of the artificial shelters should be covered. Therefore, on 19 December 2003 five of the ten shelters were covered with aluminum sheets (about 75 x 75 cm) and secured with large cable ties. Every other shelter was covered.

3. Sampling and Data Analysis

Shelter occupancy by juvenile lobsters was checked every three months (quarterly) over a 12 month period from June 2002 to June 2003. The shelters were sampled by underwater visual observation using SCUBA gear. Two divers inspected each shelter and counted the number of juvenile lobsters observed in each. Estimates were made on the total carapace length (CL) of each lobster present. Shelters that either collapsed or became buried in sand were re-adjusted so that the block holes were clear of debris.

Because of the paucity of lobsters colonizing the shelters (total of 2 juvenile lobsters), analysis was limited.

RESULTS

Modified Witham Collectors

Five sites, with two Witham collectors each, were sampled from 18 June 2002 to 17 June 2003. A total of 202 postlarvae were observed (Table 1). During a single sampling period, a maximum of 40 pueruli settled across all collectors. Of the total catch, ten (5%) of the pueruli collected were transparent, 19 (9%) were semi-pigmented, 28 (14%) were pigmented, and 145 (72%) were early algal-phase juveniles (Table 1; Appendix 4).

Spatial Variation

The abundance of pueruli at most sites was consistently low (Table 1, Figure 4). However, overall pureuli abundance in Nazareth Bay (total = 127) was considerably higher than the other four sites (Table 1, Figure 4). The overall catch between the Mangrove Lagoon and Cas Cay sites were similar with 19 and 18 pueruli respectively. Northwest Great St. James exhibited the lowest total catch with 10 postlarvae while southwest Great St. James had a total abundance of 28 (Table 1, Figure 4).

Catch per unit effort (CPUE) varied across sites (One way ANOVA: $F_{4, 127}$=4.355, P=0.002, see Appendix 6 and compare Figures 5 to 9 and Appendix 5). Nazareth Bay consistently yielded a higher CPUE in 2002-2003 than the other four sites (compare Figures 5 to 9). Pairwise comparisons

(Tukey's test) indicated CPUE at Nazareth Bay was greater than the other sites in all cases (Appendix 6), but that no differences existed between the remaining four sites.

Temporal Variation

Peaks in pueruli settlement occurred primarily in the spring and early summer (Figure 10). The collectors at the Mangrove Lagoon, Cas Cay, and northwest Great St. James had low settlement rates not exceeding 0.15 pueruli/day/collector (CPUE) on any particular sample date (Figures 5, 6 and 8; Appendix 5). Seasonal peaks for the Cas Cay and the two Great St. James sites were the spring and summer months (Figures 6, 8, and 9). The two collectors at southwest Great St. James had high settlement rates during the summer months, which decreased and stayed below a CPUE of 0.08 pueruli/day/collector during most of the remaining sample year (Figure 8; Appendix 5). The greatest settlement rate occurred in May 2003 at the Nazareth Bay site, with a peak CPUE of 1.54 pueruli/day/collector over a single sample period (Figure 7; Appendix 5). This is mainly due to the large number of pueruli (40 pueruli) that were observed in the 6 May 2003 sample.

In 2002-2003, pueruli abundance on Witham collectors was greatest across all sites during first quarter moon phases (Table 2). The total number of pueruli collected during the first quarter phase accounted for 73% of all settlement. CPUE was combined for all sites and plotted as a function of the number of days the sample was taken after the new moon. The highest and most prevalent CPUE values occurred between the new moon and first quarter phases (Figure 11).

CPUE was generally greater in 1992-1993 than in either 1997-1998 or 2002-2003 (Table 3; Figures 12-15). Two way ANOVA indicated that there were differences in CPUE between years ($F_{2,280}$ =10.88, P<0.001) and across sites for the combined years ($F_{3,280}$= 8.798, P<0.001) (see Appendix 7). However, because only two sites were sampled in 1992-1993, there was no test for interactions as some treatments were missing. CPUE has steadily declined from 1992 to the present at both the Mangrove Lagoon site and the St. James site (see Appendix 7-Tukey test; Figure 16). From 1997-1998 to 2002-2003, CPUE declined at all sites except the St. James sites where the mean annual CPUE increased slightly from 0.02 to 0.03 pueruli/day/collector (Table 3; Figure 16).

Artificial shelters occupancy by juvenile lobsters

A total of 2 juvenile lobsters were observed during this one year study (Table 4). Only 1 juvenile lobster was found in the uncovered shelters and 1 was found in the covered shelters. The small number of lobsters in this study precluded a statistical analysis of lobster abundance among shelters.

DISCUSSION

Many variables contribute to the temporal and spatial variability in recruitment of *P. argus*. Settlement and recruitment studies are complicated by the lengthy planktonic larval stage lasting from a few months to one year (Lewis *et al.* 1952). For example, low CPUE values at the Mangrove Lagoon site in 2002-2003 may be reflective of water quality issues (as discussed in Quinn and Kojis

1997; and Kojis *et al.* 2003) and/or lack of suitable juvenile habitat. Acosta and Butler (1997) suggested that although mangrove habitats may be important nursery habitats, the use of such was dependant on sheltering characteristics. Kojis *et al.* (2003) suggested that high CPUE values in the mangrove lagoon in 1997-98 may have been a function of the site's proximity to pueruli settlement habitat. However in 1999, Hurricane Lenny disrupted the natural tidal flow at this site by piling coral rubble at the lagoon/seaward interface. The resultant berm limited water flow in this area and may have resulted in a reduction of suitable juvenile habitat as well as a reduction of larval supply to the site. A *Porites porites* bed used to lie near the collectors at the Mangrove Lagoon site. However, Hurricane Lenny devastated the *P. porites* bed (personal communication, Division of Fish and Wildlife) and reduced water flow limited *P. porites* growth. The *P. porites* bed, which at one time could have provided adequate juvenile habitat, has since been covered with sediment and algae. Post-algal spiny lobsters prefer silt-free environments with adequate amounts of stony corals, but make use of mangrove prop roots whenever coral cover is sparse (Acosta and Butler 1997). The decrease in CPUE in the mangrove lagoon before and after Hurricane Lenny, suggests that although mangrove habitats may be important nursery areas, as implied by Little (1977), the absence of coral may have a greater influence on postlarval settlement than merely the presence of mangroves.

The above is also supported by the fact that Nazareth Bay consistently demonstrated high settlement rates (see Appendix 5) despite the absence of mangroves. As discussed in Kojis *et al.* (2003), the high CPUE at Nazareth Bay is likely a function of pueruli supply to this site by currents. Conversely, lower CPUE values at the St. James sites may be due to their orientation to the mass water flow, these sites appear to be oriented in the lee of an easterly current. The northwest St. James site is situated near an area that experiences heavy tidal currents. However, the collectors' orientation to the current is such that the currents may flush pueruli past the collectors.

It has been suggested that the larval phase of lobster is 6 to 12 months (Lewis *et al.* 1952). Therefore, it is likely that pueruli settlement in the Virgin Islands is dependant on an upstream supply. Pueruli settling and recruiting in Florida are likewise believed to be transported north from the Caribbean basin by the Caribbean current (Lyons 1980). However, regional patterns in postlarval supply are highly variable and do not necessarily reflect spawning cycles (Acosta *et al.* 1997). The period of greatest settlement in this study was in the spring/summer (April- June). These findings are consistent with Quinn and Kojis (1997) in which they reported highest settlement during the summer months (April- October). Peak settlement in south Florida was from spring to early summer (April-July, Acosta *et al.* 1997).

Quinn and Kojis (1997) report higher CPUE on new moons than full moons. The findings from this study are similar. In this study, lunar cycles were broken into four lunar phases rather than two. The results of this study indicate that higher CPUE values occurred during new moon first quarter phases. In the Florida Keys peak settlement, based on collection of *P. argus,* was highly correlated to new moon and first quarter lunar phases (Acosta *et al.* 1997). Pueruli typically travel and arrive at near-shore settlement areas during new moon and first quarter lunar phases to avoid predation (Heatwole *et al.* 1992). Thus, settlement may be triggered by the dark periods of a new moon and carry through the first quarter phase resulting in high catches of pueruli during the early first quarter phase.

In general, pueruli settlement has steadily declined from 1992-1993 through 2002-2003 (Figure 16). The CPUE of lobster pueruli observed at common survey sites in 1992-93 (Quinn and Kojis 1997), 1997-98 (Kojis *et al.* 2003), and 2002-03 (this study) are compared in Table 3 and Figure 16.

At Mangrove Lagoon, the overall CPUE of lobster pueruli decreased from 0.23 pueruli/day/collector in 1992-93 to 0.09 pueruli/day/collector in 1997-98. Pueruli settlement further declined to a CPUE of 0.03 pueruli/day/collector in 2002-03. In 1997-98, CPUE at Cas Cay was 7 times greater (0.21 pueruli/day/collector) compared to a CPUE of 0.03 pueruli/day/collector in 2002-03. In recent years, the Mangrove/Cas Cay Marine reserve has been subjected to non-point and point source pollution that may affect the water quality and potential pueruli settlement in this area. Settlement rates at Great St. James Island were lower in 1997-98 (CPUE = 0.02 pueruli/ day/collector) than 1992-93 (CPUE = 0.16 pueruli/day/collector), and remained relatively low with a CPUE of 0.03 pueruli/day/collector in 2002-03. Nazareth Bay not only had the highest CPUE (0.17 pueruli/day/collector) of all the sites in 2002-03, but maintained a relatively high settlement rate compared to that of in 1997-98 (CPUE = 0.30 pueruli/day/collector). There are no clear reasons for the decline in pueruli settlement over the years. Because spiny lobster have such a lengthy larval phase (Lewis *et al.* 1952; and Kittaka 1994) pueruli supply is not likely to be related to adult mortality or catch in the U.S. Virgin Islands. It is possible, however, that natural variability and the low resolution bi-weekly sampling used in this study may have overshadowed some trends in pueruli abundance and settlement.

Artificial Shelters

Throughout the one year study period, only 2 juveniles were encountered in the artificial shelters (one in the covered shelters, one in the uncovered shelters, see Table 4). Five shelters were covered on 19 December 2003 because only 1 juvenile was observed prior. Lozaro-Alvarez *et al.* (1994) suggested that covers are an important feature on this type of artificial shelter. In addition to multiple den openings, Spanier and Zimmer-Faust (1988) reported that the presence of shaded cover was important for den choice by *Panulirus interruptus*. After placing lids, one additional juvenile was seen. These results are similar to an experimental shelter study near the Cow and Calf Rocks where no lobsters were observed from 1992 to 1994 (Quinn and Kojis 1995). Although few lobsters were encountered in the current study, both covered and uncovered block shelters were densely occupied by other marine organisms. Invertebrates encountered included cleaner shrimp, arrow and hermit crabs, brittle stars, conch, triton, and large amounts of hydroids. Some of the more common fishes observed included squirrelfish (Holocentredae), and grunts (Haemulidae). Juveniles or commercially important fishes such as coneys (*Cephalopholis fulvus*), grasbys (*Cephalopholis cruentatus*), Nassau groupers (*Epinephelus itajara*), and red grouper (*Epinephelus morio)* were also observed on or near these attractors.

There are a few possible explanations for the limited occupancy of juvenile lobsters at the artificial shelter site. The most obvious reason may be a limited larval supply. The artificial shelters were placed (Figure 2) such that the predominant current flowed across them into Nazareth Bay and the Mangrove Lagoon (as discussed earlier, also see Kojis et al. 2003). Because of this funneling effect, pueruli settlement likely occurred a considerable distance away, thereby limiting the supply of juvenile lobster to occupy the shelters. The nearest feature to attract settling pueruli was Cow and

Calf Rocks, again a considerable distance across a predominantly sand and sparse seagrass/algal plain. Cow and Calf Rocks may act as an oasis and hold juveniles until they are of a much larger size to safely venture to further reefs with a greater prey base.

In addition to postlarval supply, juvenile lobster and postlarvae may actively select natural habitats over the artificial shelters. Although Herrnkind and Butler (1986) suggest early benthic lobsters prefer to reside in substratum with seagrass and rhodophyte algae, the habitat surrounding the artificial shelters was predominately a sand flat. Conversely, both Cow and Calf Rocks and Great St. James provide rocky outcroppings with moderate coral, gorgonian, and sponge growth. The natural reefs would provide a greater food base and prey availability. Despite the complexity of the artificial shelters, the concrete blocks were narrowly colonized by sessile organisms and probably provided limited foraging habitat.

It is important to consider that although block shelters can potentially be attractive for juvenile lobsters, they only adequately function in area where lobsters gather naturally (Lozano-Alvarez *et al.* 1994). This suggests that more importantly than physical characteristics of the shelters, local habitat features and shelter proximity to such can determine the success of artificial shelters in attracting and concentrating lobsters.

Future suggestions and management strategies for pueruli study

Coordinated regional sampling, such as in the British Virgin Islands and Puerto Rico, is important in detecting correlations among lobster pueruli distribution and large scale settlement and recruitment variations. It is critical to study the relationship between lobster settlement and recruitment to understand and manage adult lobster stocks. Perhaps developing and conducting recruitment studies in and around pueruli collection sites, especially at Nazareth Bay, can help clarify the transition between settlement and recruitment. It is also important to investigate the role habitat has on newly recruited juvenile lobsters (particularly exploring mangrove and coral reef habitats).

As more Caribbean islands participate in data collection, a better understanding of local and regional spiny lobster dynamics should develop. This could be the basis for implementing a regional lobster fishery management program. The USVI Government and the Caribbean Fisheries Management Council (CFMC) use regulations that restrict harvest of undersize and berried lobsters. However, management is limited without substantial data on habitat preference and selection, hydrological factors affecting such selection, and extent of harvesting in the territory.

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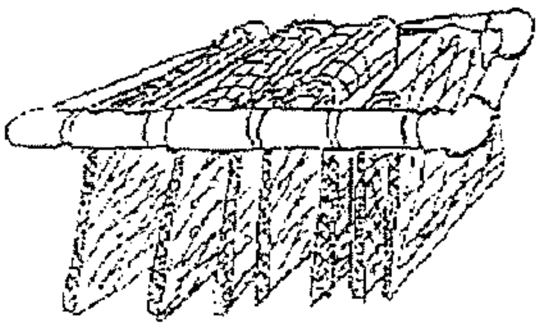
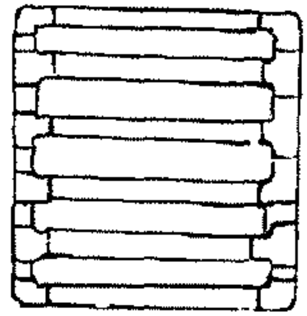


Witham Collector with "Hogs Hair" Filters (40.5 cm x 61 cm)



PVC Frame 40.5 x 40.5 cm with 1.90 cm diameter PVC Pipe

Figure 1. Modified Witham collector used in lobster pueruli settlement study (figures not drawn to scale).

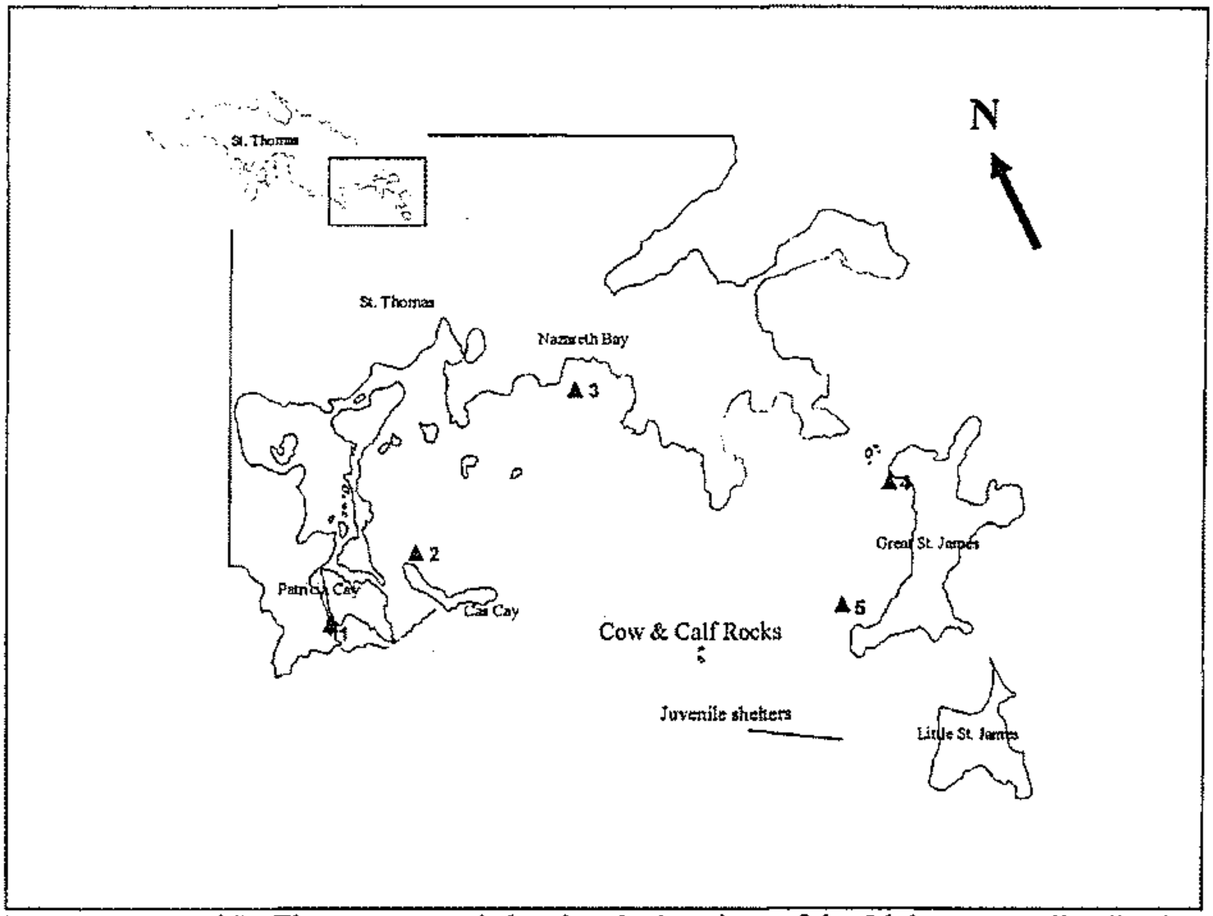
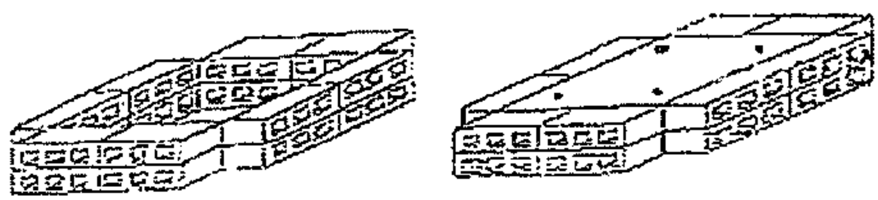


Figure 2. Map of St. Thomas east end showing the locations of the 5 lobster pueruli collection sites and the 1 juvenile shelter station (locations of pueruli collections detailed in Appendix 1, locations of juvenile lobster attractors detailed in Appendix 3).



Type 1: Uncovered **Type 2: Covered**

Figure 3. Two types of concrete block shelters used in juvenile lobster study (single block: 40 cm x 20 cm x 15 cm, cover ~ 80 x 80 cm, figures not to scale).

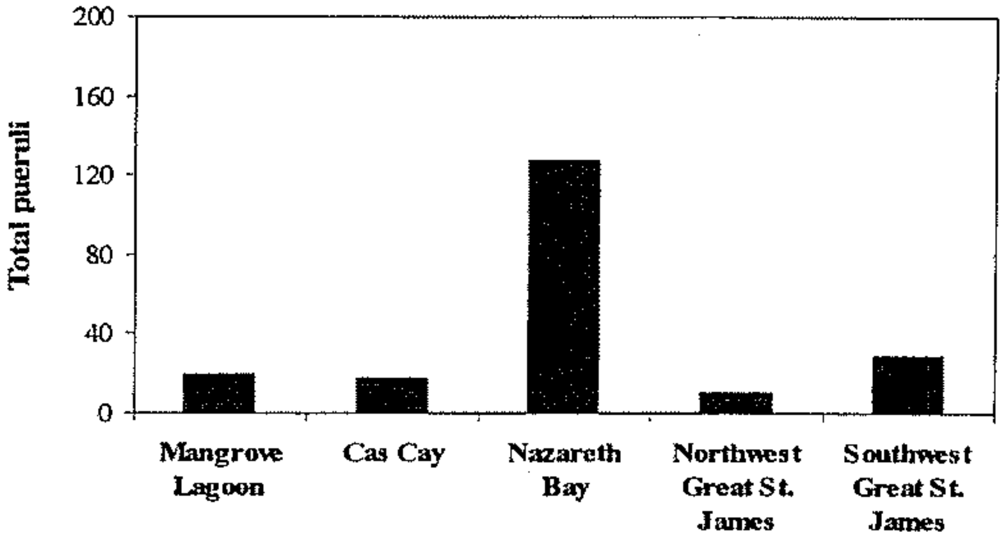


Figure 4. Total catch of *Panulirus argus* pueruli settlement on Witham colletors by site, 2002-2003.

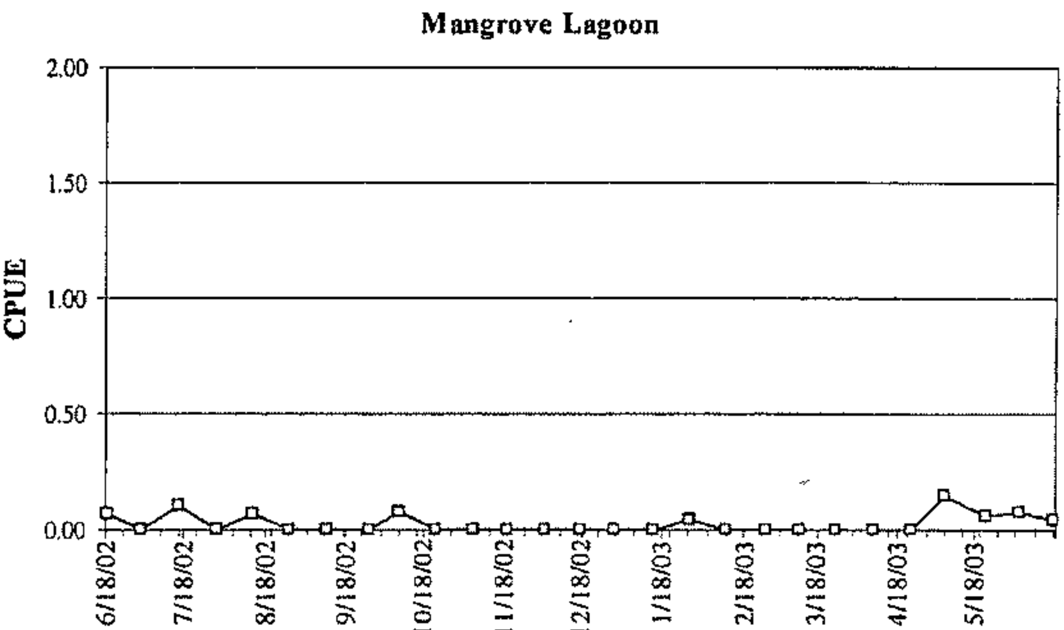


Figure 5. Catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) for the Mangrove Lagoon site (n=27) during the study period between 18 June 2002 and 17 June 2003.

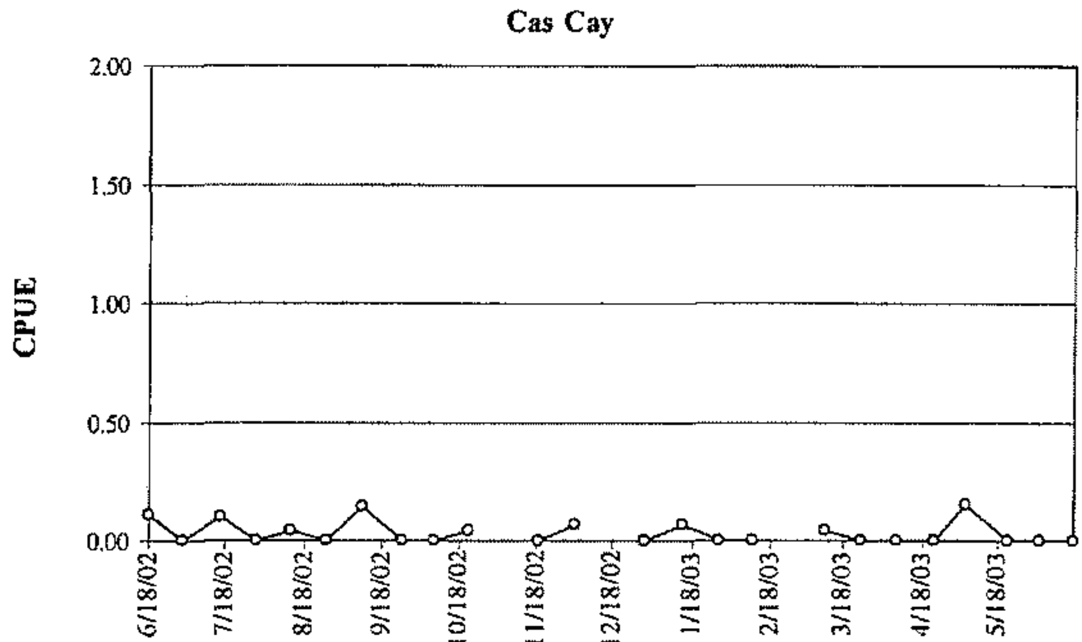


Figure 6. Catch per unit effort (CPUE = number of pueruli/number of days between sample periods/ number of Witham collectors) for the Cas Cay site (n=24) during the study period between 18 June 2002 and 17 June 2003. Gaps in data are due to broken or lost collectors.

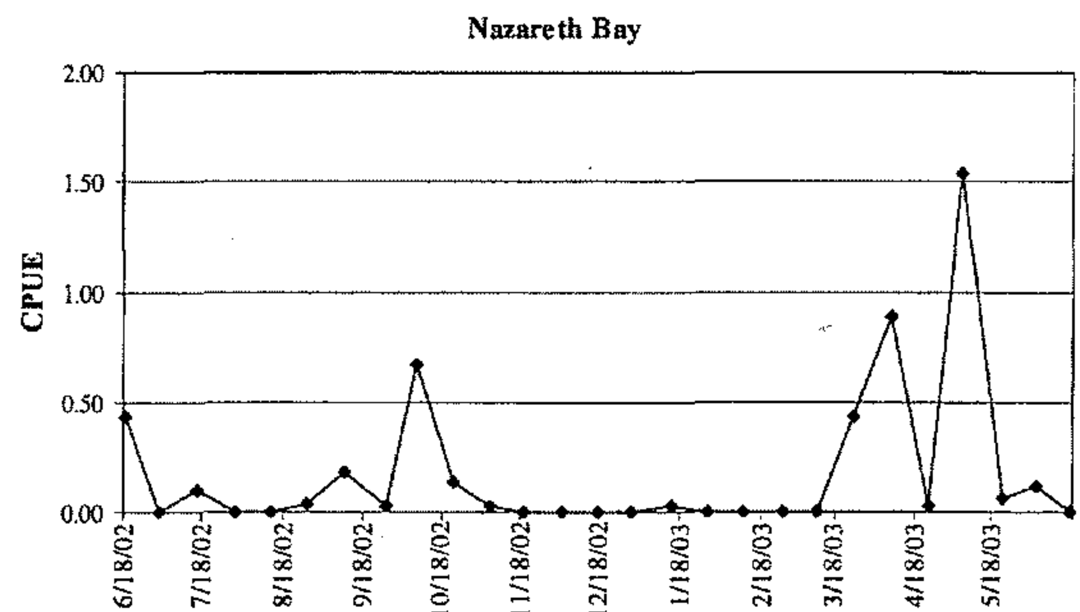


Figure 7. Catch per unit effort (CPUE = number of pueruli/number of days between sample periods/ number of Witham collectors) for the Nazareth Bay site (n=27) during the study period between 18 June 2002 and 17 June 2003.

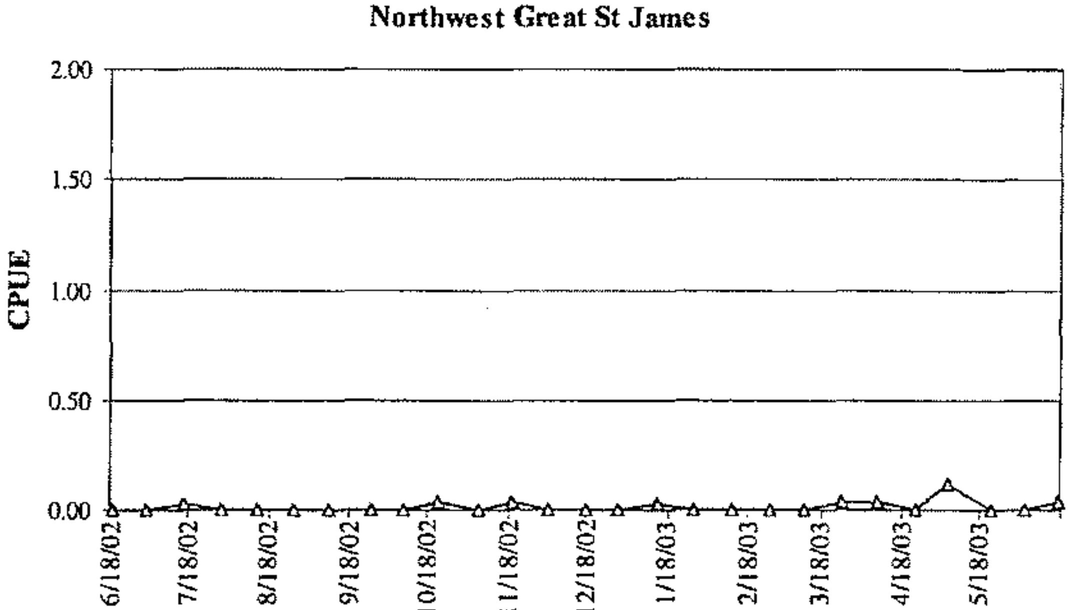


Figure 8. Catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) for the northwest St. James site (n=27) during the study period between 18 June 2002 and 17 June 2003.

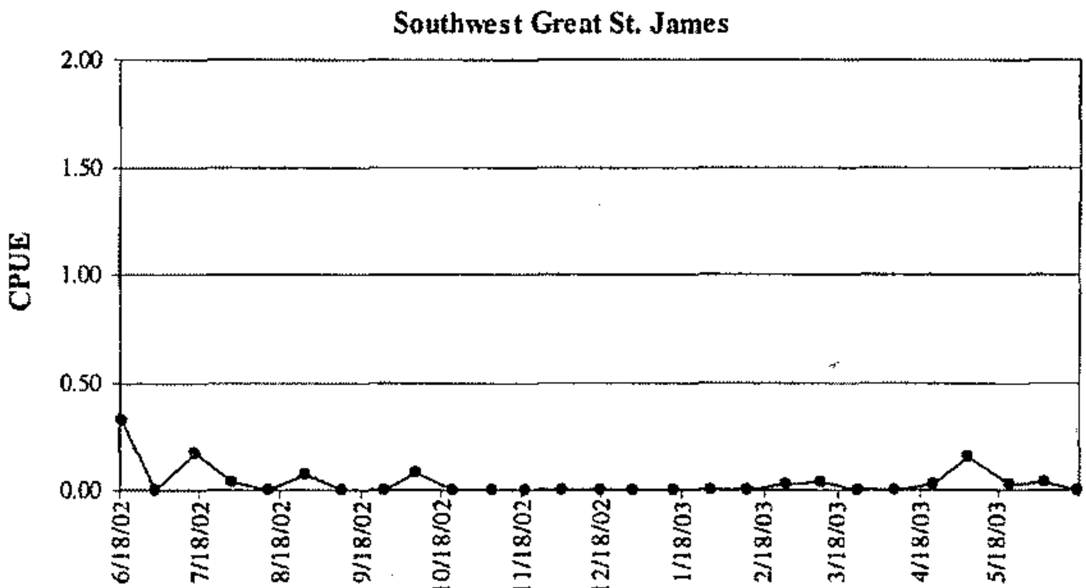


Figure 9. Catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) for the southwest St. James site (n=27) during the study period between 18 June 2002 and 17 June 2003.

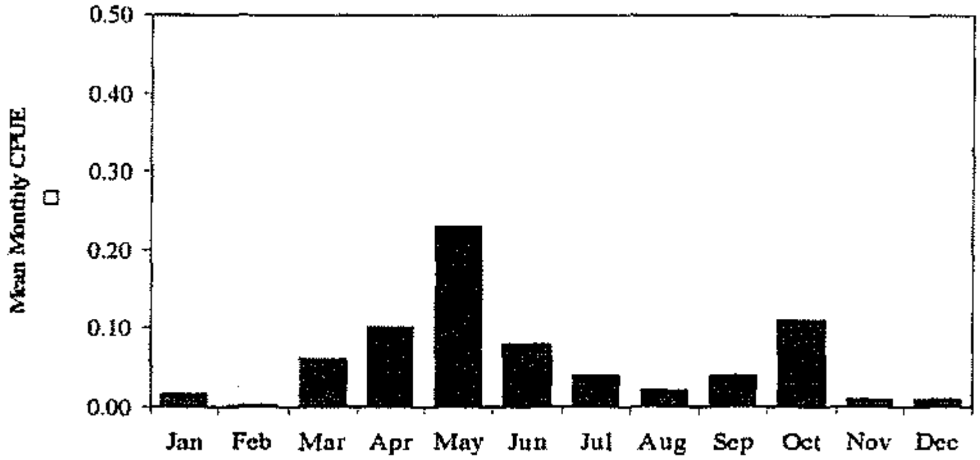


Figure 10. Mean catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) on Witham collectors summed over all sites and months, 2002-2003.

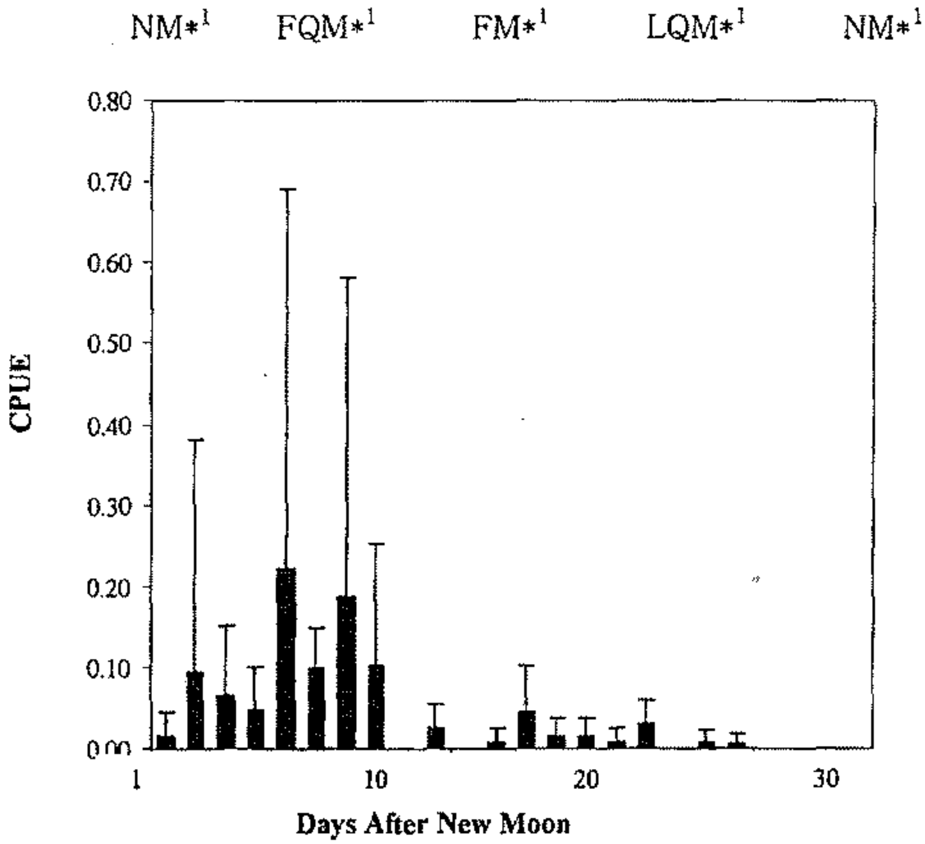


Figure 11. Lunar pattern of settlement of pueruli *Panulirus argus* on Witham collectors at all sites during 2002-2003 based on catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors, ±Std. Dev.). *Notes: (1) New Moon Phase, First Quarter Phase, Full Moon Phase, Last Quarter Phase, New Moon Phase.

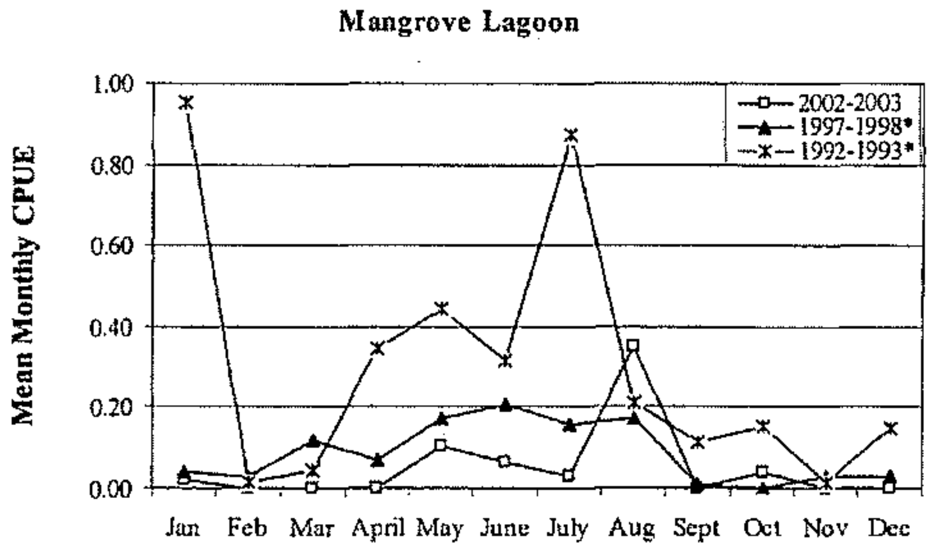


Figure 12. Monthly comparison of catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) of *Panulirus argus* pueruli settlement on Witham collectors among years for Inner Mangrove Lagoon. *Note: 1992-1993 data from Quinn and Kojis (1997); 1997-1998 data From Kojis *et al.* (2003).

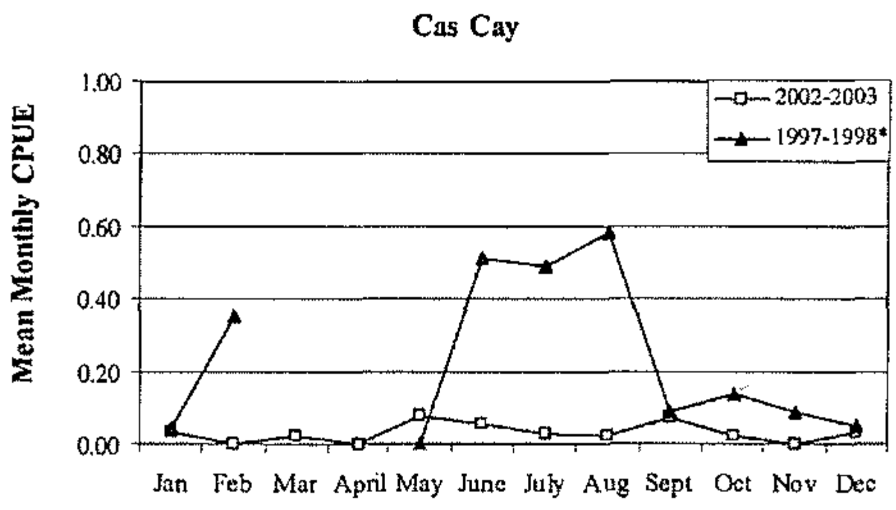


Figure 13. Monthly comparison of catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) of *Panulirus argus* pueruli settlement on Witham collectors among years for Cas Cay. *Note: 1997-1998 data from Kojis *et al.* (2003).

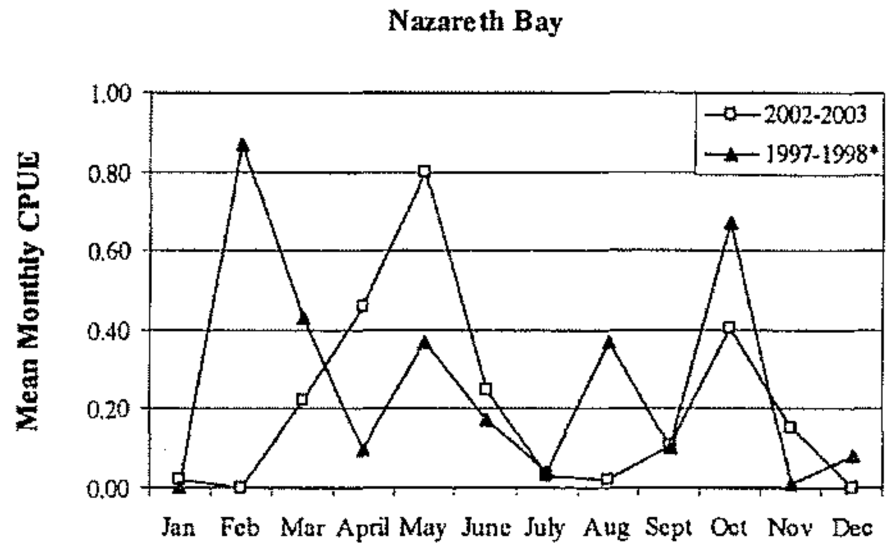


Figure 14. Monthly comparison of catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) of *Panulirus argus* pueruli settlement on Witham collectors among years for Nazareth Bay. *Note: 1997-1998 data from Kojis *et al.* (2003).

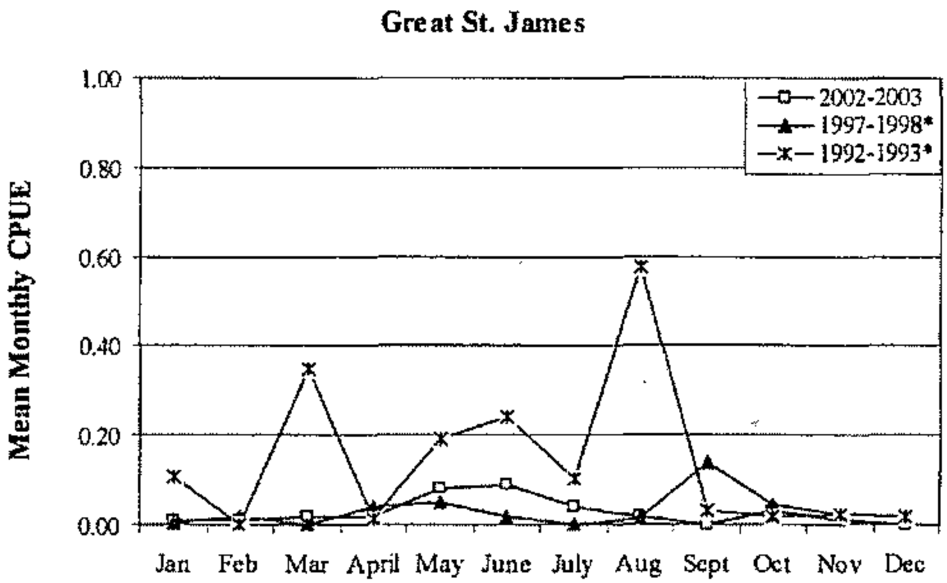


Figure 15. Monthly comparison of catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) of *Panulirus argus* pueruli settlement on Witham collectors among years for Great St. James Island. Northwest and southwest Great St. James sites were combined for comparison to previous years. *Note: 1992-1993 data from Quinn and Kojis (1997); 1997-1998 data from Kojis *et al.* (2003).

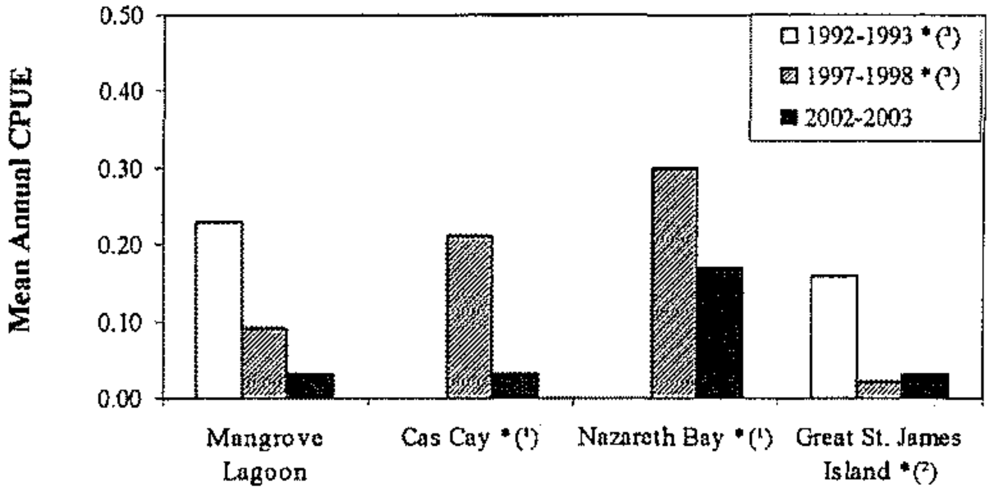


Figure 16. Comparison of catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) on Witham collectors among common sites between 1992-2003. *Notes: (1) Cas Cay and Nazareth Bay were not sampled in 1992-1993; (2) For 2002-2003, Great St. James sites were combined for comparison to previous years; (3) 1992-1993 data from Quinn and Kojis (1997); 1997-1998 data cited from Kojis *et al.* (2003).

Table 1. Number of *Panulirus argus* pueruli on Witham collectors of different stages settling at each site, 2002-2003.

Site	n*	Transparent	Semi-pigmented	Pigmented	Juvenile	Total
Mangrove Lagoon	27	0	1	0	18	19
Cas Cay	24	0	4	0	14	18
Nazareth Bay	27	8	10	25	84	127
Northwest Great St. James	27	1	3	0	6	10
Southwest Great St. James	27	1	1	3	23	28
Totals (132)	132	10	19	28	145	202

*Note: n = total number of samples per site.

Table 2. Abundance of *Panulirus argus* pueruli on Witham collectors, 2002-2003, as associated to lunar phase and the combined mean catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) for each phase.

Site	Total number of pueruli new moon (n = 2)*[1]	Total number of pueruli first quarter (n = 11)*[1]	Total number of pueruli full moon (n = 5)*[1]	Total number of pueruli last quarter (n = 9)*[1]
Mangrove Lagoon	2	15	1	1
Cas Cay	2	15	1	0
Nazareth Bay	16	91	5	15
Northwest Great St James	0	6	3	1
Southwest Great St James	2	21	0	5
Totals	22	148	10	22
Combined CPUE	0.09 ± 0.21*[2]	0.10 ± 0.24*[2]	0.02 ± 0.03*[2]	0.02 ± 0.07*[2]

*Notes: (1) n = total number of lunar phases.
(2) Standard Deviation of the mean

Table 3. Mean annual catch per unit effort (CPUE = number of pueruli/number of days between sample periods/number of Witham collectors) on Witham collectors by site between years, 1992-2003.

Year	Site Mean Annual CPUE (±SD)				Combined Mean Annual CPUE (±SD)
	Mangrove Lagoon	Cas Cay	Nazareth Bay	Great St. James	
1992-1993*[1]	0.23 ± 0.30	*[3]	*[3]	0.16 ± 0.30	0.20 ± 0.29
1997-1998*[2]	0.09 ± 0.10	0.21 ± 0.31	0.30 ± 0.46	0.02 ± 0.04	0.15 ± 0.30
2002-2003	0.03 ± 0.04	0.03 ± 0.05	0.17 ± 0.35	0.03 ± 0.04	0.07 ± 0.19

* Notes: (1) 1992-93 data reworked from DFW database.
(2) 1997-98 data reworked from DFW database.
(3) Cas Cay and Nazareth Bay were nonexistent sites in 1992-1993.

Table 4. Number of juvenile *Panulirus argus* residing in ten juvenile lobster shelters deployed southeast of Cow & Calf, St. Thomas, 2002/2003.

Date	No. of Uncovered Shelter*	No. of Lobsters	No. of Covered Shelter*	No. of Lobsters
September 2002	10	0	-	-
December 2002	10	1	-	-
March 2003	5	0	5	0
June 2003	5	0	5	1
Total Lobsters		1		1

*Note: All shelters were uncovered in September and December 2002. Covers were deployed in December 2002 after sampling.

Appendix 1. U.S. Virgin Islands pueruli settlement sites, GPS coordinates, habitat and depths, 2002-2003

Sites	Habitat	Depth (m)	WAAS GPS Location	
			Lattitude	Longitude
Inner Mongrove Lagoon	Seagrass/Algae	2.0	18° 18.333'N	64° 52.474'W
Cas Cay	Seagrass/Algae	1.5	18° 18.548'N	64° 52.118'W
Nazareth Bay	Patchy Seagrass/Sand	6.1	18° 19.069'N	64° 51.416'W
Northwest Great St. James	Patchy Coral Reef/Sand	8.2	18° 18.794'N	64° 49.975'W
Southwest Great St. James	Patchy Seagrass/Sand	10.6	18° 18.403'N	64° 50.140'W

Appendix 2. Stage categories of the Caribbean spiny lobster (*Panulirus argus*) puerulus

Category*	Description
Transparent	No body pigment; only eye pigmented
Semi-pigmented	Light lateral pigmentation, limited to base of antennas with faint pigmentation at base of antennas and sides of carapace and along sides of tail; body dorso-ventrally depressed
Pigmented	Laterally pigmented (well-defined light brown color); light stripe extending the length of the carapace and tail; body depressed
Algal-phase Juvenile	First post-puerulus stage/early benthic stage (body undergone one molt), dark band runs along side of the body; 5-15 mm carapace length (CL), this phase remain for a few months in vegetation, where they are sheltered from predators

*Note: Stage descriptions are from Bannerot, *et al.* (1992); CARICOM (1996); and Butler and Herrnkind (1997).

Appendix 3. U.S. Virgin Islands Juvenile Lobster Shelter Station, 2002-2003

Block Set No.	Bearing from next block set	Distance (m) to next block set from previous set	Depth (m)	WAAS GPS location of ending buoys * (1)	
				Lattitude	Longitude
1	130° * (2)	31.8	20		
2	165°	29.4	20	18° 17.986'N	64° 50.230'W
3	45°	33.3	20		
4	140°	33.3	20		
5	95°	40.9	20		
6	115°	31.8	20		
7	98°	32.4	20		
8	95°	37.6	20		
9	92°	38.2	20		
10	--	--	20	18° 17.998'N	64° 50.375'W

*Notes: (1) GPS coordinates were recorded only for juvenile lobster shelters 2 and 10.
(2) This bearing starts at block set number 2.

Appendix 4. Settlement by stages of *P. argus* pueruli at all sites.											
	Mangrove Lagoon										
	Collector 1					Collector 2					Catch Total
Date	transparent	semi-transparent	pigmented	juvenile	Catch total	transparent	semi-transparent	pigmented	juvenile	Catch total	
4 Jun 02*											
18 Jun 02	0	0	0	2	2	0	0	0	0	0	2
1 Jul 02	0	0	0	0	0	0	0	0	0	0	0
16 Jul 02	0	0	0	2	2	0	0	0	1	1	3
30 Jul 02	0	0	0	0	0	0	0	0	0	0	0
13 Aug 02	0	0	0	0	0	0	0	0	2	2	2
27 Aug 02	0	0	0	0	0	0	0	0	0	0	0
10 Sep 02	0	0	0	0	0	0	0	0	0	0	0
26 Sep 02	0	0	0	0	0	0	0	0	0	0	0
8 Oct 02	0	0	0	0	0	0	0	0	0	0	0
22 Oct 02	0	0	0	0	0	0	0	0	2	2	2
6 Nov 02	0	0	0	0	0	0	0	0	0	0	0
19 Nov 02	0	0	0	0	0	0	0	0	0	0	0
3 Dec 02	0	0	0	0	0	0	0	0	0	0	0
17 Dec 02	0	0	0	0	0	0	0	0	0	0	0
30 Dec 02	0	0	0	0	0	0	0	0	0	0	0
14 Jan 03	0	0	0	0	0	0	0	0	0	0	0
28 Jan 03	0	0	0	1	1	0	0	0	0	0	1
11 Feb 03	0	0	0	0	0	0	0	0	0	0	0
26 Feb 03	0	0	0	0	0	0	0	0	0	0	0
11 Mar 03	0	0	0	0	0	0	0	0	0	0	0
25 Mar 03	0	0	0	0	0	0	0	0	0	0	0
8 Apr 03	0	0	0	0	0	0	0	0	0	0	0
23 Apr 03	0	0	0	0	0	0	0	0	0	0	0
6 May 03	0	0	0	0	0	0	0	0	4	4	4
22 May 03	0	1	0	1	2	0	0	0	0	0	2
4 Jun 03	0	0	0	1	1	0	0	0	1	1	2
17 Jun 03	0	0	0	1	1	0	0	0	0	0	1
Totals	**0**	**1**	**0**	**8**	**9**	**0**	**0**	**0**	**10**	**10**	**19**

*Note: Collectors were installed on 4 June 03 thus no sample was taken on this date

Appendix 4 continued. Settlement by stages of *P. argus* pueruli at all sites.

	Cas Cay										
	Collector 1					Collector 2					Site Catch
Date	transparent	semi-transparent	pigmented	juvenile	Catch total	transparent	semi-transparent	pigmented	juvenile	Catch total	
4-Jun 02*[1]											
18 Jun 02	0	0	0	3	3	0	0	0	0	0	3
1 Jul 02	0	0	0	0	0	0	0	0	0	0	0
16 Jul 02	0	0	0	2	2	0	0	0	1	1	3
30 Jul 02	0	0	0	0	0	0	0	0	0	0	0
13 Aug 02	0	0	0	1	1	0	0	0	0	0	1
27 Aug 02	0	0	0	0	0	0	0	0	0	0	0
10 Sep 02	0	0	0	2	2	0	0	0	1	1	3
26 Sep 02	*[2]	*[2]	*[2]	*[2]	*[2]	0	0	0	0	0	0
8 Oct 02	0	0	0	0	0	0	0	0	0	0	0
22 Oct 02	0	0	0	0	0	0	0	0	1	1	1
6 Nov 02	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]
19 Nov 02	0	0	0	0	0	*[2]	*[2]	*[2]	*[2]	*[2]	0
3 Dec 02	0	2	0	0	2	0	0	0	0	0	2
17 Dec 02	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]
30 Dec 02	0	0	0	0	0	0	0	0	0	0	0
14 Jan 03	0	1	0	1	2	0	0	0	0	0	2
28 Jan 03	0	0	0	0	0	0	0	0	0	0	0
11 Feb 03	0	0	0	0	0	0	0	0	0	0	0
26 Feb 03	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]	*[2]
11 Mar 03	0	0	0	0	0	0	1	0	0	1	1
25 Mar 03	*[2]	*[2]	*[2]	*[2]	*[2]	0	0	0	0	0	0
8 Apr 03	0	0	0	0	0	*[2]	*[2]	*[2]	*[2]	*[2]	0
23 Apr 03	0	0	0	0	0	0	0	0	0	0	0
6 May 03	0	0	0	2	2	*[2]	*[2]	*[2]	*[2]	*[2]	2
22 May 03	0	0	0	0	0	0	0	0	0	0	0
4 Jun 03	0	0	0	0	0	0	0	0	0	0	0
17 Jun 03	*[2]	*[2]	*[2]	*[2]	*[2]	0	0	0	0	0	0
Totals	**0**	**3**	**0**	**11**	**14**	**0**	**1**	**0**	**3**	**4**	**18**

*Notes: (1) Collectors were installed on 4 June 03 thus no sample was taken on this data.
(2) Collectors were found broken and either dragging on the bottom or completely detached or missing from the mooring.

Appendix 4 continued. Settlement stages of *P. argus* pueruli at all sites.

Date	Nazareth Bay										
	Collector 1					Collector 2					Site Catch
	transparent	semi-transparent	pigmented	juvenile	Catch total	transparent	semi-transparent	pigmented	juvenile	Catch total	
4-Jun 02*											
18 Jun 02	1	0	3	0	4	1	1	6	0	8	12
1 Jul 02	0	0	0	0	0	0	0	0	0	0	0
16 Jul 02	0	0	0	3	3	0	0	0	0	0	3
30 Jul 02	0	0	0	0	0	0	0	0	0	0	0
13 Aug 02	0	0	0	0	0	0	0	0	0	0	0
27 Aug 02	0	0	0	0	0	0	0	0	1	1	1
10 Sep 02	0	0	0	0	0	0	2	1	2	5	5
26 Sep 02	0	0	0	0	0	0	0	0	1	1	1
8 Oct 02	0	1	2	8	11	1	0	1	3	5	16
22 Oct 02	0	0	0	4	4	0	0	0	0	0	4
6 Nov 02	0	0	0	1	1	0	0	0	0	0	1
19 Nov 02	0	0	0	0	0	0	0	0	0	0	0
3 Dec 02	0	0	0	0	0	0	0	0	0	0	0
17 Dec 02	0	0	0	0	0	0	0	0	0	0	0
30 Dec 02	0	0	0	0	0	0	0	0	0	0	0
14 Jan 03	0	0	0	1	1	0	0	0	0	0	1
28 Jan 03	0	0	0	0	0	0	0	0	0	0	0
11 Feb 03	0	0	0	0	0	0	0	0	0	0	0
26 Feb 03	0	0	0	0	0	0	0	0	0	0	0
11 Mar 03	0	0	0	0	0	0	0	0	0	0	0
25 Mar 03	0	0	0	0	0	0	0	0	12	12	12
8 Apr 03	1	0	1	8	10	2	0	0	13	15	25
23 Apr 03	1	0	0	0	1	0	0	0	0	0	1
6 May 03	0	1	3	6	10	1	4	8	17	30	40
22 May 03	0	0	0	2	2	0	0	0	0	0	2
4 Jun 03	0	1	0	2	3	0	0	0	0	0	3
17 Jun 03	0	0	0	0	0	0	0	0	0	0	0
Totals	**3**	**3**	**9**	**35**	**50**	**5**	**7**	**16**	**49**	**77**	**127**

*Note: Collectors were installed on 4 June 03 thus no sample was taken on this date.

Appendix 4 continued. Settlement stages of *P. argus* pueruli at all sites.											
	Northwest St. James										
	Collector 1					Collector 2					Site Catch
Date	transparent	semi-transparent	pigmented	juvenile	Catch total	transparent	semi-transparent	pigmented	juvenile	Catch total	
4 Jun 02*											
18 Jun 02	0	0	0	0	0	0	0	0	0	0	0
1 Jul 02	0	0	0	0	0	0	0	0	1	1	1
16 Jul 02	0	0	0	0	0	0	0	0	0	0	0
30 Jul 02	0	0	0	0	0	0	0	0	0	0	0
13 Aug 02	0	0	0	0	0	0	0	0	0	0	0
27 Aug 02	0	0	0	0	0	0	0	0	0	0	0
10 Sep 02	0	0	0	0	0	0	0	0	0	0	0
26 Sep 02	0	0	0	0	0	0	0	0	0	0	0
8 Oct 02	0	0	0	0	0	0	0	0	0	0	0
22 Oct 02	0	0	0	1	1	0	0	0	0	0	1
6 Nov 02	0	0	0	0	0	0	0	0	0	0	0
19 Nov 02	0	0	0	1	1	0	0	0	0	0	1
3 Dec 02	0	0	0	0	0	0	0	0	0	0	0
17 Dec 02	0	0	0	0	0	0	0	0	0	0	0
30 Dec 02	0	0	0	0	0	0	0	0	0	0	0
14 Jan 03	0	0	0	0	0	0	0	0	1	1	1
28 Jan 03	0	0	0	0	0	0	0	0	0	0	0
11 Feb 03	0	0	0	0	0	0	0	0	0	0	0
26 Feb 03	0	0	0	0	0	0	0	0	0	0	0
11 Mar 03	0	0	0	0	0	0	0	0	0	0	0
25 Mar 03	0	0	0	0	0	0	0	0	1	1	1
8 Apr 03	0	0	0	0	0	0	1	0	0	1	1
23 Apr 03	0	0	0	0	0	0	0	0	0	0	0
6 May 03	1	1	0	0	2	0	1	0	0	1	3
22 May 03	0	0	0	0	0	0	0	0	0	0	0
4 Jun 03	0	0	0	0	0	0	0	0	0	0	0
17 Jun 03	0	0	0	0	0	0	0	0	1	1	1
Totals	**1**	**1**	**0**	**2**	**4**	**0**	**2**	**0**	**4**	**6**	**10**

*Note: Collectors were installed on 4 June 03 thus no sample was taken on this date.

Appendix 4 continued. Settlement stages of *P. argus* pueruli at all sites.

Date	Southwest St. James										
	Collector 1					Collector 2					Site Catch
	transparent	semi-transparent	pigmented	juvenile	Catch total	transparent	semi-transparent	pigmented	juvenile	Catch total	
4 Jun 02*[1]											
18 Jun 02	0	0	0	3	3	0	0	3	3	6	9
1 Jul 02	0	0	0	0	0	0	0	0	0	0	0
16 Jul 02	0	0	0	4	4	0	0	0	1	1	5
30 Jul 02	0	0	0	0	0	0	0	0	1	1	1
13 Aug 02	0	0	0	0	0	0	0	0	0	0	0
27 Aug 02	0	0	0	1	1	0	0	0	1	1	2
1 Sep 02	0	0	0	0	0	0	0	0	0	0	0
26 Sep 02	0	0	0	0	0	0	0	0	0	0	0
8 Oct 02	0	0	0	2	2	0	0	0	0	0	2
22 Oct 02	0	0	0	0	0	0	0	0	0	0	0
6 Nov 02	0	0	0	0	0	0	0	0	0	0	0
19 Nov 02	0	0	0	0	0	0	0	0	0	0	0
3 Dec 02	0	0	0	0	0	0	0	0	0	0	0
17 Dec 02	0	0	0	0	0	0	0	0	0	0	0
30 Dec 02	0	0	0	0	0	0	0	0	0	0	0
14 Jan 03	0	0	0	0	0	0	0	0	0	0	0
28 Jan 03	0	0	0	0	0	0	0	0	0	0	0
11 Feb 03	0	0	0	0	0	*[2]	*[2]	*[2]	*[2]	*[2]	0
26 Feb 03	1	0	0	0	1	0	0	0	0	0	1
11 Mar 03	0	0	0	0	0	0	0	0	1	1	1
25 Mar 03	0	0	0	0	0	0	0	0	0	0	0
8 Apr 03	0	0	0	0	0	0	0	0	0	0	0
23 Apr 03	0	0	0	0	0	0	0	0	1	1	1
6 May 03	0	1	0	0	1	0	0	0	3	3	4
22 May 03	0	0	0	1	1	0	0	0	0	0	1
4 Jun 03	0	0	0	0	0	0	0	0	1	1	1
17 Jun 03	0	0	0	0	0	0	0	0	0	0	0
Totals	**1**	**1**	**0**	**11**	**13**	**0**	**0**	**3**	**12**	**15**	**28**

*Notes: (1) Collectors were installed on 4 June 03 thus no sample was taken on this data.
(2) Collectors were found broken and either dragging on the bottom or completely detached or missing from the mooring.

Appendix 5. Catches and catch per unit effort (CPUE = number of pueruli/number of days in sample period/number of collectors) for of *P. argus* pueruli at each site (2002-2003).

	Inner Mangrove Lagoon				Cas Cay				Nazareth Bay			
Date	**Collector 1**	**Collector 2**	**Catch total**	**CPUE**	**Collector 1**	**Collector 2**	**Catch total**	**CPUE**	**Collector 1**	**Collector 2**	**Catch total**	**CPUE**
4 Jun 02*[1]												
18 Jun 02	2	0	2	0.07	3	0	3	0.11	4	8	12	0.43
1 Jul 02	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
16 Jul 02	2	1	3	0.10	2	1	3	0.10	3	0	3	0.10
30 Jul 02	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
13 Aug 02	0	2	2	0.07	1	0	1	0.04	0	0	0	0.00
27 Aug 02	0	0	0	0.00	0	0	0	0.00	0	1	1	0.04
10 Sep 02	0	0	0	0.00	2	1*[2]	2	0.14	0	5	5	0.18
26 Sep 02	0	0	0	0.00	*[2]	0	0	0.00	0	1	1	0.03
8 Oct 02	0	2	2	0.08	0	0	0	0.00	11	5	16	0.67
22 Oct 02	0	0	0	0.00	0	1	1	0.04	4	0	4	0.14
6 Nov 02	0	0	0	0.00	*[2]	*[2]			1	0	1	0.03
19 Nov 02	0	0	0	0.00	0	*[2]	0	0.00	0	0	0	0.00
3 Dec 02	0	0	0	0.00	2	0	2	0.07	0	0	0	0.00
17 Dec 02	0	0	0	0.00	*[2]	*[2]			*[2]	0	0	0.00
30 Dec 02	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
14 Jan 03	0	0	0	0.00	2	0	2	0.07	1	0	1	0.03
28 Jan 03	1	0	1	0.04	0	0	0	0.00	0	0	0	0.00
11 Feb 03	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00
26 Feb 03	0	0	0	0.00	*[2]	*[2]			0	0	0	0.00
11 Mar 03	0	0	0	0.00	0	1	1	0.04	0	0	0	0.00
25 Mar 03	0	0	0	0.00	*[2]	0	0	0.00	0	12	12	0.43
8 Apr 03	0	0	0	0.00	0	*[2]	0	0.00	10	15	25	0.89
23 Apr 03	0	0	0	0.00	0	0	0	0.00	1	0	1	0.03
6 May 03	0	4	4	0.15	2	*[2]	2	0.15	10	30	40	1.54
22 May 03	2	0	2	0.06	0	0	0	0.00	2	0	2	0.06
4 Jun 03	1	1	2	0.08	0	0	0	0.00	3	0	3	0.12
17 Jun 03	1	0	1	0.04	*[2]	0	0	0.00	0	0	0	0.00
Totals	9	10	19		14	3	17		50	77	127	

*Notes: (1) Collectors were installed on 4 June 03 thus no sample was taken on this date.
(2) Collector was found broken and either dragging on the bottom or was completely detached from the mooring, therefore sample was discarded from analysis.

Appendix 5 (continued). Catches and catch per unit effort (CPUE = number of pueruli/number of days in sample period/number of collectors) for of *P. argus* pueruli at each site (2002-2003).

	Northwest St. James				Southwest St. James			
	Collector 1	**Collector 2**	**Catch total**	**CPUE**	**Collector 1**	**Collector 2**	**Catch total**	**CPUE**
4 Jun 02*[1]								
18 Jun 02	0	0	0	0.00	3	6	9	0.32
1 Jul 02	0	0	0	0.00	0	0	0	0.00
16 Jul 02	0	1	1	0.03	4	1	5	0.17
30 Jul 02	0	0	0	0.00	0	1	1	0.04
13 Aug 02	0	0	0	0.00	0	0	0	0.00
27 Aug 02	0	0	0	0.00	1	1	2	0.07
10 Sep 02	0	0	0	0.00	0	0	0	0.00
26 Sep 02	0	0	0	0.00	0	0	0	0.00
8 Oct 02	0	0	0	0.00	2	0	2	0.08
22 Oct 02	1	0	1	0.04	0	0	0	0.00
6 Nov 02	0	0	0	0.00	0	0	0	0.00
19 Nov 02	1	0	1	0.04	0	0	0	0.00
3 Dec 02	0	0	0	0.00	0	0	0	0.00
17 Dec 02	0	0	0	0.00	0	0	0	0.00
30 Dec 02	0	0	0	0.00	0	0	0	0.00
14 Jan 03	0	1	1	0.03	0	0	0	0.00
28 Jan 03	0	0	0	0.00	0	0	0	0.00
11 Feb 03	0	0	0	0.00	0	*[2]	0	0.00
26 Feb 03	0	0	0	0.00	1	0	1	0.03
11 Mar 03	0	0	0	0.00	0	1	1	0.04
25 Mar 03	0	1	1	0.04	0	0	0	0.00
8 Apr 03	0	1	1	0.04	0	0	0	0.00
23 Apr 03	0	0	0	0.00	0	1	1	0.03
6 May 03	2	1	3	0.12	1	3	4	0.15
22 May 03	0	0	0	0.00	1	0	1	0.03
4 Jun 03	0	0	0	0.00	0	1	1	0.04
17 Jun 03	0	1	1	0.04	0	0	0	0.00
Totals	4	6	10		13	15	28	

*Notes: (1) Collectors were installed on 4 June 03 thus no sample was taken on this date.
(2) Collector was found broken and either dragging on the bottom or was completely detached from the mooring, therefore sample was discarded from analysis

Appendix 6. Test by site on catch per unit effort (CPUE = number of pueruli/number of sample days/number of collectors) for the year 2002-2003.

One Way Analysis of Variance
Normality Test: Failed (P = <0.001)
Equal Variance Test: Passed (P = 0.430)

Group	N	Missing
lagoon	27	0
cas cay	27	3
nazareth	27	0
nw st james	27	0
sw st james	27	0

Group	Mean	Std Dev	SE of Mean
lagoon	0.0257	0.0419	0.00806
cas cay	0.0313	0.0492	0.0100
nazareth	0.175	0.353	0.0679
nw st james	0.0136	0.0258	0.00497
sw st james	0.0373	0.0725	0.0140

Power of performed test with alpha = 0.050: 0.841

Source of Variation	DF	SS	MS	F	P
Between Treatments	4	0.479	0.120	4.355	0.002
Residual	127	3.491	0.027		
Total	131	3.969			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.002).

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor:

Comparison	Diff of Means	p	q	P<0.05
nazareth vs. nw st james	0.161	5	5.056	Yes
nazareth vs. lagoon	0.149	5	4.676	Yes
nazareth vs. cas cay	0.144	5	4.365	Yes
nazareth vs. sw st james	0.138	5	4.312	Yes
sw st james vs. nw st james	0.0237	5	0.744	No
sw st james vs. lagoon	0.0116	5	0.364	No
sw st james vs. cas cay	0.00598	5	0.182	No
cas cay vs. nw st james	0.0178	5	0.540	No
cas cay vs. lagoon	0.00564	5	0.171	No
lagoon vs. nw st james	0.0121	5	0.380	No

Appendix 7. Two Way analysis of variance for site and year (because not all site were sampled in all years, some treatments were missing therefore there was no test for interactions)

General Linear Model (No Interactions)
Dependent Variable: CPUE (CPUE = total catch / number of sample days / number of collectors)
Normality Test: Failed (P = <0.001)
Equal Variance Test: Passed (P = 0.083)

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
year	2	1.398	0.699	10.881	<0.001
site	3	1.695	0.565	8.798	<0.001
Residual	280	17.987	0.0642		
Total	285	20.459	0.0718		

The difference in the mean values among the different levels of year is greater than would be expected by chance after allowing for effects of differences in site. There is a statistically significant difference (p = <0.001). To isolate which group(s) differ from the others use a multiple comparison procedure.

The difference in the mean values among the different levels of site is greater than would be expected by chance after allowing for effects of differences in year. There is a statistically significant difference (p = <0.001). To isolate which group(s) differ from the others use a multiple comparison procedure.

Power of performed test with alpha = 0.0500: for year : 0.990
Power of performed test with alpha = 0.0500: for site : 0.993

Least square means for year

Group	**Mean**	**SEM**
2003.000	0.0657	0.0248
1998.000	0.150	0.0242
1992.000	0.265	0.0353

Least square means for site

Group	**Mean**	**SEM**
1.000	0.113	0.0263 *(Mangrove Lagoon)*
2.000	0.167	0.0413 *(Cas Cay)*
3.000	0.292	0.0354 *(Nazareth Bay)*
4.000	0.0682	0.0265 *(Great St. James)*

Appendix 7 (continued). Two Way analysis of variance for site and year (because not all site were sampled in all years, some treatments were missing therefore there was no test for interactions)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: year

Comparison	Diff of Means	p	q	P<0.05
1992.000 vs. 2003.000	0.199	3	6.524	Yes
1992.000 vs. 1998.000	0.114	3	3.775	Yes
1998.000 vs. 2003.000	0.0847		3.462	Yes

Comparisons for factor: site

Comparison	Diff of Means	p	q	P<0.05
3.000 vs. 4.000	0.224	4	7.173	Yes