Postlarval Recruitment of the Spiny Lobster, *Panulirus argus* (Latreille 1804), in Bahía de la Ascensión, Q.R.

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ABSTRACT

Postlarval spiny lobster (*Panulirus argus*) settlement on artificial collectors was studied for 1 year (March 1987 to March 1988) in Bahía de la Ascensión, Quintana Roo, Mexico. We examined the temporal and spatial patterns of postlarval influx by deploying GuSi collectors at five sampling stations, visiting them every lunar phase. A total of 529 postlarvae were collected during this study, of which 58% were caught at only one station. Settlement was highest during the first half of the lunar month while seasonally, settlement was greatest in March-April and September-October. This settlement pattern may be related to changes in water temperature, but hydrological information for this area is scarce. The study is continuing to determine if this pattern is consistent among years.

INTRODUCTION

The spiny lobster, *Panulirus argus* (Latreille 1804), comprises the most important fishery along the Caribbean coast of the Mexican state of Quintana Roo (Secretaría de Pesca, 1987). This species is fished using a variety of techniques in different areas, the most important being wire traps, SCUBA diving with hooks and spears, and artificial habitats called "casitas cubanas" or "sombras" (Miller, 1982a; Lozano *et al*, 1988).

One of the most productive areas for spiny lobsters in Quintana Roo is the Bahía de la Ascension (Bay of Ascensión) (Figure 1), where lobsters are fished exclusively with "casitas" and, occasionally, lobster nets (Miller, 1982b; Lozano *et al*, 1988). Most of the lobsters caught at Bahía de la Ascensión are small-sized, *e.g.*, juveniles and young adults (Lozano *et al*, in prep.). Younger juveniles are found in the inner portion of the bay, whereas older juveniles occupy the more external parts. Large individuals and egg-bearing females are found only in the nearby coral banks. Thus, Bahía de la Ascensión is considered an important nursery ground for local spiny lobsters.

Spiny lobsters (Palinuridae) have a long and complex life cycle (Phillips and Sastry, 1980). The planktonic larval period lasts for a number of months (6-22 months) and after reaching the last phyllosoma larval stage, they metamorphose into a puerulus postlarva similar to the adult, but natant and transparent. This stage returns to the coastal waters, where it settles after encountering an appropriate substratum. Once settled, it molts and begins its

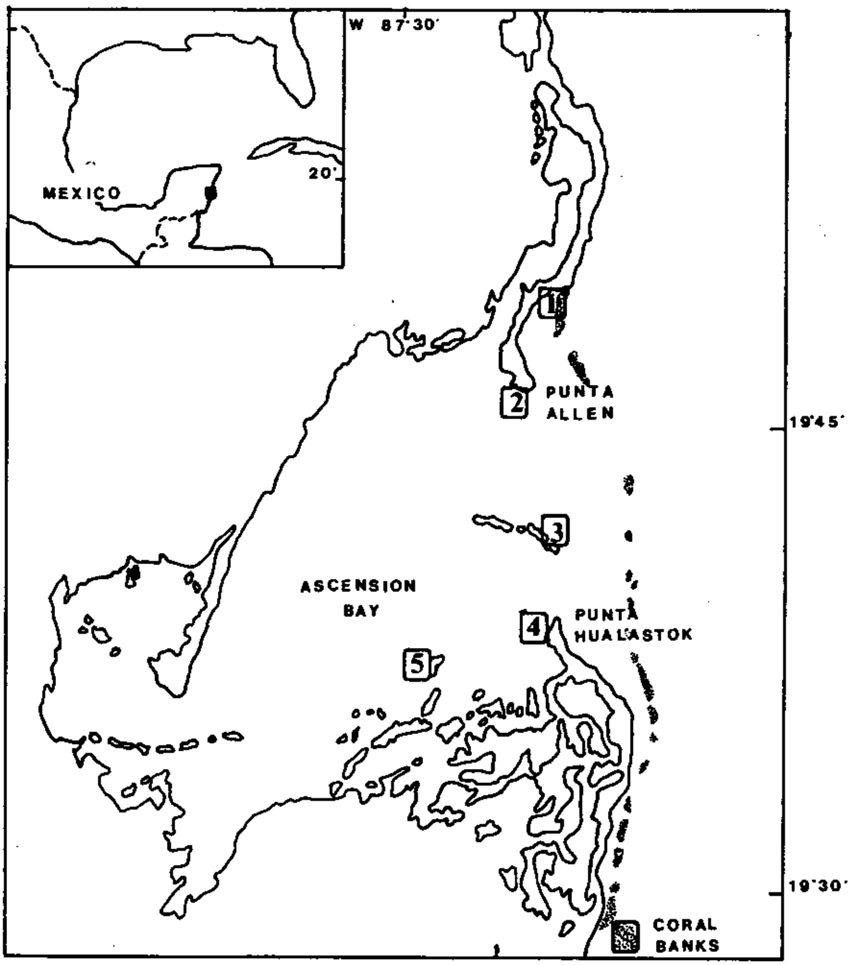

Figure 1. Sampling stations in Bahía de la Ascensión.

benthic life.

Several authors have developed artificial collectors to obtain pueruli of different species of spiny lobsters (Witham *et al*, 1968; Phillips, 1972; Serfling and Ford, 1975; Booth, 1979). In Australia, the continuous collection of pueruli has proved useful to develop predictive models for the fishery of *P. cygnus* (Phillips, 1986).

The wide geographic distribution of *P. argus*, from northern Brazil to the North Atlantic and along the Caribbean, and the possible mix of phyllosoma larvae in the Yucatan Current and the Gulf Stream (Ingle *et al*, 1963; Sims and Ingle, 1967; Menzies, 1981) have precluded the use of a stock-recruitment approach in fishery models for *P. argus*. Thus, the study of the postlarval recruitment in the Caribbean is necessary for the determination of seasonal trends in recruitment as well as its temporal and spatial dynamics. Studies of this nature have been conducted in Florida (Witham *et al*, 1968; Little, 1977; Little and Milano, 1980; Menzies, 1981). Marx (1986) reviewed these studies and concluded that postlarval recruitment is year-long and variable with no consistent seasonal trend. Postlarval recruitment is also under study in Puerto Rico (Monterrosa, 1991), Antigua (Bannerot *et al*, 1991), Grenada (Calinski and Lyons, 1983) and in Florida (Heatwole *et al*, 1991).

Postlarval recruitment in Mexico is restricted to that of Gracia and Lozano (1981) who found considerable numbers of pueruli of *P. gracilis - P. inflatus* in the stomach contents of an abundant demersal fish, and hypothesized the possibility of studying the postlarval settlement of these species by this method.

The objective of this study was to determine the temporal and spatial patterns of *P. argus* puerulus in Bahía de la Ascensión, using artificial collectors.

MATERIALS AND METHODS

Study site

Bahía de la Ascensión is located in the central coast of the state of Quintana Roo (between 19°35' and 19°45' L N, and 87°30' and 87°45' L W) on the Mexican Caribbean coast (Figure 1). It is a shallow bay (< 1-6 m deep) of approximately 102,670 ha., bordered by mangroves and grass swamps, and containing several mangrove cays in its central and southern sections. A discontinuous line of coral banks lies roughly parallel to the coastline at the bay's mouth (Jordan, 1988) and reduces wave surge within the bay. A network of channels connects the bay with inner lagoons. Substrates in the bay are diverse, ranging from soft, unconsolidated sediments in the inner half of the bay to hard limestone pans and coral banks in the outer bay. Turtlegrass (*Thalassia testudinum*) and green and red algae form extensive beds throughout the bay.

Stations

Five study stations were selected representing three major bay environments: a) backreef environment (Station 1), b) mangrove-lined areas with high water flow (Stations 2 and 3), and c) mangrove-lined areas with low water flow (Stations 4 and 5). The characteristics of each station are the following:

Station 1, the northernmost station, was located approximately 50 m inshore of a coral bank at a depth of 1 m (Figure 1). A land point (Punta Xohken) north of it and the coral bank protect this area from wave surge. The water is clear at this protected site and the bottom is sandy and covered by octocorallians, sparse turtlegrass and patches of algae *e.g.*, *Laurencia scoponia*, *Laurencia* sp., *Halimeda incrassata*, *H. monite*, and *Dictyota divaricata* among others.

Station 2 was located 50 m from the mangrove-lined extreme of Punta Allen Point in water 2 m deep (Figure 1). Turbidity varies markedly at this site due to periodic, wind-generated (E and SE trade winds) waves. The bottom is unconsolidated sand with conspicuous burrows and sparse stands of turtlegrass and algae (*Acanthophora spicifera*, *Dasya* sp., *Sypridia filamentosa*, and *Polysiphonia* sp.).

Station 3 was situated among the mangrove cays in the central part of the bay. Strong currents in the interisland channels create the turbid conditions characteristic of this site. Numerous burrows and benthic medusae of the genus *Cassiopea* litter the fine sand bottom at site 3 where vegetation (*Halimeda opuntia* and *Penicillus capitatus*) is very sparse. The mean depth at this site is 2.5 m.

Located at the southern entrance of the bay, Station 4 was located in shallow water (1.5 m) about 50 m from Punta Hualastok, a mangrove-lined point. Water currents are minimal at this site where the substrate is covered by dense turtlegrass beds interspersed with algae (*Laurencia intricata*, *Dictyota divaricata*, *Jania adhaerens*, and *Batophora oerstedii*).

The southernmost station, Station 5, established close to a mangrove cay, is representative of the inner bay with variably turbid water and a depth of 2 m. During the winter the area is exposed to waves from the north. The bottom is sandy at Station 5 with sparse, but diverse patches of algae, *e.g.*, *Laurencia intricata*, *L. poitei*, *Thalassia testudinum*, *B. oerstedii*, *Digenia simplex*, *Dictyosphaeria cavernosa*, *Caeramium niteus*, and *Chrondia tenuissima*.

Collectors

Five "GuSi" collectors were deployed in a line 50 m apart at each of the five stations (Gutiérrez *et al*, 1992). Due to occasional losses, the total number of collectors used ranged from 22 to 25. At Station 1, the line of collectors was diagonal to the coral reef; at the rest of the stations, the line was parallel to the nearest coastline. Green and red artificial seaweed were used to simulate the settling substrata seemingly preferred by pueruli (Witham *et al.*, 1968) and red algae beds (Marx and Herrnkind, 1985; Herrnkind and Butler, 1986).

One Witham type (Witham *et al.*, 1968) artificial habitat was also deployed at Stations 1, 2, and 3 for six months. The fibers of the GuSi collectors and the pages of the Witham habitats became fouled after 2-3 weeks. Fouling was permitted because it improves the efficiency of the collector (Phillips, 1972; Little and Milano, 1980; Monterrosa, 1991). When fouling became dense, the collectors were cleaned to avoid clustering of the fibers.

Sampling periodicity

Preliminary tests of the GuSi collectors were made from October 1986-January 1987 and actual monitoring began the first week of March, 1987. Collectors were examined one to two days after each lunar phase from March 17, 1987 to March 4, 1988.

Witham habitats were set at Stations 2 and 3 on March 24 and at Station 1 on April 8, 1988, but these collectors deteriorated rapidly and were useless by August-October when they were removed. A comparison of the performance of both types of collectors is described by Gutiérrez *et al.* (1992).

During each sampling we recorded the number of pueruli and postpueruli recovered from each collector, the superficial water temperature, and the direction of the wind and current. Postlarvae have a dorsoventrally flattened cephalothorax, and may or may not be pigmented while postpueruli (recently molted first benthic stage juveniles) are pigmented, have a rounded carapace with spines, and have hairs on their antennae (Lewis *et al.*, 1952). The pueruli and postpueruli removed from the collectors were released far from the sampling stations.

Data analysis

A two-way analysis of variance (ANOVA) with a log (x + 1) transformation to equalize variances (Sokal and Rohlf, 1981) was applied to the results among stations and among lunar phases. The Tukey-Kramer method for multiple comparisons among pairs of means based on unequal sample sizes (Sokal and Rohlf, 1981) was used to detect differences among lunar phases and stations.

To further test the possible importance of artificial seaweed color on postlarval settlement, an approximate t-test for sample means with unequal variances (Sokal and Rohlf, 1981) was applied to the CPUE between red and green collectors.

RESULTS

The temperature of the surface water for Bahía de la Ascensión ranged from 24.4 to 32.2°C and between October and March some periods of low temperature were evident (Figure 2). These sudden decreases in temperature represent the arrival of "nortes", cold fronts that reach the area in late autumn and winter. A total of 529 postlarvae were caught, with a mean cpue (catch per collector per week) of 0.53 postlarvae per collector per week (Table 1).

Two seasonal peaks in postlarval influx were evident: one in March-April (spring) and another in September-October (autumn), the latter being the greatest (Figure 3). Postlarval catch differed significantly among lunar phases and stations (Table 2). Significantly, more postlarvae were obtained during the new moon and first quarter phases than during full or last quarter moon phases (Table 3).

Station 1 consistently caught larger numbers of postlarvae (58% of the total), followed by Stations 2, 3, 4, and 5, respectively (Table 1). Postlarval catch at Station 1 differed from the remaining stations, whereas Stations 2 and 3, and Stations 4 and 5 were similar. These similarities were expected, since Station 1 represents one kind of environment (backreef area); Stations 2 and 3 shared some characteristics (mangrove-lined coast with moderate to strong water flow), and Stations 4 and 5 also had similar environments (mangrove-lined coast with weak water flow).

Catch-per-unit-effort data for Stations 2 and 3, and those for Stations 4 and 5, were grouped to better compare the CPUE per lunar phase for each of the three environments considered (Figure 4). The peaks for the three environments are coincident.

Although the red collectors consistently caught slightly higher numbers of postlarvae, there were no significative differences in catch between red and green collectors.

DISCUSSION

Bahía de la Ascensión is a natural nursery ground for juveniles of *P. argus*. Although the postlarval catch we obtained resembled that reported from Bermuda (Ward, 1989), it was not as large as that reported in some areas of Florida (Little, 1977; Little and Milano, 1980) and was larger than those reported for Puerto Rico (Monterrosa, 1991). Tests of collector efficiency indicated that the GuSi collector yields larger CPUE than the modified Witham Habitat (Gutiérrez *et al.*, 1992). Another possible explanation for the low number of postlarvae obtained is that the year sampled corresponded to a low-recruitment year. Postlarval settlement reportedly varies by an order of magnitude over a few years (Morgan *et al.*, 1982). Because Bahía de la Ascensión holds a large population of juveniles (Lozano *et al*, in prep.), postlarvae reaching this area presumably have strong probabilities of survival to the juvenile stage. The large areas of the bay covered by turtlegrass and red algae (*Laurencia* spp.) could offer both refuge and food in large quantities, thus reducing the risk of mortality by predation or starvation of the pueruli and small

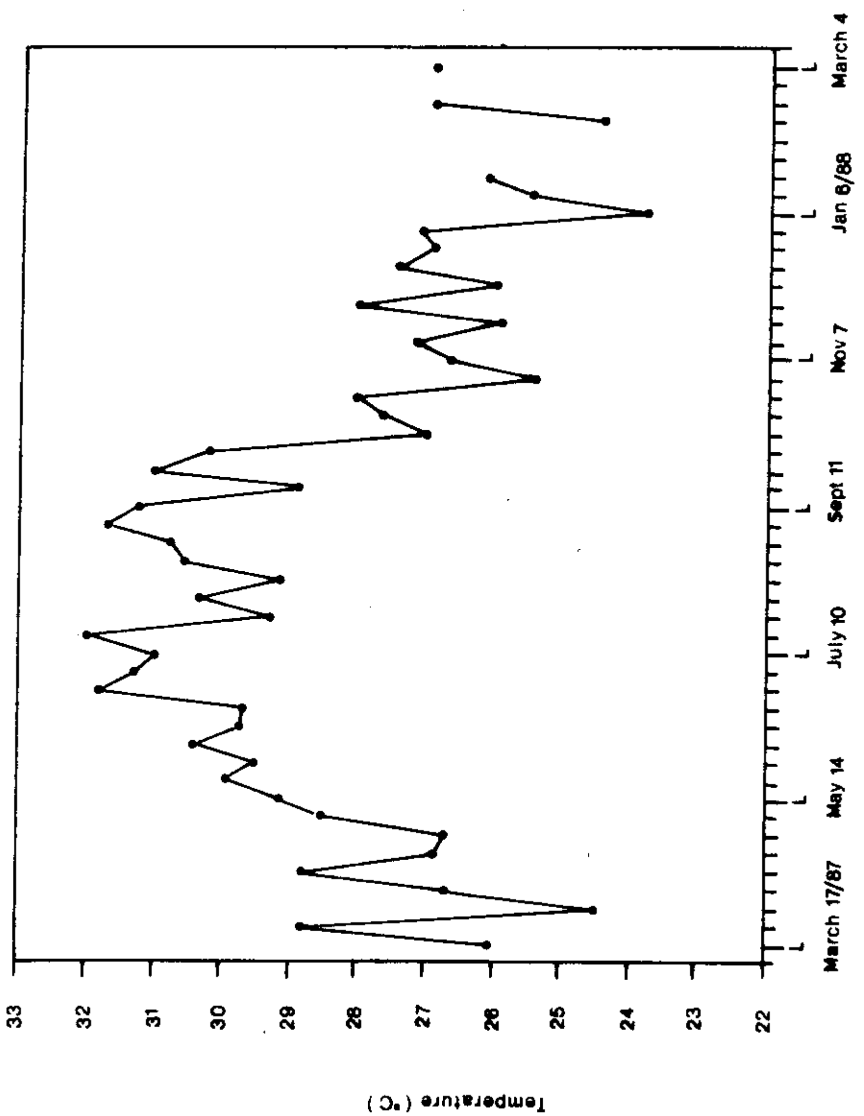

Figure 2. Mean surface temperatures of Bahía de la Ascensión.

Table 1. Summary of results.

STATION	CATCH Pueruli	Post-Pueruli	Total	NO. OF COLLECTORS EXAMINED	CPUE (catch/collector/day)
Xohken	72	237	309	175	1.77
El Faro	13	78	91	216	0.42
Valencia	27	47	74	210	0.35
Hualastok	7	24	31	219	0.14
Cedros	6	18	24	186	0.13
TOTALS	125	404	5529	1006	*0.53

*(Mean)

Table 2. ANOVA of CPUE transformed by log (x+1) for lunar phases and stations.

SOURCE OF VARIATION	SS	df	MS	F-ratio
LUNAR PHASES	1.049	3	0.035	15.441*
STATIONS	2.219	4	0.555	24.513*
ERROR	4.821	213	0.023	
TOTAL	8.089	220		

*(P = 0.05)

juveniles (Kanciruk, 1980; Marx and Herrnkind, 1985; Herrnkind and Butler, 1986; Marx, 1986).

Settlement was significantly higher during new moon-first quarter phases than during full moon-last quarter phases. This has been reported for *P. argus* (Witham *et al.*, 1968; Sweat, 1968; Little, 1977; Little and Milano, 1980; Marx and Herrnkind, 1985; Ward, 1989; Monterrosa, 1991), *P. cygnus* (Phillips, 1972; 1975) and *P. marginatus* (MacDonald, 1986). Thus studies of postlarval influx could reduce sampling effort without seriously affecting catch by examining the collectors only during the second half of the lunar month.

Settlement of pueruli also occurred throughout the year with peaks of settlement in spring (March-April) and autumn (September-October) relating to times when water temperatures are rising and falling. When temperatures were highest (May-August), settlement was low, although a peak was also noted in February. No explanation is yet evident for this mid-winter peak. Little (1977) also found spring and fall peaks in the Florida Keys, as did Peacock (1974) in Antigua. In Bermuda, Ward (1989) reported peaks in late summer for four

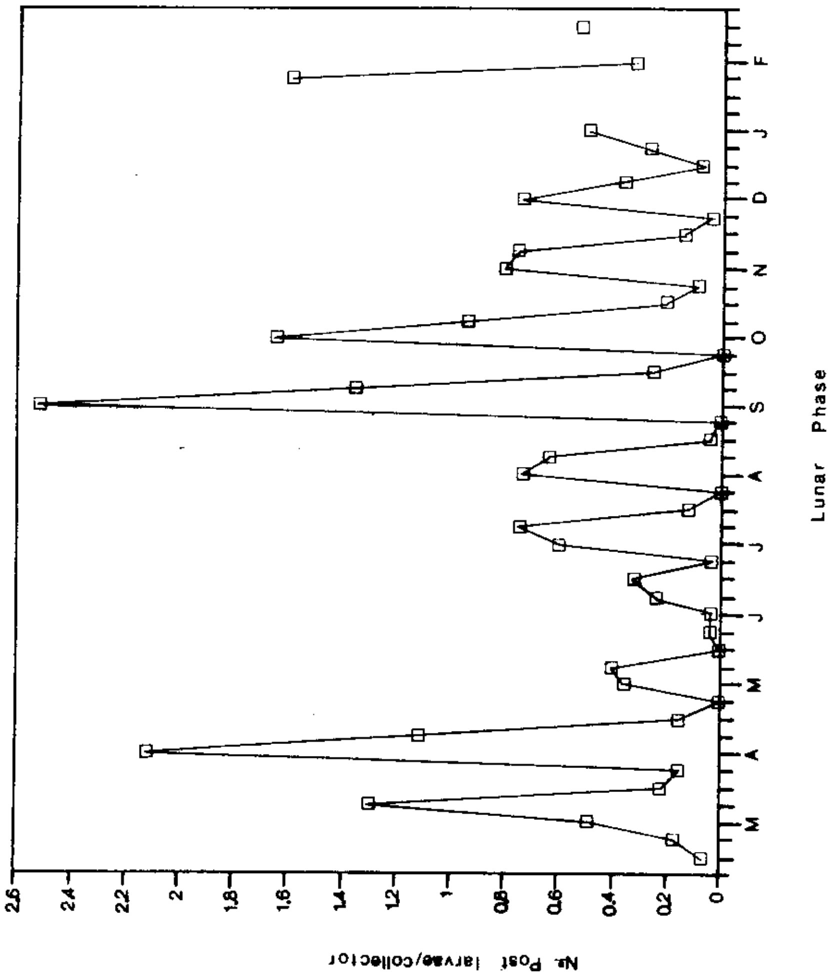

Figure 3. Mean CPUE (number of postlarvae/collector/week) vs. lunar phase of the five stations samples.

Table 3. Catch per station per lunar phase (NM=New moon, FQ=First quarter, FM=Full moon, LQ=Last quarter).

DATE	LUNAR PHASE	STATION NO. 1	2	3	4	5	TOTAL CAPT.
17-Mar-87	FM	1	0	0	-	-	1
24-Mar-87	LQ	0	0	4	0	0	4
31-Mar-87	NM	1	0	10	1	1	13
08-Apr-87	FQ	22	9	4	0	0	35
14-Apr-87	FM	3	2	1	0	0	6
21-Apr-87	LQ	3	1	0	0	0	4
29-Apr-87	NM	44	2	5	4	2	57
06-May-87	FQ	17	10	1	2	0	30
14-May-87	FM	1	1	1	1	0	4
21-May-87	LQ	0	0	0	0	0	0
27-May-87	NM	3	1	5	0	0	9
06-Jun-87	FQ	5	0	1	2	2	10
12-Jun-87	FM	0	0	0	0	0	0
18-Jun-87	LQ	0	1	0	0	0	1
25-Jun-87	NM	0	0	1	0	0	1
02-Jul-87	FQ	2	1	1	1	1	6
10-Jul-87	FM	5	0	0	2	1	8
18-Jul-87	LQ	1	0	0	0	0	1
26-Jul-87	NM	8	0	3	2	2	15
03-Aug-87	FQ	12	1	1	2	2	18
08-Aug-87	FM	3	0	0	0	0	3
16-Aug-87	LQ	0	0	0	0	0	0
24-Aug-87	NM	15	0	0	1	1	17
03-Sep-87	FQ	9	3	1	0	1	14
11-Sep-87	FM	1	0	0	0	0	1
18-Sep-87	LQ	-	0	-	-	-	0
26-Sep-87	NM	45	10	2	0	1	58
03-Oct-87	FQ	22	2	2	2	3	31
10-Oct-87	FM	3	2	0	0	0	5
16-Oct-87	LQ	0	0	0	0	0	0
23-Oct-87	NM	30	0	1	1	1	33
29-Oct-87	FQ	13	3	2	0	0	18
07-Nov-87	FM	1	2	1	0	0	4
15-Nov-87	LQ	1	0	1	0	0	2
21-Nov-87	NM	6	2	5	2	2	17
30-Nov-87	FQ	6	5	5	0	0	16
06-Dec-87	FM	2	0	1	0	0	3
14-Dec-87	LQ	1	0	0	0	0	1
21-Dec-87	NM	6	5	1	2	1	15
27-Dec-87	FQ	3	1	2	0	1	7
06-Jan-88	FM	-	-	1	0	0	1

Table 3. Ctd.

DATE	LUNAR PHASE	STATION NO. 1	2	3	4	5	TOTAL CAPT.
12-Jan-88	LQ	1	3	1	0	0	5
19-Jan-88	NM	2	2	2	2	-	8
26-Jan-88	FQ	-	-	-	-	-	-
02-Feb-88	FM	-	-	-	-	-	-
11-Feb-88	LQ	5	14	8	3	2	32
18-Feb-88	NM	4	2	0	0	0	6
25-Feb-88	FQ	-	-	-	-	-	-
04-Mar-88	FM	2	6	0	1	0	9
TOTALS		309	91	74	31	24	529

consecutive years and Monterrosa (1991) found peaks in late summer and early autumn in Puerto Rico. However, in a review of postlarval influx data, Marx (1986) concluded that no consistent seasonal trend is apparent in Florida. Because of the highly complex pattern of water circulation in the Caribbean (Merino-Ibarra, 1987), long-term monitoring of settlement peaks is necessary if interannual variability is to be detected and related to large scale hydographic events.

Of the five stations sampled, Station 1 was the most subject to direct influences of sea water entering the bay and consistently caught larger numbers of postlarvae (Table 2). In contrast, Little (1977) and Little and Milano (1980) mentioned that areas with strong movement of water yielded poor catches of postlarvae in the Florida Keys. Ward (1989) stated that large numbers of postlarvae were caught in two of his stations in Bermuda located close to, but not directly in, areas with strong water flux.

There is little information on hydrological processes and current patterns in Bahía de la Ascensión. However, in a study of surface currents in the Mexican Caribbean, Merino-Ibarra (1987) offers a tentative scheme describing surface circulation in the coastal zone of Quintana Roo. His Figure 6 shows that the main flux of water is north, but that close to the shore, a weaker littoral countercurrent is present. This southernly flowing current enters Bahía de la Ascensión from the north where Station 1 was established, flows through the middle of the bay, and exits the bay near Stations 4 and 5. Merino-Ibarra also proposes that gyres exist very close to the coast.

Phillips (1975) found no apparent relationship between the number of pueruli entering the area of Seven Mile Beach, Australia, and the volume of water flow into the area. However, he suggested that postlarvae may make use of the incoming water currents to approach the coastal areas, where they would eventually settle. A similar mechanism could be operating in Bahía de la

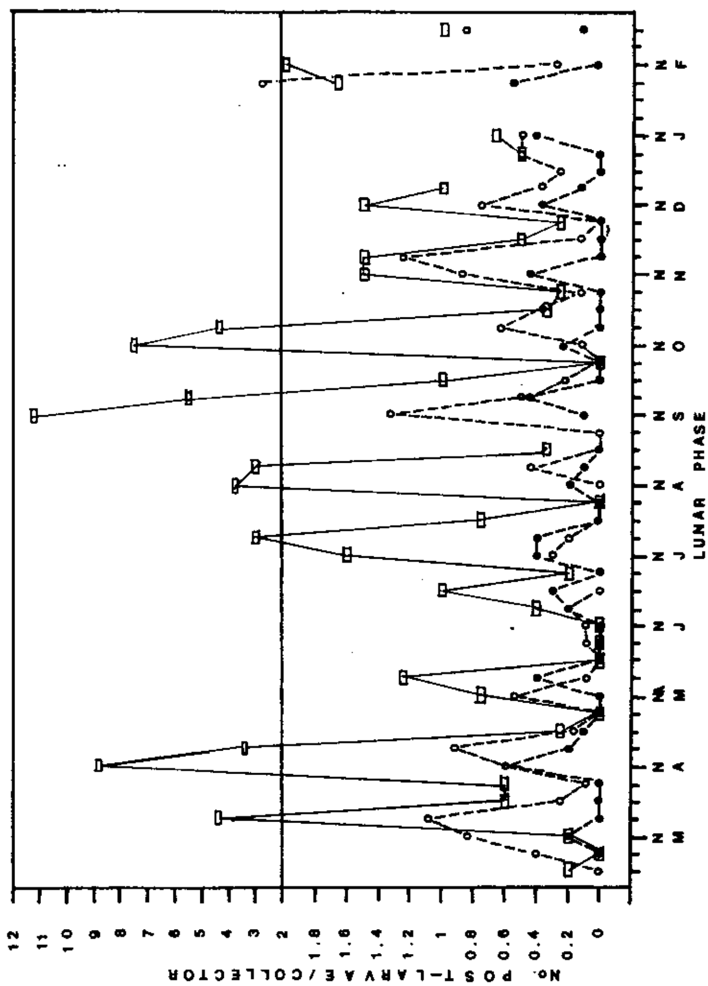

Figure 4. CPUE (number of postlarvae/collector/week) of three different areas within the bay: hollow rectangle = back reef area; hollow dot = mangrove-lined area with strong water flow; filled dot = mangrove-lined area with weak water flow.

Ascensión, thus explaining the larger numbers of postlarvae in Station 1 and the small numbers in Stations 4 and 5. This implies that the "upstream" stations receive more postlarvae that the "downstream" stations. However, longer-term studies on this subject are required, because other factors, such as turbidity or bottom type, could mediate this pattern of settlement.

The color of the fibers used to construct the collector apparently does not effect postlarval settlement, although the red collectors did maintain a higher CPUE. The possibility of some interactions between color of the collector and station cannot be excluded and further studies on this are currently underway.

Further studies are in progress to determine if the seasonal patterns noted here are consistent among years and at other locations along the coast of Quintana Roo.

ACKNOWLEDGEMENTS

We gratefully acknowledge the invaluable assistance of Jorge Simonín D. in our field and laboratory work. David L. Miller kindly offered the three modified Witham habitats to use in this study. Marco Aguilar identified the algae of the five sampling stations. Thanks also to Enrique Lozano, Fernando Negrete, Félix Colinas, MariCarmen Martínez, Martha Fonseca and Gabriela Contreras for helping with the field work, and to Eric Jordán for locating the coral banks on the map and for his lively discussions. We also appreciate the comradeship of the members of the Soc. Coop. Pesquera "Pescadores de Vigia Chico" at Punta Allen, who lent us their boats and/or motors when ours failed, and their locale to pass so many nights. This study was supported in part by World Wildlife Fund-U.S. and Asociación de Amigos de Sian ka'an, A.C.

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