PUERTO RICO DEPARTMENT OF NATURAL AND ENVIRONMENTAL RESOURCES

Partial Report

To

National Marine Fisheries Service
NOAA

Entitled

Caribbean/NMFS Cooperative SEAMAP Program- Spiny lobster, *Panulirus argus*, Assessment

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INTRODUCTION

The spiny lobster is the most valuable and important fishery in Puerto Rico. The species is harvested using SCUBA or by traps (fish and lobster). Lobster landings show a drastic decline from 512,000 lbs in 1979 to 143,761lbs in 1988. From 2004 to 2006, its landing reports went from 212,226 to 169,098 lbs, respectively (Matos, 2007). To date there have been few stock assessment in Puerto Rico of this resource (SEDAR, 2005; Bohnsack et al, 1991; Boardman and Weiler, 1982). To fully understand the fisheries decline two processes must be study: pueruli settlement and juvenile recruitment.

Spiny lobster can spend 6 to 9 months as planktonic larvae drifting with water currents. Therefore, local lobster recruitment can be dependent on lobsters stocks and spawning success in a far away place. Recognizing this fact, in 1995 the Caribbean Community Secretariat (CARICOM) sponsored a workshop on lobsters and conch in Jamaica. At this meeting, it was recommended that pueruli collectors and juvenile artificial shelters be established (CFRAMP, 1997) in a number of CARICOM countries to monitor the recruitment through the Caribbean.

In Puerto Rico three studies on pueruli were conducted. The first study was a master degree thesis (Monterrosa, 1991), the second in 1996 to 1997 (Rosario and Figuerola, 1998) and the third in 2003. Results are not conclusive, but indicate that there are a few key locations where pueruli settlement is common. Unpublished data from a study in Culebra Island suggests that pueruli are found in greater quantity at depth under strong currents conditions. It will be necessary to keep sampling with different techniques and in new areas to determine if the problem is that not enough pueruli are reaching Puerto Rico's waters or that the study is being conducted in low abundance areas.

In 2003 artificial shelters were located at two different sites to study the juvenile stages of the lobster. Preliminary results showed a preference for shallow seagrass beds. It is necessary to run more essays and corroborate previous findings.

OBJECTIVES

- To collect, manage, and disseminate fishery-independent data on the relative magnitude of recruitment of postlarval *Panulirus argus* resources and their environment, encompassed in marine waters within the territorial sea and Exclusive Economic Zone contiguous to Puerto Rico.
- Provide Puerto Rico with a time series data on pueruli settlement at seven sites off the west coast of Puerto Rico.
- To assess pueruli abundance by depth on the west coast of Puerto Rico.
- Provide information to support the Caribbean Fishery Management Council's effort to implement and monitor the effectiveness of fishery management plans for fisheries in the U.S. EEZ.
- To conduct a population dynamics spiny lobster survey to determine the spatial and temporal variations in larval settlement, distribution and

recruitment within the territorial sea of P.R. and the U.S. EEZ, off the west coast of Puerto Rico.

STUDY SITE

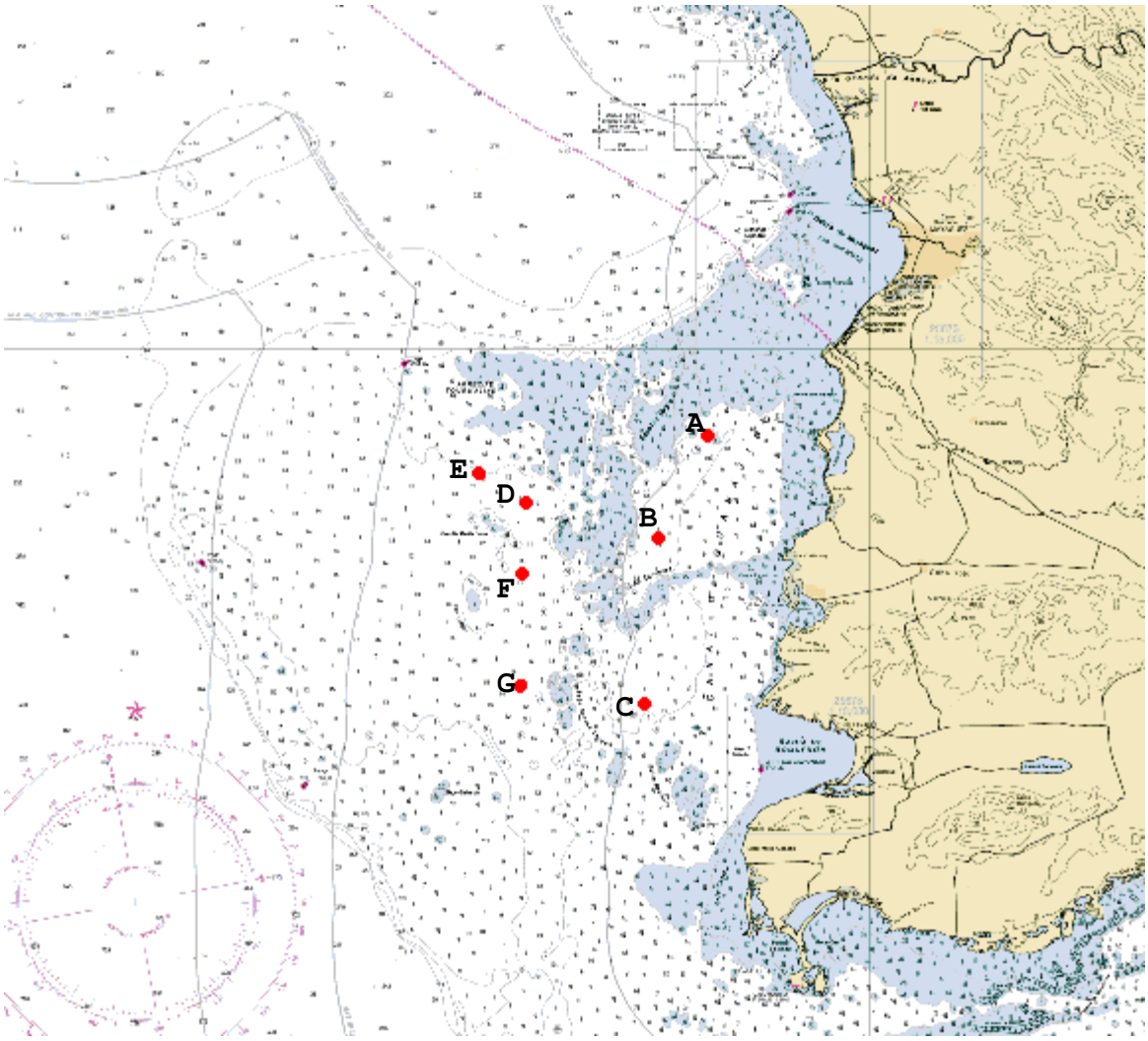
Study 1- Pueruli settlement

Seven stations were selected to place the collector's base on depth, distance from shore and from a reef (Figure 1). Table 1 summarizes the coordinates for each station, including date of deployment or if it was necessary to replace lost one.

Table 1. Description of station coordinates, deployment dates and replacements.

Station	Id	Latitude	Longitude	Date deployed
A	A1	18°08.113	67°13.704	3-Mar-08
	A2	18°08.105	67°13.692	3-Mar-08
	A2	18°08.040	67°13.673	5-Aug-08
B	B1	18°05.900	67°14.812	3-Mar-08
	B1	18°05.916	67°14.813	29-Apr-08
	B2	18°05.915	67°14.791	3-Mar-08
C	C1	18°02.291	67°15.240	3-Mar-08
	C2	18°02.231	67°15.260	3-Mar-08
D	D1	18°06.671	67°17.954	3-Mar-08
	D1	18°06.728	67°17.968	29-Apr-08
	D2	18°06.690	67°17.954	3-Mar-08
	D2	18°06.788	67°17.996	29-Apr-08
E	E1	18°07.258	67°18.941	3-Mar-08
	E2	18°07.247	67°18.968	3-Mar-08
F	F1	18°05.068	67°18.053	3-Mar-08
	F2	18°05.051	67°18.069	3-Mar-08
G	G1	18°02.627	67°18.031	3-Mar-08
	G1	18°02.682	67°18.050	19-Aug-08
	G2	18°02.661	67°18.033	3-Mar-08

Figure 1. Location of stations for the spiny lobster pueruli collector's study.



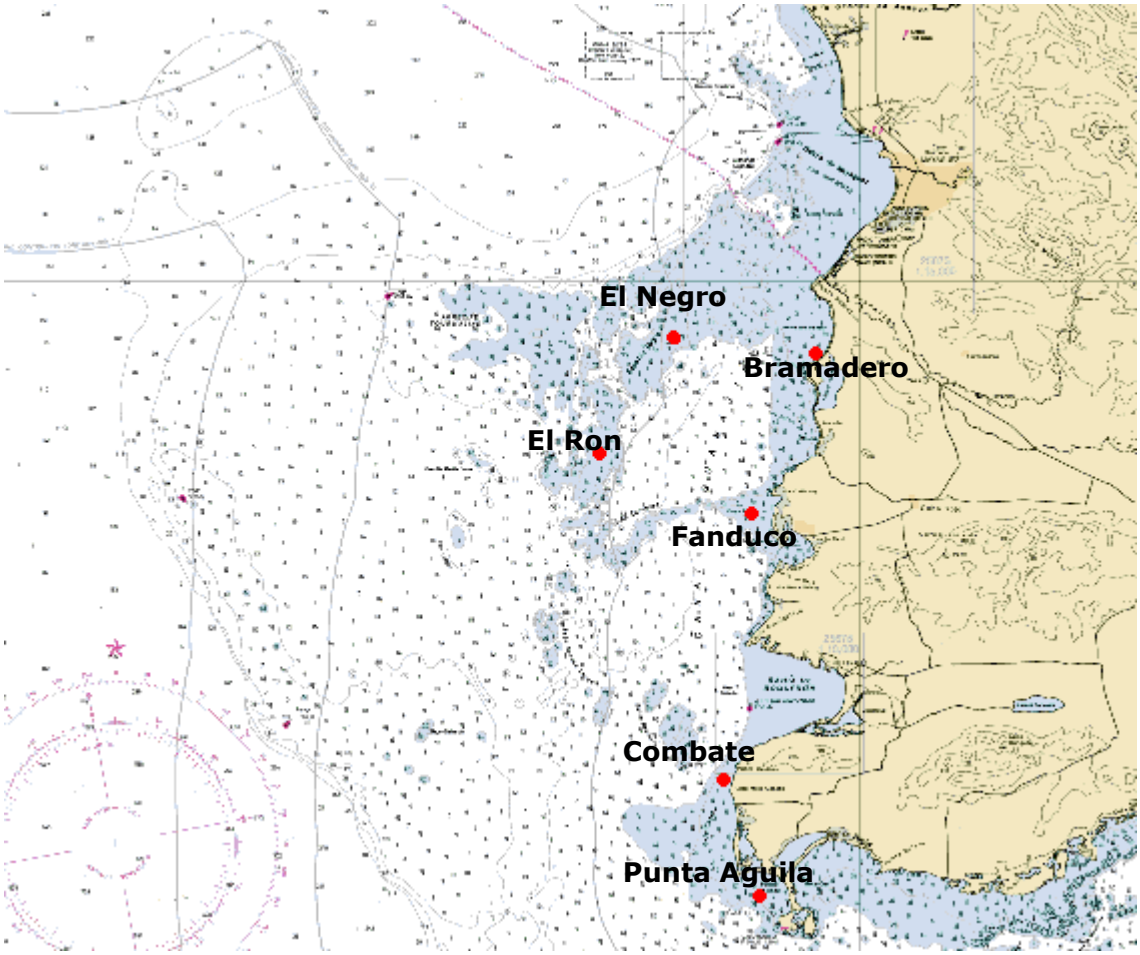
Study 2- Artificial shelters for juvenile lobsters

Six areas were selected base on depth, bottom type and proximity to a reef (Figure 2). Table 2 summarizes the coordinates for every artificial shelter deployment within each station.

Table 2. Coordinates of the spiny lobster artificial shelters

ID	Latitude	Longitude
Bramadero	18°08.331	67°11.136
El Negro	18°08.795	67°14.208
Fanduco	18°05.002	67°12.435
El Ron	18°06.344	67° 16.046
Combate	17°59.266	67°13.113
Pta. Aguila	17°56.724	67°12.260

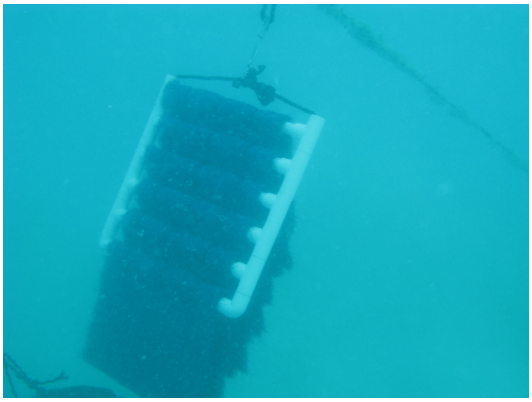
Figure 2. Spiny lobster artificial shelter stations.



METHODOLOGY

Study 1- Pueruli settlement

Figure 3. Spiny lobster pueruli collector.



1. Seven stations were selected along the west coast platform according to depth and distance from the shoreline (Figure 1.).

2. Fifty six modified Witham pueruli collectors (Witham et al, 1968; Pillips et al., 2005) were constructed of rectangular PVC frame with 6 sheets of air conditioning filter materials, each measuring 30 x 30 cm. Each sheet was folded around the PVC frame making 12 sheets. A piece of rope was passed inside the PVC frame to keep the frame together in case it broke. The rope went out through two of the corners of the frame. The two ends of the rope were nut tightly and a clip loop in the nut (Figure 3.).

3. The collectors were attached with the clip directly to a buoyed line anchored to the bottom. The line from the collector to the anchored line, used previously, was modified to prevent incidental entanglements of sea turtles. The anchored line had two buoys, one with the identification number and the other with a DO NOT DISTURB, STUDY ON PROGRESS signed carved on it.

4. Two sets of collectors were deployed at each station, 30 m apart from each other. Each set consisted of two collectors hooked to an anchored line. One of the collectors was hook at a depth range between 30-40 feet and the other at a depth range of 60-80 feet, 2m above the sea floor.

5. Fifty six (56) pueruli collectors were constructed in order to monthly replace the collectors sampled.. This was done to control overgrowth of other organisms in the structures. The collectors sampled were taken back to land and placed on the ground to dry with the sun.

6. Collectors were sampled once a month, between the new and the full moon. For sampling, a diver covered the collector with a fine mesh netting (so the pueruli couldn't escape), unsnap the collector, and clip it to a line with a buoy, while the replacement collector was placed in position. Once both collectors were clipped, they were brought to the boat. The anchored line was clean from organism on each visit.

7. Collectors were search for spiny lobster pueruli. All pueruli found were counted, classified according to developmental stage (transparent, pigmented and juveniles). Juveniles were distinguished from pueruli by their rounded carapace and erect

supraorbital spines. The pueruli were kept in a small aquarium and released away from the area of the collectors.

8. Damaged or lost collectors were replaced.

Study 2- Artificial shelters for juvenile lobsters

1. Six sets of ten juvenile lobster artificial shelters were constructed at various sites on the west coast platform. Each shelter was at least 30 m apart from each other.

Figure 4. Spiny lobster artificial shelter.

2. Each artificial shelter was built using 16 cement blocks. Eight of the blocks were placed on the seafloor forming a square shape, two cement blocks per side. The other eight blocks were placed in top of the first layer of blocks (Figure 4). The blocks were tied to each other with nylon rope.

3. Sampling was done monthly between the full and the new moon.

4. For sampling, divers inspected each shelter once a month and count the number of juvenile lobsters in the shelter. Lobsters were measured using a measuring stick.

5. Lobsters found on the shelters were left in place.

6. Surveys were clean during each visit and octopuses were removed as possible.

RESULTS

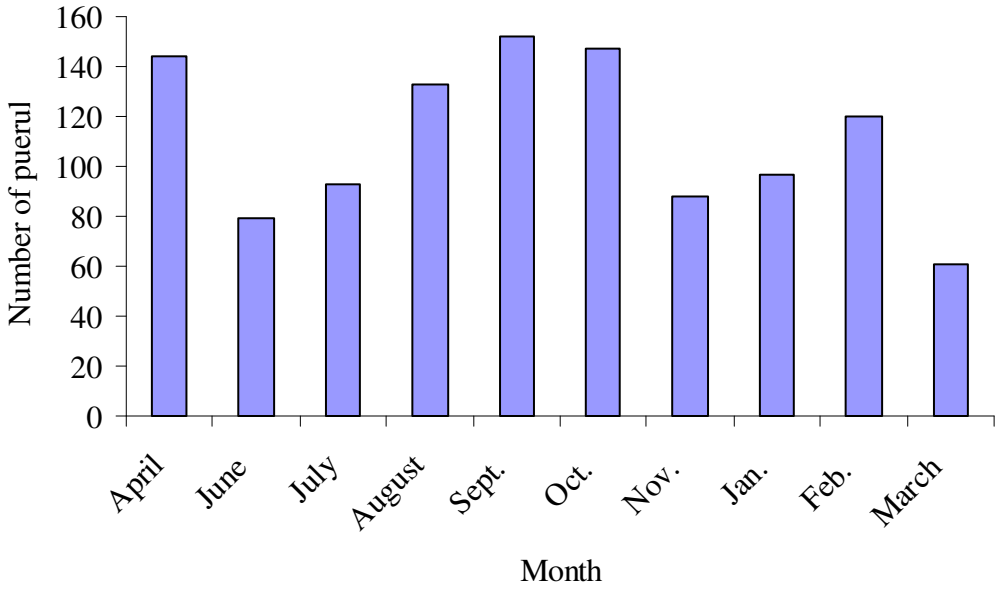
Study 1- Pueruli settlement

Stations were sampled monthly from April 18 2008 to March 10 2009. Gaps on data collection were due to collector lost or bad weather. Total number of pueruli found on any particular station ranged from 0 to 103. Table 3 summarizes the data for each station per month (Graph 1). No statistical difference was found, using ANOVA, comparison of means and variance check, on total number of pueruli and juveniles sampled through the year.

Table 3. Total number of pueruli and juveniles at each collector station

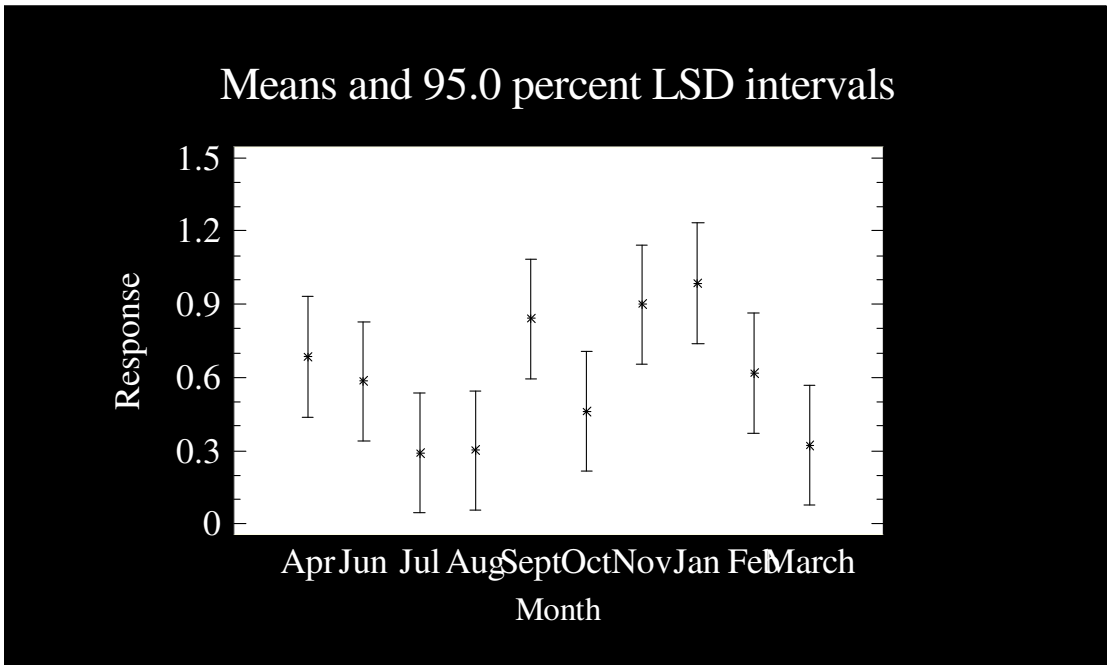
	April	June	July	August	Sept.	Oct.	Nov.	Jan.	Feb.	March	Total
A	9	0	3	6	7	4	3	10	0	0	42
B	3	5	1	6	3	0	4	17	3	0	42
C	18	15	5	2	9	0	12	17	11	46	135
D	0	6	15	22	17	40	6	13	37	0	156
E	26	8	35	51	48	103	47	28	52	3	401
F	56	28	19	22	45	0	8	8	17	12	215
G	32	17	15	24	23	0	8	4	0	0	123
Total	**144**	**79**	**93**	**133**	**152**	**147**	**88**	**97**	**120**	**61**	**1,114**

Graph 1. Total number of pueruli collected per month.

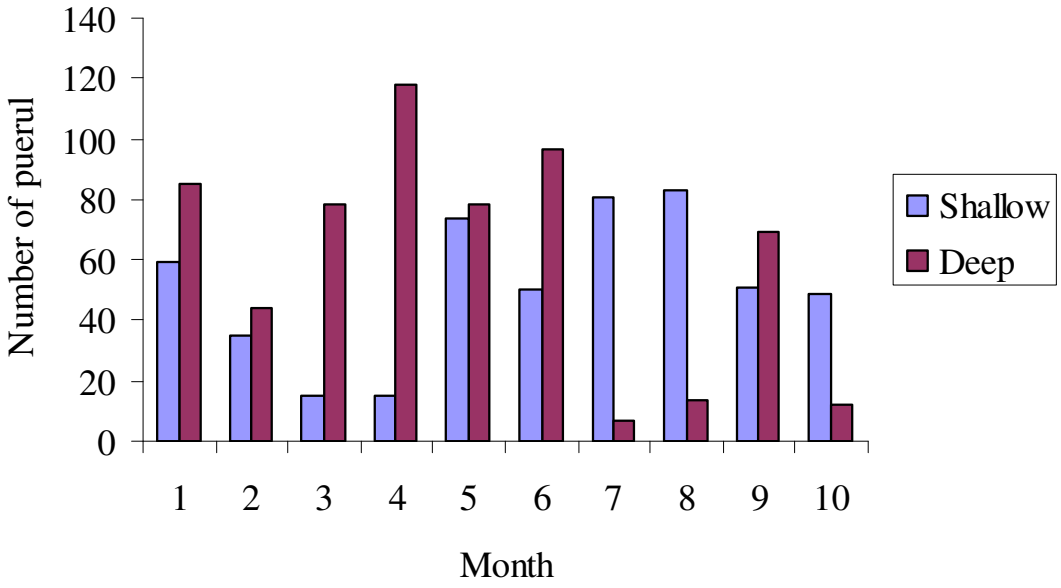


There were significant differences on overall monthly reports for shallow spiny lobsters collectors. September and January were the months in which greater amounts of pueruli were observed in the shallow collectors. Graph 2 shows the mean analysis for monthly total reports on shallow spiny lobster collectors. For this analysis the data was log transformed. No significant difference was found for overall monthly reports of deeper spiny lobster collectors. No significant difference was found between the number of juveniles and pueruli observed in shallow versus deep collectors over the year (Graph 3).

Graph 2. Mean analysis for total monthly spiny lobster juveniles and pueruli capture on shallow collectors.

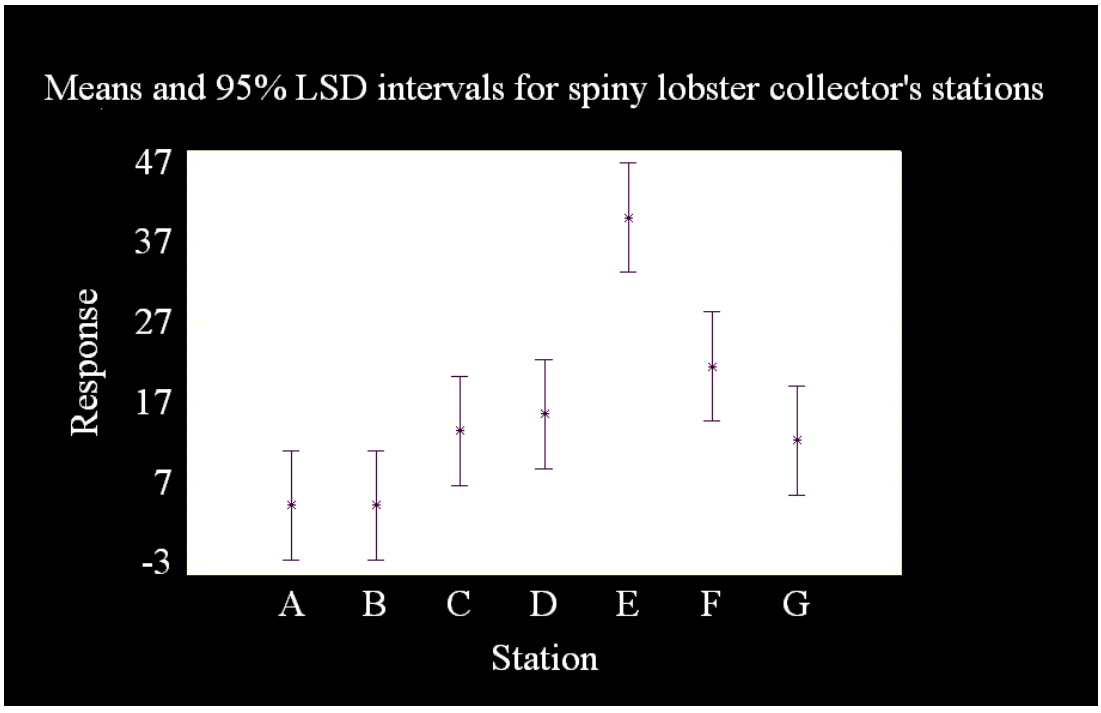


Graph 3. Comparison of pueruli and juveniles spiny lobster sampled at shallow and deep collectors.



There were significant differences between stations on the amount of total pueruli and juveniles observed. Station E reported the major amount of pueruli followed by F, D, C, G, B and A. Graph 4 shows the mean analysis for the amount of pueruli and juveniles reported monthly for each collector's station.

Graph 4. Mean analysis of monthly captured juveniles and pueruli at the spiny lobster collector's stations.

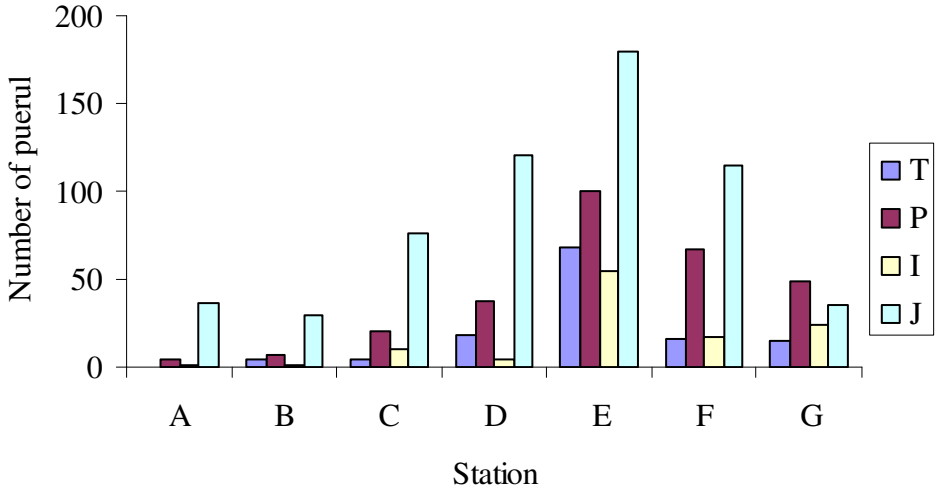


The most often found stage in the collectors were juveniles (703), followed by the pigmented stage (286) and the transparent stage (125). The puerulus stages (transparent and pigmented) were more often found on the deep collectors. Juvenile stages were more often found on the shallow collectors. Table 4 summarizes overall data for puerulus stages and juveniles found in shallow and deep collectors. Patterns of abundance of the different stages followed the same pattern observed for overall abundance by station (Graph 5.).

Table 4. Obtained results of total sampled larvae, transparent, pigmented and juvenile stages, found in deep and shallow water collectors.

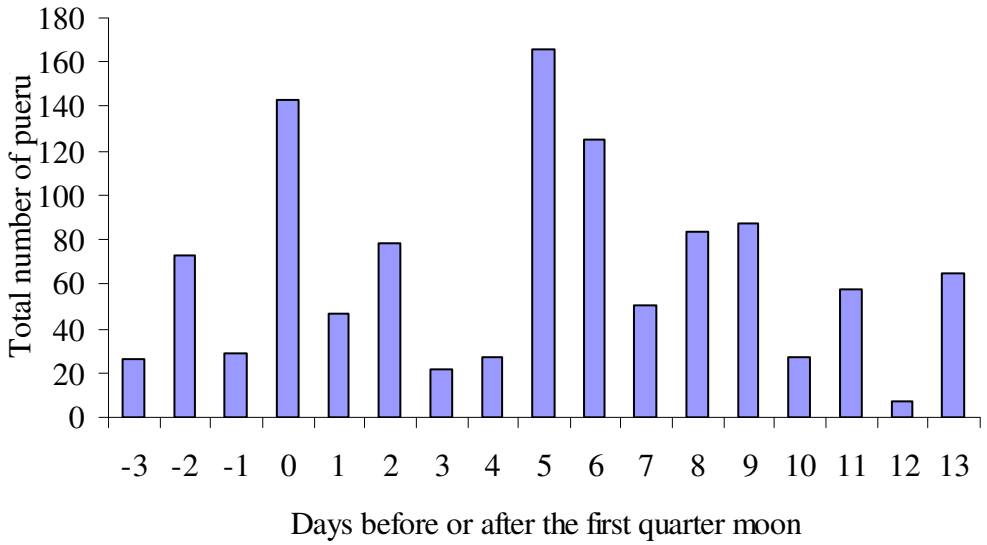
	Transparent	Pigmented	Juvenile
Deep	105	200	297
Shallow	20	86	406

Graph 5. Number of different spiny lobster developmental stages by station.

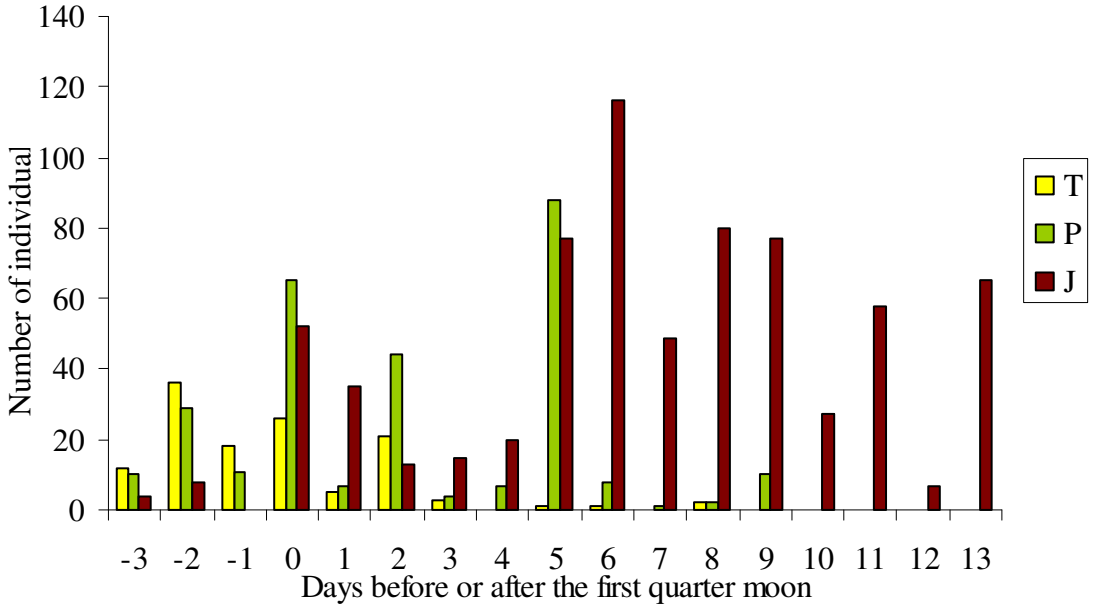


There is a relation between moon phase and total number of pueruli and juveniles settlement. The major abundance of pueruli and juveniles was observed during the first quarter and five days after the first quarter (almost full moon). There was significant differences between the quantity of juveniles and pueruli observed during those days and those observed close to the third quarter (Graph 6). Transparent pueruli were observed mainly around the first quarter and towards the new moon (Graph 7). Pigmented pueruli followed the pattern observed for general collector catch (Graph 6 and 7). Juveniles were observed in greater abundance between the full moon and the third quarter (Graph 7).

Graph 6. Relationship between pueruli and juveniles' settlement and moon phase.



Graph 7. Distribution of observed developmental spiny lobster stages in relation to the moon phase.



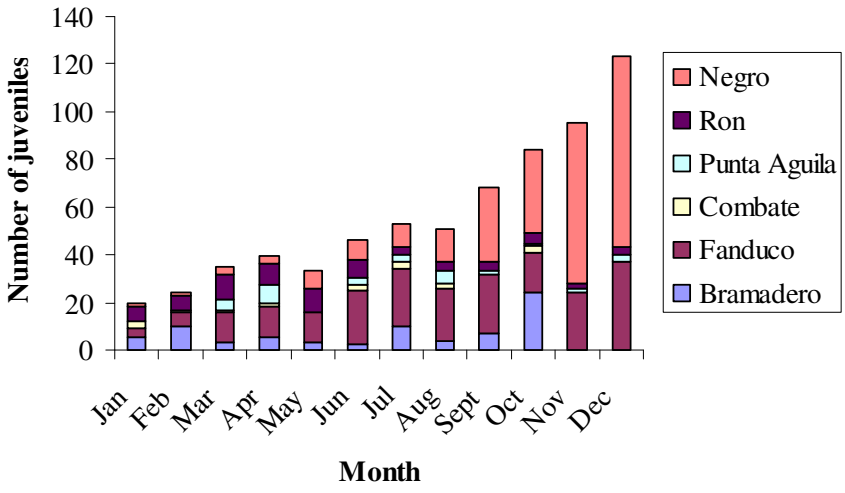
Study 2- Artificial shelters for juvenile lobsters

Stations were sampled monthly from January, 2008 to December, 2008. Gaps on data collection were due to water turbidity which in various occasion made impossible the evaluation of the artificial shelters. Total number of juveniles found in a station ranged from 0 to 80. Table 5 summarizes the data for each station per month. As a visual aid the data is presented in Graph 8, showing the increment over the time on overall number of juveniles observed. Three stations: El Negro, Fanduco and Bramadero were responsible for the increment of sampled juveniles.

Table 5. Total number of juveniles observed at the artificial shelters by month.

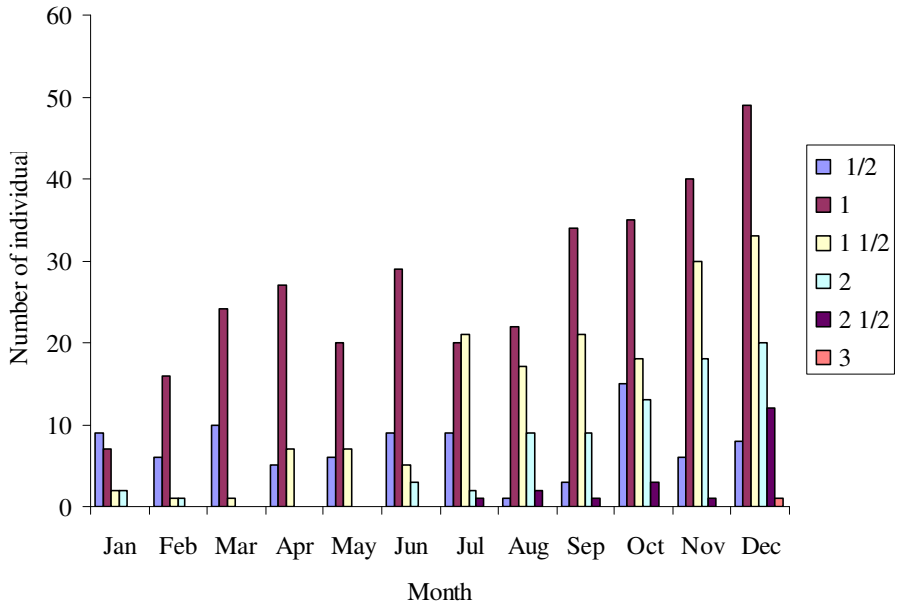
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Bramadero	5	10	3	5	3	2	10	4	7	24	NS	NS
Fanduco	4	6	13	13	13	23	24	22	25	17	24	37
Combate	3	1	1	2	NS	2	3	2	0	3	0	0
Pta. Aguila	0	0	4	7	NS	3	3	5	1	1	2	3
Ron	6	6	11	9	10	8	3	4	4	4	2	3
Negro	2	1	3	3	7	8	10	14	31	35	67	80
Total	**20**	**24**	**35**	**39**	**33**	**46**	**53**	**51**	**68**	**84**	**95**	**123**

Graph 8. Total number of juveniles observed at the artificial shelters by month.



The size of juveniles found at the artificial shelters ranged from 0.5 inches to three inches. Graph 9 shows the total number of juveniles by size category.

Graph 9. Total of juveniles by size category per month



Octopuses were removed, as possible, whenever found at the artificial shelters. Table 6 summarizes the number of octopus found at each artificial shelter station, including those that were removed.

Table 6. Number of octopus observed at the artificial shelters.

Month	Pta. Aguila	El Negro	El Ron	Fanduco	Bramadero	Combate	Total
Jan	0	4	2	9	1	2	18
Feb	0	2	1	14	1	3	21
Mar	0	1	0	10	4	1	16
Apr	0	2	0	2	0	2	6
May	0	1	0	0	0	0	1
Jun	0	0	0	0	1	2	3
Jul	0	0	0	0	0	1	1
Aug							0
Sep			1	2	2	2	7
Oct	1		1	1			3
Nov	1	4		4		2	11

Month	Pta. Aguila	El Negro	El Ron	Fanduco	Bramadero	Combate	Total
Dec	1	3		3		1	8
Total	3	17	5	45	9	16	95

DISCUSSION

Peaks on spiny lobster recruitments have been reported occurring at different times of the year. Calinski (1981) reports that September, December and May yielded the largest number of recruits maybe associated to wind and water currents, during the new moon, in Grenada, West Indies. In Florida, recruitment peaks during spring, summer and autumn (Lyons, 1980). Others report peaks during March (Phillips, 2000). During this study, sampling could not be conducted during May and December. Previous studies in the area report greater recruitment between August and October (Rosario and Figuerola, 2004). Looking roughly at the collector's data, the largest number of recruits was observed during September-October and April. Notwithstanding, the difference between the amounts observed each month during the year was not statistically significant.

The length of the post-larval period of spiny lobster is unaffected by chemical or structural cues from the settlement habitat, but depends on temperature (Phillips, 2000). This could be a determining factor in recruitments patterns. Higher temperatures could induce metamorphoses and thus recruitment. Unfortunately, temperature was not a variable measured for this study, although an analysis could be attempt looking at available information on water temperature either from other studies or satellite images.

Studies using floating and benthic collectors found no difference between them (Phillips, 2000). Our study used the collectors in another way, in the water column at 30-40 feet and above the sea floor at 60-80 feet. A difference was detected between them. Contrary to the overall recruitment data, shallow collectors show statistically? significant peaks during the year in September and January.

The spiny lobster larval stage metamorphoses into puerulus after 6 to 24 months depending on food availability and nutrition, and it then cues the coastline and swim towards it (Phillips, 2000). According to other studies, this is done swimming in the surface or close to it, during the new moon. On the contrary, this study found more pueruli on the deep collectors than on the shallow ones.

The arrival of pueruli has been tied to the lunar cycle, peaking at or just after new moon (Acosta et al., 1997; Phillips, 2000). It is speculated this is to reduce risk of predation (Phillips, 2000). The relation with the moon cycle observed in this study is slightly off the expected. The peak was observed around the first quarter and towards the full moon (five days after the first quarter). A gap of information during the period between the new moon and the first quarter prevent any conclusion for that period. Despite, it is noticeable the amount of recruitment observed close to the full moon,

especially for juveniles. The peak towards the new moon was observed for the transparent stage maybe suggesting greater predation pressure.

The stability effect (Jimenez, 2004) is likely to be the reason for which an almost constant increment on juvenile recruits was observed in the artificial shelters. In addition, the recruits were not removed, and judging for the addition of individuals in the different size categories with time (Graph 9), the recruits were using the artificial shelters as their habitat. Spiny lobster greater than 15mm (0.6 inches) carapace length secrete chemicals that attract conspecifics (Phillips, 2000), thus concentrating them.

Recruitment of juveniles has been correlated to the supply of post larvae (Forcucci et al., 1994). The difference between stations observed for collectors and artificial shelters seems to support that finding. Station E, D and F yielded greater number of recruits, and are in the vicinity of El Negro, which was the artificial shelter station that yielded the greatest number of juveniles. The same could be remarked for station C and G and Fanduco. El Ron is a station in which a greater number of recruits could be expected, but its proximity to a coral reef might have prevented it. Chemoreception helps den-seeking individuals locate their shelters, and it has been suggested that they avoid the reef (Phillips, 2000).

Knowing that spiny lobster larvae have a lengthy planktonic stage, water currents play an important roll in their distribution and dispersal. The data presented here should be analyzed with available information on water currents in the insular western platform. Origin of the spiny lobster larvae in Puerto Rico is still uncertain. Some argue that the exchange of post-larvae occurs at smaller scales, like between St. Thomas and Jamaica, not likely to be Pan-Caribe (Menzies, 1980). Others support that it occurs at a greater scale, like Florida receiving larvae from the western Caribbean or the north region of South America (Lyons, 1980). Evidently genetic studies should be supported and international management to preserve spiny lobster stocks in the Wider Caribbean should be encouraged (Lyon, 1986).

In Florida the spiny lobster usually settles in clumps of the red macroalga *Laurencia* spp (Phillips, 2000). In other areas the reported settlement habitats are so broad that it suggests it is opportunistic (Phillips, 2000). The artificial shelters placed in this study were in seagrass beds. In 2004 (Jimenez) settlement was recorded in the stations placed in seagrass beds and none at coral reef stations. Settlement habitats must be identified and protected to assure spiny lobster fishery productivity (Marx, 1986).

Spiny lobster allegedly avoid octopus by chemoreception (Phillips, 2000). Notwithstanding, we observed octopus sharing the artificial shelters with the spiny lobster quite often, at close proximity. Since we only registered the presence of octopus, it is uncertain if the chemoreception reaction is mediated by size of both, the lobster and the octopus, with maybe a distance range as a variable. Octopuses were more abundant from January to March, which is not related to recruitment abundance.

Cannibalisms, disease, predation, lack of shelter or food are the primary cause of death of juveniles (Phillips, 2000). They settle randomly and remain solitary as early benthic juveniles (Phillips, 2000). At this stage they do not venture far from the settling area (Phillips, 2000). Abundance could be limited by shelter availability presumably through predation (Phillips, 2000) or recruitment supply. In the study area shelter seem not to be the lacking resource as there were shelters with significantly less recruits within a station.

As suggested by Ting (1975), studies on pueruli and post-larvae stages of the spiny lobster should be conducted for a period of two years, jointly with surface and deep currents on nearshore and offshore waters to determine origin and flux patterns.

The adult stage of the spiny lobster is not included in this study. Although surveys could be an option to study them, it might not be cost effective, and will then be done every couple of years. On the other hand, information could be obtained from the fisheries statistics. If more detail information is requested to determine catch per unit effort, we will be able to observe trends. Right now a decrease is observed in landings, but many variables could affect that information.

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