Settlement Patterns of Spiny Lobster (*Panulirus argus*) Postlarvae on Collectors in Jamaican Waters and Culture of Juveniles

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ABSTRACT

This project investigated the patterns of settlement of postlarval spiny lobster (*Panulirus argus*) using the modified GUSI collector. Growth rates of lobsters in captivity were also investigated using food comprising green mussel, *Perna viridis,* and squid, in a series of mariculture experiments. In the settlement study, a total of 449 postlarvae and 119 juveniles were caught during a 16 month period using two collectors per month at each of three sites distributed around the coast of the island. These sites were all in nearshore coastal waters accessible by boat. Results revealed periods of peak settlement in July and between October and November annually. Comparative catchability of the GUSI collector and modified Witham collector used exclusively by an earlier study, suggested that the Modified GUSI yielded slightly more larvae than the latter type. Growth experiments in aquaria under laboratory conditions, showed that juvenile piny lobsters could be grown in captivity by feeding them green mussel, *Perna viridis,* and squid.. Lobsters in these experiments grew for up to twelve months after which they were released back to the wild. The lobsters showed very little intra-specific aggression in captivity. Their territoriality also appeared to break down as up to five individuals could be reared in a single tank, thus permitting higher stocking densities than one per tank. Lobsters readily accepted prepared food and after the inclusion of squid to the diet, experienced little apparent difficulty while moulting.

KEY WORDS: Spiny lobster, *Panulirus argus*, Jamaica, postlarval collectors, mariculture

Las Pautas del Arreglo de Langosta del Caribe (*Panulirus argus*) Postlarvales En Recaudadores en Aguas y Cultura Jamaiquinas de Jóvenes

Este projecto se ha investigado en Jamaica, la captura relativa utilisando los colectores langosta del Caribe postlarvales modificados tipo GUSI. La maricultura del los juveniles en las estanques se han probados con el alimentacion con *Perna viridis* y el carne del *Sepioteuthis* (Cephalopoda) en una serie de los investigaciones. En el parte del estudio, un total de 449 larvales y 119 juveniles se han capturados durante el periodo total de 16 meses utilisando dos collectors por cada mes en los lugares se han investigados. Estos sitios se han colocados en las aguas littorales no muy lejo de la costa. Los resultados se han indican picos en los niveles de abundancia de los larvales entre Julio y Octubre hasta Noviembre cada ano. Los ratos del la capturas del los dos tipos de colectores se han comparado y se lo parece que el tipo GUSI modificado estaba mas mejor. Las pruebas del crecimiento en el laboratorio, los se han indican que los langostas juveniles se han criada bien durante la captividad con el alimentacion de una mexcla de *Perna viridis* y *Sepioteuthis*. Durante un periodo de un ano, los langostas se han cultivados bien y no le se parece los conflictos intra-specificas, en este caso. Entonces, este se le permite un total de 5 langostas por cada piscina en el laboratorio. Este se le permite un nivel de mas alto densidad mas que uno langosta por cada piscina. Los langostas se han acceptados bienes el alimentacion artificial, despues de lo se incluye el carne del pulpo.

PALABRAS CLAVE: Langosta, *Panulirus argus*, Jamaica, postlarvales, colectores, maricultura

Les Modèles de Règlement de Homard Épineux (*Panulirus argus*) Postlarvae sur les Collecteurs dans les Eaux et la Culture Jamaïcaines de Juvéniles

MOTS CLÉS: Homard épineux, *Panulirus argus*, Jamaïque, collecteurs, culture

INTRODUCTION

The spiny lobster, *Panulirus argus*, is found as far north as North Carolina, USA and as far south as Rio de Janeiro, Brazil (Cobb AND Phillips 1980a). It is widely distributed in the coastal and offshore waters around Jamaica where it is a highly prized resource, representing an essential component of the total landings of the Jamaican Fisheries (Haughton and King 1990). Six species of lobsters are found in Jamaican waters *viz*., *Panulirus argus, .P.guttatus, Justitia longimanus, Palinurellus gundlachi, Scyllarides aequinoctialis* and *Parribacus antarcticus*, of which *P. argus* and *P. guttatus.* are the only two species that are commercially valuable (Aiken 1983). Intense levels of fishing for lobster and other fishery resources continue in Jamaican waters. As a result, it is becoming increasingly important to gain information on postlarval settlement and survival so that proper management can be provided for what appears to be a limited resource.

The spiny lobster, *P. argus*, like other Palinuridae, has a relatively lengthy planktonic larval life, living between 6 – 24 months in the water column (Phillips and Olsen 1975, Phillips and McWilliam 1986, Calinski and Lyons 1983). On approaching suitable coastline or potential settlement area, the phyllosoma larva metamorphoses into a mobile,

transparent, non-feeding stage, about 6 – 7 mm carapace length (CL), called the puerulus (from a Latin word meaning "schoolboy"). The animal then makes its way to the settlement surface after which it metamorphoses to an opaque, feeding individual that resembles a miniature adult spiny lobster. It is this stage, after settlement and metamorphosis into the feeding stage that is calledd the "postlarva".

In Australia, settlement information has been used to accurately predict future adult population density (Chittleborough 1975). Settlement information has therefore become important in predicting catches, seasonality, and locations of lobster fishing. Lobster farming or mariculture is an option that can be utilized in order to protect this resource while providing a source of income. Mariculture may also be viewed as a positive conservation step as it involves taking the lobster at a critical stage in its life cycle (the puerulus, where mortality is very high) and increasing its chances of surviving to adulthood; however the techniques need to be mastered. Spiny lobster pueruli are abundant in most areas where adult spiny lobsters are found and fished. Mortality of lobsters between larval and adult stages however, is very high due to predation, lack of shelter and starvation. Pueruli could therefore be collected and grown in mariculture systems to improve their chances of survival and increase their growth rates. The older, larger lobsters could then be marketed, or put back into the ocean at a size that its chances of survival are higher. This study therefore set out to examine how easily juvenile spiny lobsters could be cultured.

OBJECTIVES

The objectives of this study were:

i) To investigate postlarval settlement of the spiny lobster, *Panulirus argus*, around the island of Jamaica focusing on magnitude of settlement and periods of peak settlement.
ii) To investigate, for the first time in Jamaica, the effectiveness of the Modified GUSI Collector at catching postlarvae of the spiny lobster, *Panulirus argus*.
iii) To compare the catchability of the Modified GUSI Collector with that of the Modified Witham Collector used by Young in 1992.
iv) To investigate growth rates of different sized spiny lobsters in captivity outlining the relationship between moulting and growth.
v) To study the growth of the lobsters in captivity in order to determine a possible minimum time to grow to a predetermined optimum size.

METHODS

This study examined postlarval settlement in selected bays around the island of Jamaica between 2000 and 2002, in an attempt to provide information on periods of peak settlement in Jamaica as well as the effectiveness of the modified GUSI collector at attracting spiny lobster postlarvae. The bays included Discovery Bay, St. Ann, and Orange Bay, Portland, both on the north coast, as well as Little Bay, Westmoreland, Bowden Harbour, St. Thomas and Kingston Harbour, St. Andrew, all on the south coast. Bowden Harbour and Discovery Bay were revisited for settlement research as similar work had been done in these locations by Young (1993). A different collector was used in this study, the GUSI type, to determine if recruitment would be higher compared to that which was obtained before in Discovery Bay by Young. Mariculture studies examined growth rates of captive spiny lobsters of different size classes. Experiments focused on determining a food type that the lobsters would readily accept, growth rates in captivity, and mortality rates.

Puerulus Collection

Collectors were developed to obtain animals for study in the laboratory (Witham et al. 1968, Phillips 1975), to investigate the levels of puerulus settlement (Booth and Tarring 1986) and for mariculture purposes. Collectors act as attractants more than trapping devices. When in coastal waters searching for habitat, pueruli may encounter collectors and use them as habitats, and they settle on the collectors that mimic their natural shelter. Settlement refers to the moment at which the puerulus ceases forward swimming and becomes benthic or colonizes a collector (Booth and Phillips 1994). The puerulus has several preferred natural settlement habitats. Some include mangroves, seagrass beds, coral reefs and algal beds. Algae associated with these habitats are not uncommon and may serve to induce settlement. It is difficult to say which of these habitats is preferred for settlement as different species have different preferences. Collectors may be broadly grouped into two main types: *a)* those that provide crevices and spaces for settlement, and *b)* those that imitate seaweed and may evoke the grasping response of pueruli. Collectors that are designed for surface collections are normally suspended within six feet of the water's surface. When collectors are put out into the ocean, they become fouled with algae. The artificial habitat together with the algae provide shelter, while epibionts associated with the algae, such as gastropods, isopods, amphipods and amphineurans, are the source of food for the lobsters.

Two collector types were used in this study, the GUSI and the Witham collector. The GUSI collector is a surface collector that is suspended within the first 2 metres of the water column. This collector originated in Mexico (Gutierrez-Carbonnell et al. 1989). Its frame is a 19 x1itre plastic bucket, 35 cm high and 30 cm in diameter, of a type commonly used for holding paint. Its outside surface is covered with bands of synthetic sacking to which are tied 110 tassels made of strips of artificial seaweed. The strips were 1 cm wide and of a material commonly used as protection for shrimp trawls. Shredding the tassels by repeatedly pulling them through two pieces of wood with protruding nails improves the efficiency of the collector.

Loops of rope that are attached to the base of the bucket assist handling of the collector. The holes through which the handles of the bucket were originally attached are enlarged to accommodate a 1 cm diameter polypropylene rope, which moors the collector to a concrete weight. These collectors can last 8 - 10 months but must be cleaned regularly. Cleaning was done by leaving them outdoors for a week and then "shaving" the tassels with a knife. In this study each collector started with a 30.3 litre (8 gallon) plastic bucket, 35 cm in length and 30 cm in width, for its frame. Nylon rope 1.6 cm in diameter was wrapped around this frame so that its surface, with the exception of the top and bottom, was covered. Small holes were then drilled into the bucket and plastic cable ties threaded through these holes and the rope secured to the bucket (see Figure 1 of GUSI collector). Tassels of rope were then added. These were the most important part of the collector as they actually formed the post larval shelter. The tassels were black in colour as previous research revealed a preference by pueruli for dark coloured habitats. They were made by shredding nylon rope 0.94 cm in diameter and placing this shredded rope into bundles 0.5 cm in diameter. Tassels were 35 cm in length. In all, one hundred and ten tassels were tied to the rope encircling each of the buckets of each collector, and allowed to hang from it. All collectors of both types were anchored to the substrate.

The Witham collector (Witham et al. 1968) was designed to catch the puerulus stage of the Florida spiny lobster, *P. argus*. It is a surface collector constructed of a polyurethane float, 30 cm square and 2.5 cm thick, with leaves of 3M (Minnesota Mining and Manufacturing Co., Minnesota, U.S.) nylon webbing, 30 cm wide and 15 cm long attached to one side. The float was coated with fibreglass resin for strength and weatherproofing. Currently the most widely used version of the Witham collector is the hogs-hair collector developed in Florida (Hunt Pers. Comm.). That collector has been used to catch the puerulus stage of *P. argus* in many parts of the Caribbean. The hogs-hair collector was recommended for sampling *P.argus* settlement throughout the Caribbean (Miller and Goodwin 1989) and is sometimes referred to as the "PVC hog-fur collector".

Postlarval settlement occurs throughout any given month; however, the number settling appears to be strongly related to lunar periodicity. Greatest settlement rates have been recorded at times of the new moon and first quarter (Witham et al. 1968, Phillips 1975, Young 1993). For this reason, sampling sites, four of which were situated in rural Jamaica were visited once a month and collectors checked three to four days after every new moon at the time of maximum settlement. In March 2000, a series of GUSI collectors was deployed in the waters of the five different locations around the island. They were all left for a period of two months prior to the first collection to allow adequate fouling to take place. Fouling enhances the collectors' ability to simulate the postlarval habitat. After the first collection, previously fouled collectors were deployed for one month, between sampling, allowing time to be fouled again as well as attract settling pueruli.

Collectors were put out in duplicate at each location and they were always approximately ten meters apart. The locations included Orange Bay, Portland and Discovery Bay, St. Ann, both on the North Coast of the island; and Bowden Harbour, St Thomas; Little Bay, Westmoreland and the Port Royal Cays/Kingston Harbour, Kingston, all on the south coast (see Figure 2). Sampling continued for

Plate 1. Modified GUSI lobster postlarval collector used in present study with central plastic bucket and teased-out black synthetic rope tassels forming "skirt" around bucket.

fifteen lunar months at each location. Collectors were retrieved by clipping them off their anchors and placing them into mesh bags made from old plankton nets. This prevented the escape of captured young lobsters. Having retrieved the collectors, they were thoroughly searched by hand for spiny lobster postlarvae. Having collected and tallied postlarvae found, another set of collectors was deployed for collections a week after the following new moon. This method allowed enough time for the newly deployed collectors to be fouled. Individuals from the collectors that were placed in the mesh bag were then counted and relevant observations of other organisms, such as possible prey and predators, were recorded.

All sites samples were similar in that they were:

i) Not deeper than 20 m,
ii) Not more than 100 m from the MHWST mark on the nearest beach,
iii) Had substrates with sea grass and/or scattered coral heads, and
iv) Were located in relatively calm zones in the back-reef lagoon habitat and protected from strong wave action.

The majority of the sites were at the eastern (upcurrent) end of the island, but Little Bay, Westmoreland, was at the opposite end.

Mariculture

Because of the severe pressure on spiny lobster fisheries there is a strong desire to culturetoto reduce this fishing pressure. The life cycle of spiny lobsters includes a complex and long planktonic larval stage that is very likely to die from starvation or predation. High mortality rates however, are counteracted by the production of copious amounts of these larvae; this way many are likely to survive to other stages of development. One such stage is the postlarva. Like the larval stage, the postlarva exists in large amounts and is also likely to suffer from starvation and predation. Past experiments (Ingle and Witham 1968, Ryther et al. 1988, Forcucci et al. 1994) have shown that this is the youngest stage that can be grown in captivity to adulthood with minimal mortality. The present study cultured the juvenile spiny lobster from three different size classes (explain them here) onwards, using the invasive green mussel *Perna viridis* combined with squid, as food. Lobsters for these growth exercises were obtained from the same collectors used in the settlement studies. All postlarvae and juveniles came from St. Thomas or Port Royal on the south coast, as consistently larger numbers could be found here and these sites were relatively more accessible than the others. Culture of postlarval and juvenile lobsters were the focus of this particular section of the study to determine how quickly they would grew from the early puerulus stage into larger juveniles. Three types of artificial shelters were provided for small juvenile lobsters made from PVC piping, fine plastic mesh and motor vehicle tyre scraps. Juveniles larger than 2.5cm CL were placed in larger tanks (approximately 3.4m^3 in volume) and given 6 inch concrete building blocks as shelters. The PVC pipe used was 2.5cm diameter and 15 cm long. Grey plastic mesh was cut into 10cm x10cm squares and folded like a paper fan, to create grooves that postlarvae could enter or lie beneath. Tyre material was obtained from Bowden Harbour, St. Thomas, from a small mangrove oyster (*Crassostria sp.*) farm was located. Pieces used as shelter for small lobsters were approximately 15cm x 8cm .

Figure 2. Map of Jamaican showing sampling sites (circles) in present study. L—R Little Bay, Westmoreland; Discovery Bay, St. Ann; Kingston Harbour, Kingston; Orange Bay, Portland and Bowden Harbour, St. Thomas.

Two types of feed were used throughout the study. The first was made from the flesh of the invasive green mussel, *Perna viridis.* The meat was scraped from the shell and then ground with commercial cornmeal so that it would hold its shape as a paste in the water. The second was made with squid mixed with mussel. Mussels were obtained from the jetty pillars at the Port Royal Marine Lab and squid was obtained from a local supermarket.

RESULTS

Settlement Patterns

Bowden Harbour — A total of 176 postlarvae were counted from two collectors during the sixteen-month period between May 2000 and August 2001 at Bowden Harbour, St. Thomas. A mean of 11 per month was caught. The greatest number of postlarvae caught in a single month was 30 in July 2000. The lowest number was 2 in January, 2001. There were three major settlement peaks in the sixteen-month sample period at Bowden (see Figure 3 below). These were in July and October, 2000 and June to July, 2001, respectively. In all, 133 out of the 176 specimens or 76% were caught during these peak months. In the first year of the study (May 2000 – April 2001) 124 postlarvae were caught with 92 (75%) caught in the peak months. Small juveniles (> 0.8cm CL) were often caught in addition to postlarvae. In all, 37 of these juveniles were caught during the 16 month period. A total of 3 juveniles > 3.0cm CL were also caught in the same period.

Figures 4, 6, and 5 show mean annual settlement of postlarvae over a 12 month period at Bowden Harbour, Little Bay & Kingston Harbour, respectively. Each of the graphs includes a polynomial trend line extracted from the mean, which gives a summary of overall settlement for the period.

Little Bay, Westmoreland

Over the 16 month sampling period at Little Bay, Westmoreland, 128 postlarvae were caught at with a mean of 8 per month (Figure 5). The greatest number of postlarvae settling in a single month was 18 in April, 2001, while the lowest was 2 in January, 2001. There were three major peaks in settlement at this location, the first from October to November 2000, the second in April 2001 and the third June to July, 2001. A total of 75 (59%) were

caught in the peak periods. A total of 94 postlarvae were collected in the first year of the study between May 2000 and April 2001. Some 49 (52%), were caught in the peak months. Very few juveniles were taken from collectors here at Little Bay. A total of 17 were collected during the sixteen-month sampling period (see Figures of total numbers and mean annual numbers found , which follow).

The plot mean annual numbers which settled (Figure 6) shows a maximum from July to August and minima in January and December. The graph itself shows peaks in April, July and October.

Kingston Harbour

A total of 145 postlarvae were collected in Kingston Harbour in the period between September 2000 and November 2001 (Figure 7). The mean number collected per month was approximately 10. A total of 20 postlarvae were caught in November of 2001. This was the highest collected in any one month and the lowest was 2. There were two major peaks observed in the sampling period, the first in September to November, 2000, and the second in September to November 2001. A total of 82 or 57% of postlarvae collected, settled in September to November in the years 2000 and 2001. Catch per month was fairly consistent in Kingston Harbour, resulting in fewer peaks than at other sites. Many small juveniles (> 0.8 cm CL) were caught during the sampling period. In all 67 were caught.

The figure of mean annual settlement above shows a

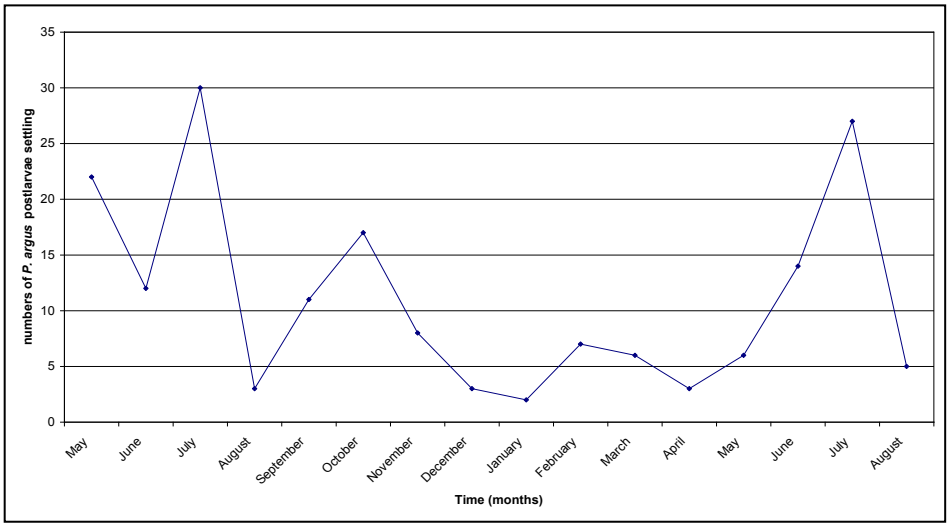

Figure 3. Total number of *P. argus* postlarvae settling on GUSI collectors at Bowden harbor, St. Thomas 2000 - 2001.

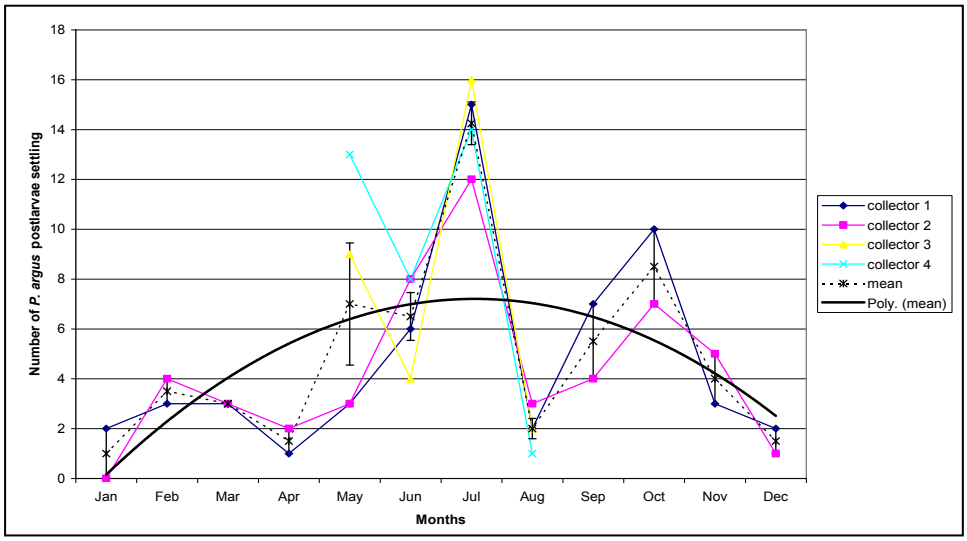

Figure 4. Mean annual settlement for *P. argus* postlarvae settling on GUSI collectors at Bowden Harbour, St. Thomas.

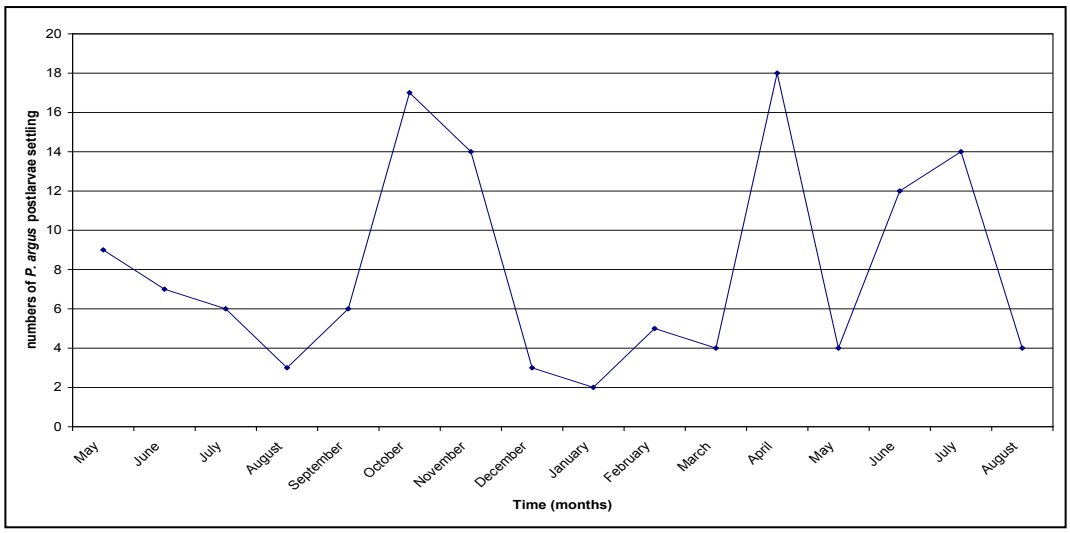

Figure 5. total numbers of *P. argus* postlarvae settling on GUSI collectors at Little Bay, Westmoreland 2000 - 2001.

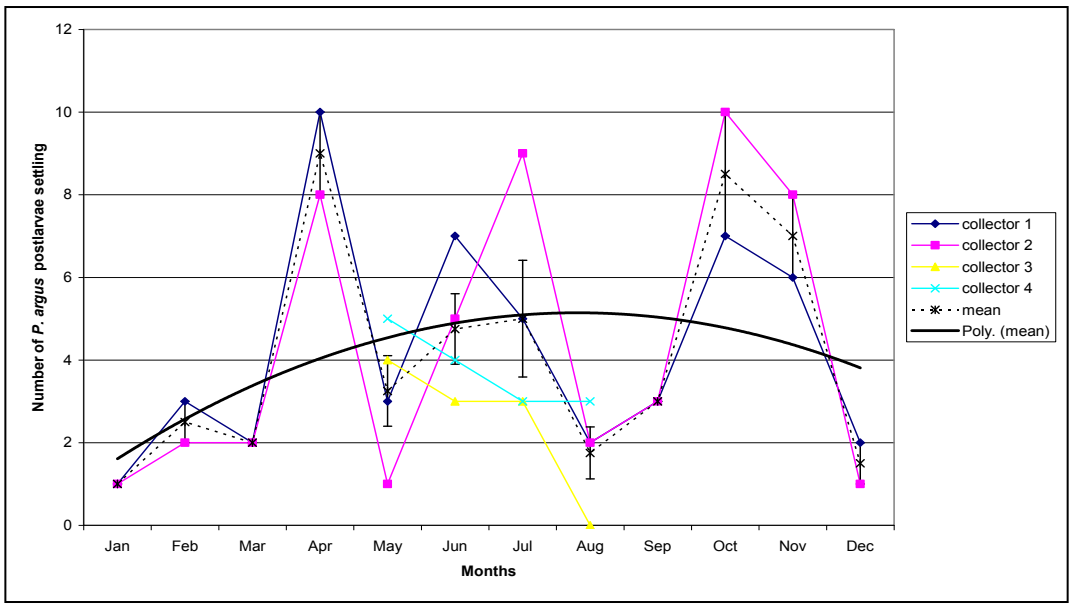

Figure 6. Mean annual settlement of *P. argus* postlarvae settling on GUSI collectors at Little Bay Westmoreland.

peak in November. Individual settlement plots also show that settlement generally slowly increases after July and reaches a maximum in November decreasing thereafter.

If we compare all postlarval settlement between sites on the south coast (Bowden harbor, Kingston Harbour, Little Bay), we see there are two major peaks, the first in July and the second, October to November. Peaks are separated by a significant trough, particularly in August. The polynomial trend line is bell-shaped with a peak in July to August (Figure 9).

Comparisons of settlement between GUSI and Witham collectors showed that there was firstly, fewer postlarvae settling on the collectors of both types in Kingston Harbour where they are compared over a six month period. Secondly, the peak settlement period was in November which was different from all other sites where there was useful data collected (Figure 10).

In the six-month period of this comparative study, 63 postlarvae were collected from the Modified GUSI collector and 30 from the Modified Witham collector. The GUSI produced more postlarvae monthly than the Witham

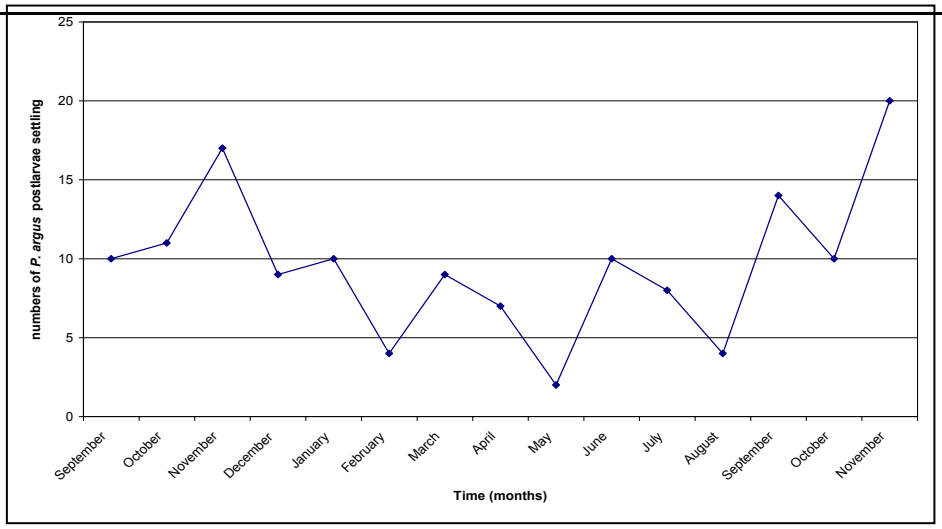

Figure 7. Total numbers of *P. argus* postlarvae settling on GUSI collectors in the Kingston Harbour 2000 - 2001.

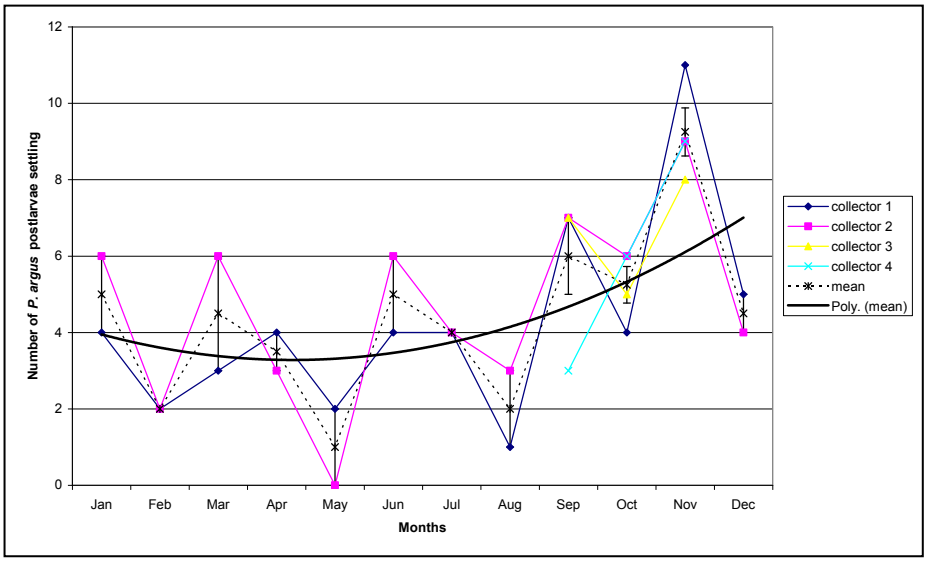

Figure 8. Mean annual settlement for *P. argus* postlarvae settling on GUSI collectors at Kingston Harbour, Kingston.

collector. The GUSI collector yielded its maximum catch in Kingston Harbour in November 2002 with 24 postlarvae. The minimum was 2 each in February & April 2003. Maximum settlement for the Witham collector was 13 in November 2002 and the minimum zero in February 2003. Maximum postlarval numbers settling for both collectors was in November with a smaller peak in January. There was a significant decline after January and overall from February 2003 to April 2003.

Postlarval Settlement on the North Jamaican Doast

Collectors were deployed at two locations on the north coast of Jamaica from March 2000 to October 2000. The sites were in Discovery Bay, St. Ann (centre of northern coastline) and Orange Bay in Portland (at eastern end). There was no catch in Discovery Bay while in Portland, there was insignificant settlement with two post larvae caught on the GUSI collector in June 2000 and none thereafter. After six months of collections, the collectors were moved to different sub-sites within each of the locations, however, no further postlarva was collected. After a total of eight months of sampling at these sites, collectors were removed and deployed elsewhere.

Mariculture of Juveniles

Three size classes of lobsters investigated over 12 months with two food types. Class 1 was 0.6 – 07 cm Carapace Length (CL), class 2: 1.2 – 1.8 cm CL and Class 3: 2.5 – 3.5 cm CL. Lobsters in this investigation were stocked at numbers not exceeding five per tank or 5 per 0.5 m^3. Each group belonging to a size class was replicated in an adjacent tank to allow for comparison. Two types of

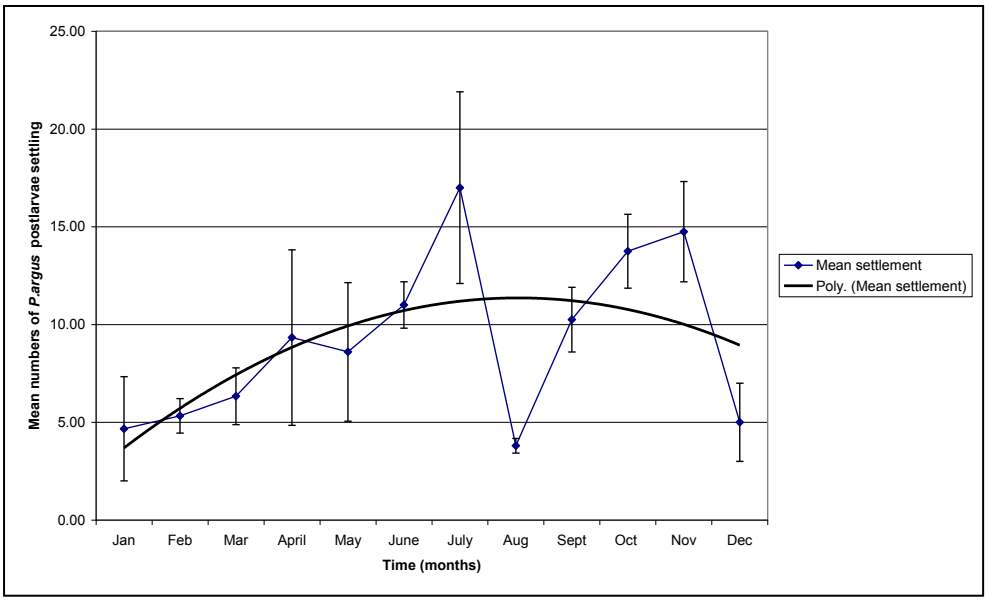

Figure 9. Annual summary of mean settlement rates for *P. argus* postlarvae settling on GUSI collectors on the south coast of Jamaica.

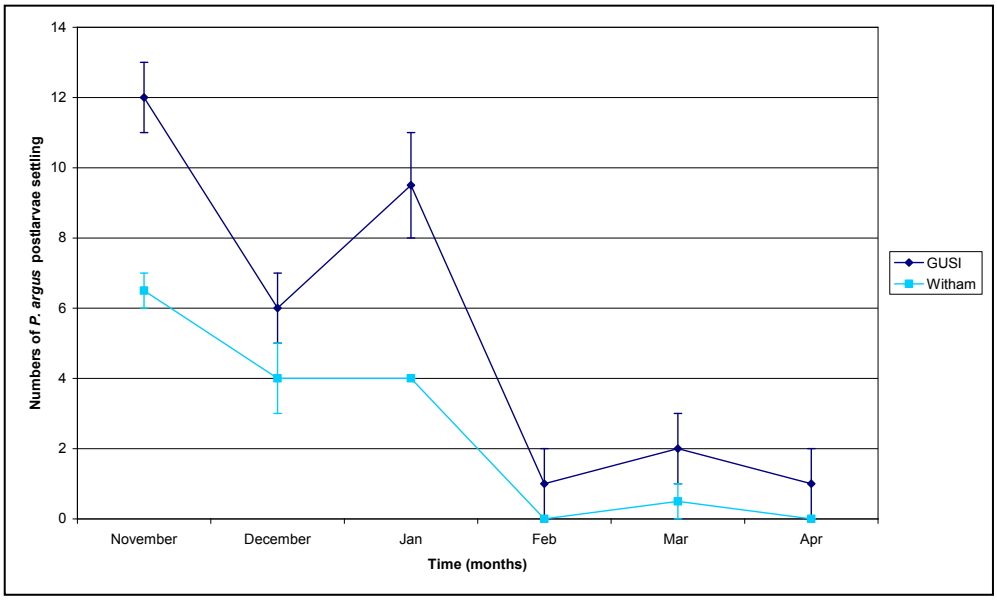

Figure 10. Comparison of mean numbers of *P. argus* postlarvae settling on GUSI and Witham collectors between November 2001 and April 2003 at Kingston Harbour.

food were used throughout the study. The first was made from the flesh of the mussel, *Perna viridis*. Ground with cornmeal to hold its shape in water. The second was made in a similar manner with squid added. Results are shown for the purposes of brevity, of the Class 1 juveniles only. The growth trends for a total of 16 specimens is shown in Figure 11 below.

DISCUSSION

Generally, the major peak of settlement of postlarval spiny lobsters was found to exist in July annually with a secondary peak in November. Cuba, Jamaica's closest neighbor geographically, has two settlement peaks. The first is between May and July and the second between September and November (Cruz et al. 1992a). This is very similar to the settlement results found in this investigation (Table 1).

Note that comparisons of spiny lobster postlarval set-

tlement between territories are made difficult due to the significant variations in methods of sampling and collectors used. Sampling methods and collectors used varied with available resources such as money and accessibility of material for collectors, and also with the characteristics of the area to be investigated. Nevertheless, these data can yield valuable indicators of settlement patterns and also form a historical database for future work.

Lobster settlement was found not to be of great magnitude on the northern coast of Jamaica. In 1989-1990, there was no postlarval settlement shown by collectors placed in Discovery Bay, St. Ann located in the middle of the north coast (Young 1993). In the present study Discovery Bay also yielded no postlarva at two locations in the period 2000 - 2001. An investigation carried out at Orange Bay, Portland, also on the north coast, yielded two postlarvae over eight months of sampling. These results were obtained despite juvenile lobsters being observed by the author and fishers within 50 metres of the collectors. The cause(s) for these results are unknown at this time. The observation that there may be settlement in close proximity to collector location posed several questions that could not be accurately answered, given the variables.

The GUSI collector caught more than twice the number of postlarvae(63) than the Witham collector (30) in the 6 month sampling period (see Figure 10). However, a one-way ANOVA test did not support the assumption that the Modified GUSI collector was more effective ($p = 0.09$). The results thus indicated that there was no significant difference between number settling on the two different collector types. The Modified GUSI collector appeared to be no more effective than the Modified Witham collector used by Young (1993). The pattern of settlement was the same for the two collectors for the six-month period of sampling although the Witham collector caught fewer individuals than the GUSI collector did in each month. What was relatively distinct was that there were two peaks of settlement of pueruli, the first in July and a greater one between October and November annually. Generally, this pattern was in keeping with the findings of Young (1993).

Table 1. Peak postlarval settlement periods for locations with spiny lobsters.

Location	Peak months of settlement	Reference
Australia	September to January	Phillips 1986
Antigua	February, May September to October & December	Bannerot et al. 1987b
Puerto Rico	June - August	Bannerot,1987b
Cuba	May to July & September to November	Cruz et al. 1992a
Florida	February to May	Menzies & Kerrigan 1980
Mexico	March to April & September to October	Gutierrez et al. 1989
Jamaica	July & October to November	Current investigation

Spiny lobster growth rates in captivity have improved tremendously over the years. Chittleborough (1974a & b), succeeded in rearing *Panulirus argus* from the puerulus stage to reproductive maturity in approximately five years (Cobb and Phillips 1980). Sweat (1968) reared pueruli to juveniles 50 mm CL in 28 months. The prediction was then made that *P. argus* should take 4 – 5 years to grow from puerulus to the then legally harvestable size of 76.3 mm CL under conditions similar to Sweat in 1968 (Tamm 1980). It could take 12 months for *P. argus* postlarvae to grow to 60mm CL in captivity (Jeffs and Davis 2003). Implementing certain techniques could see this size attained in 5 - 6 month. If this is growth rate could be im-

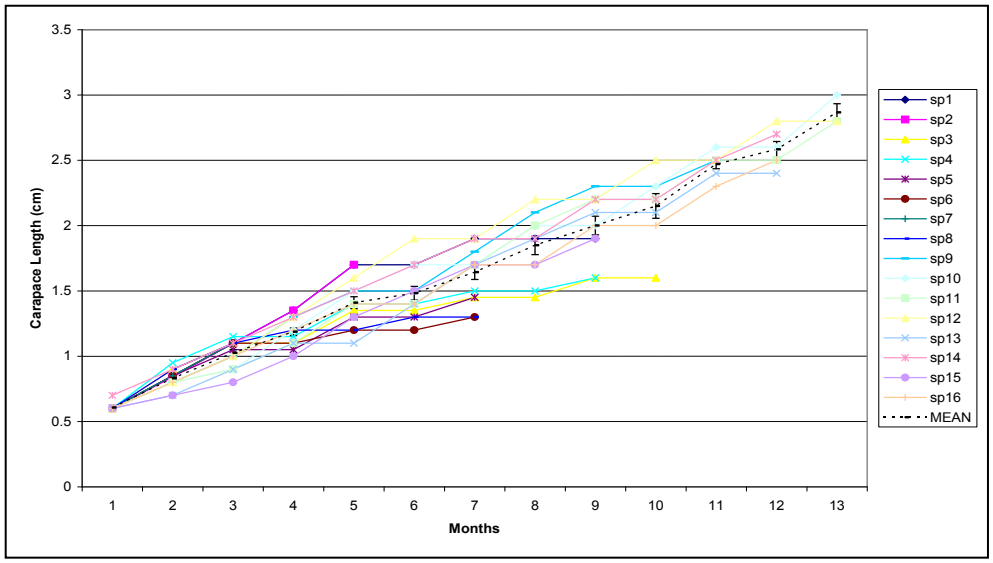

Figure 11. Variation in carapace length over 12 months for class 1 *P. argus* lobsters fed mussel and squid (n = 16).

proved upon it would directly benefit lobster mariculture.

In the present study, lobsters were grown in different size classes with the specific objective to grow each size class to the one just larger than the previous one. This was done successfully and the data for all size classes were merged to determine the length of time lobsters would take to grow to the maximum size achieved in the investigations. In summary the class 1 juveniles increased in carapace length a mean of 2.25 cm CL in 12 months.

The mean carapace increase indicated that *P. argus,* could be grown from the postlarval stage to a carapace length of 48 mm or 4.8 cm in approximately 25 months or just over 2 years. This present growth rate was however, nearly twice as long as described in Jeffs and Davis (2003). Using data taken at monthly intervals, at the end of the 12 month growth period, results showed that older, larger juvenile lobsters moulted fewer times than younger, smaller postlarval lobsters. That is, class 3 lobsters moulted fewer times than class 2 lobsters which in turn moulted fewer times than class 1 lobsters (see Table 2).

Overall, the investigation was relatively successful with interesting results for settlement patterns, especially showing that north coastal settlement was extremely poor, relatively to the south coast where settlement occurred in July and October to November annually. Growth of early settled postlarvae was relatively slow and suggested commercial culture would be relatively expensive due to the protein-rich diet required.

Table 2. Mean number of moults after 9 and 12 months for all three classes of *P. argus* lobsters fed mussel and squid.

	mean # of moults after 9 months	mean # of moults after 12 months
class 1	6.63	8.67
class 2	5.14	8.00
class 3	3.80	5.00

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