Patterns of Settlement of Spiny Lobster (*Panulirus argus*) Post Larvae at Bermuda

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ABSTRACT

En años recientes el seguimiento y estudio de los asentamientos de etapas post-larvales de la langosta como herramienta para entender los patrones de reclutamiento y sus efectos subsiguientes en los desembarcos de pesca han generado un interés considerable. La esperanza de muchos administradores pesqueros es que ésta técnica pueda ser usada para predecir tendencias en las capturas. Para que esto se convierta en realidad se necesita un entendimiento cabal de los patrones en tiempo y espacio de los asentamientos anuales de las etapas post-larvales. La estacionalidad de estos asentamientos requiere además que para identificar el número de los grupos contemporáneos que comprenden cada clase-año, es esencial que se tenga a mano información sobre la distribución de largos basado en técnicas de avalúo de poblaciones de esta especie. La identificación de áreas con mayor número de asentamientos es útil en el trazado de mapas que indiquen la sensitividad del ambiente a éstos asentamientos y para establecer programas de mejoramiento de habitat, encaminados a aumentar el éxito en los reclutamientos.

Utilizando los habitats "Whitham", se llevaron a cabo estudios de seguimiento en los patrones de asentamiento en las aguas cercanas a las costas de Bermuda durante el tiempo comprendido entre agosto de 1983 hasta octubre de 1986. Se escogieron sitios para poner estos colectores en un intento por determinar las agregaciones de asentamiento alrededor de la isla.

Se encontró que el asentamiento en Bermuda es tanto estacional como por grupos (patchi) con un auge en dichos asentamientos durante la última parte del verano (de julio a septiembre) y la mayoría de las etapas post-larvales coleccionadas ocurrieron en una sola estación (79% de las cinco estaciones iniciales).

El tiempo de mayor auge en asentamiento durante agosto-septiembre de 1983, fue mucho mayor que en los años 1984 y 1985, ésto pudo haber sido como resultado de remolinos provenientes de la corriente del Golfo que se acercaron a la isla durante agosto de 1983.

La periocidad lunar fue observada en relación a dichos asentamientos y se encontró que los mismos aumentaban durante el tiempo de luna nueva y cuarto creciente.

INTRODUCTION

Management of spiny lobsters, *Panulirus argus*, at Bermuda utilizes several classical tactics: closed spawning season, minimum size limit, protection of egg bearing females, as well as the limiting of entry to the trap fishery. These approaches are largely directed towards ensuring adequate larval

production to replenish the harvested stock. For such management to be effective on a local basis some larval retention mechanism, acting over the entire larval duration, is necessary. The present study is part of an integrated larval (Farmer *et al.*, 1989) and post-larval investigation aimed at determining whether Bermuda's spiny lobster stock can be managed in isolation.

The concept of forecasting recruitment to the fishery, based on the level of puerulus settlement, is an attractive option which has proven to be useful in the Western Australian *P. cygnus* fishery (Phillips, 1986). Work by Chittleborough and Phillips (1975) showed that density dependent mortality on post settlement stages tended to damp out the effects of any exceptionally high recruitment of pueruli. They concluded that the predictive value of puerulus settlement patterns was limited to the identification of poor year classes and the subsequent poor success of the fishery. High settlement levels would be reduced by natural mortality to an equilibrium carrying capacity. Morgan *et al.* (1982), with the benefit of a longer time series, found that there was, in fact, a good relationship between settlement levels and recruitment to the fishery. As this relationship is asymptotic in nature, at very high settlement levels the effect is obscured. The present paper reports on the first three years of an ongoing monitoring programme which will be used to determine whether a similar predictive index may be developed at Bermuda.

The seasonal and lunar nature of the recruitment of pueruli of several Panulirus species at widely distributed sites has been reported. Phillips (1977) observed that both P. interruptus and *P. cygnus* pueruli display peak settlement during spring and summer. Year round settlement of *P. argus* occurs in Florida, peaks are found in spring and fall (Little, 1977 ; Little and Milano, 1980). Peacock (1974) found year round settlement of *P. argus* with peaks in spring and late summer at Antigua. The seasonality of settlement of *P. marginatus* at widely spaced sites throughout the Hawaiian Archipelago was found to vary greatly (MacDonald, 1986). Stations at opposite ends of the archipelago displayed strong seasonality with peaks observed at reciprocal times of the year. Central stations yielded irregular settlement throughout the year. These differences were attributed to seasonal changes in the large scale current patterns of the region. Regional differences in the seasonality of puerulus recruitment may occur within species as the result of hydrographic or other environmental factors. Due to the isolated nature of Bermuda and its peripheral position in the range of *P. argus*, the study of puerulus recruitment here may help in identifying some of the factors responsible. Correlation of settlement peaks with Gulf Stream eddies impinging on Bermuda may clarify the effects such hydrographic events have on local lobster recruitment.

The general lunar pattern of settlement found throughout the genus is one of maximum levels occurring during the first half of the lunar cycle (Little, 1977; Little and Milano, 1980; MacDonald, 1986; Phillips, 1977). The present study examines the effect of lunar state on puerulus settlement.

An understanding of recruitment patterns is valuable for aging small animals and for identifying the number of cohorts in a given year class. Both seasonal and spatial settlement patterns are useful for environmental sensitivity mapping as they are for the selection of sites for environmental enhancemen programmes aimed at increasing recruitment success.

METHODOLOGY

In August of 1983, five stations were selected throughout Bermuda (Figure 1). Five additional stations were selected in July 1984. In response to the higher settlement rates observed there (Figure 2), most of these were sited on the northern side of the island. One modified Witham Habitat collector (Little and Milano, 1980) was moored at each station. These were made of a floated piece of plywood 0.5 m on the side to which were hung eight equally spaced, 50 cm by 36 cm panels of 3M Nomad™ material folded in half at right angles to the long axis to produce 16 "leaves". Moorings were of 75-100 kg scrap steel fastened with 7 mm galvanized chain to a 12 mm polypropylene anchor line. The initial sampling procedure required the deployment of a square framed mesh bag around the collector prior to hauling in order to catch any pueruli that might be dislodged. This was discontinued as it proved impractical in heavy weather and it was discovered that losses were negligible if the collectors were hauled in a fashion such that the fabric "leaves" collapse on each other quickly.

Sampling was initially conducted twice weekly. This was modified in late October 1983 when declining catch rates made such frequent haulings non-productive. This weekly schedule has been continued to the present. All pueruli were removed from collectors and relocated at sites at least 1 km from all stations.

Each sample represented the recruitment to the collector over a one week period. For analytical purposes the sample was considered to have been taken at the mid-point of the soak period. When considering lunar effects the moon phase at this mid-point was used.

The measure of catch per unit effort (CPUE) used is catch per collector day, where the catch of a collector is divided by the number of days since the last sample was taken. All results are presented in this form to standardize for any differences in duration of the sample period.

For analysis of seasonal and lunar cycles, all stations were pooled and an average CPUE determined. To illustrate the effect of moon phaseall samples were further pooled by lunar date (0-27).

RESULTS

The data show clear seasonality in settlement with peaks in late summer and virtually no mid-winter recruitment (Figure 3). Annual settlement levels vary year to year with that of 1983 being much higher than that of subsequent years. This peak settlement was coincident with the occurrence of a Gulf Stream eddy in the Bermuda area.

Superimposed on the annual cycle of recruitment is a clear pattern of lunar cycles (Figure 4). Peak levels are observed in the period from new to full moon with little settlement occurring around the time of third quarter.

Consistent, large differences in settlement levels occur between stations. The most productive sites were Whalebone Bay and Flatts Inlet, both of which are located on the northeast shoreline (Figures 2 & 5). South shore stations were poor producers during the period over which they were sampled.

DISCUSSION

Bermuda may be considered as a point source of larval input to an oceanic pool of phyllosoma larvae of *Panulirus argus*. Studies of the

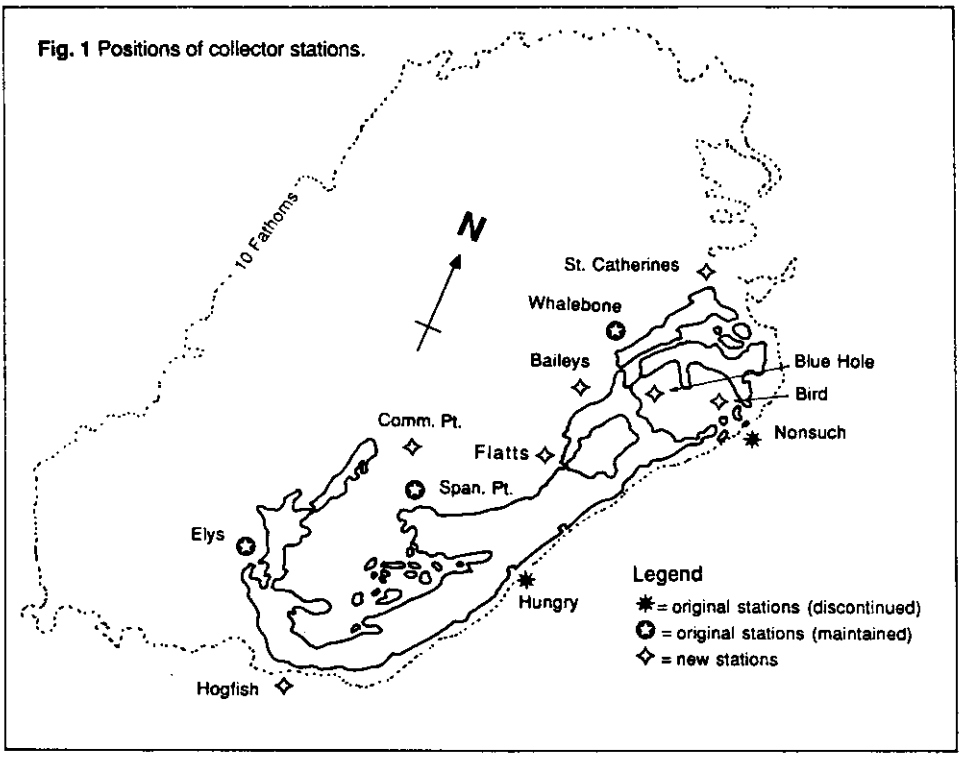


Fig. 1 Positions of collector stations.

Fig. 2 Distribution of settlement original five stations. Aug '83 - Apr ' 85

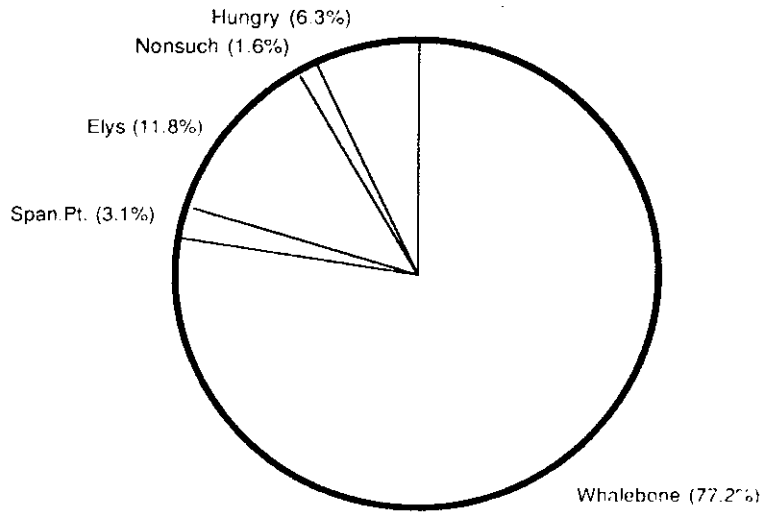


Fig. 3

Seasonality of Puerulus

settlement all stations, 1983-86

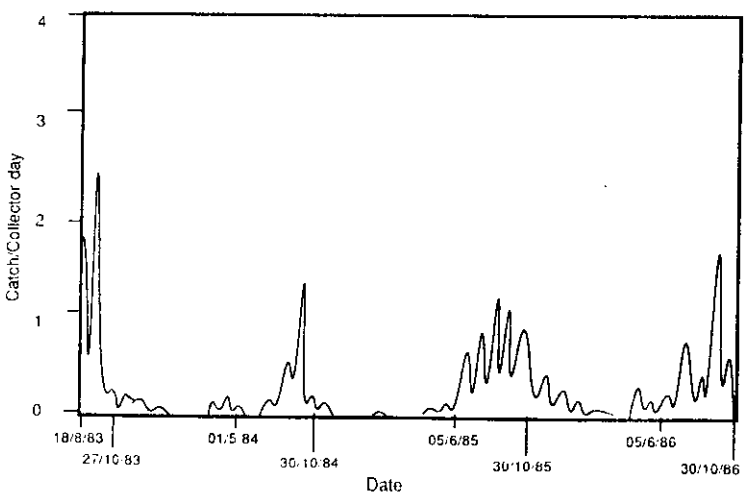
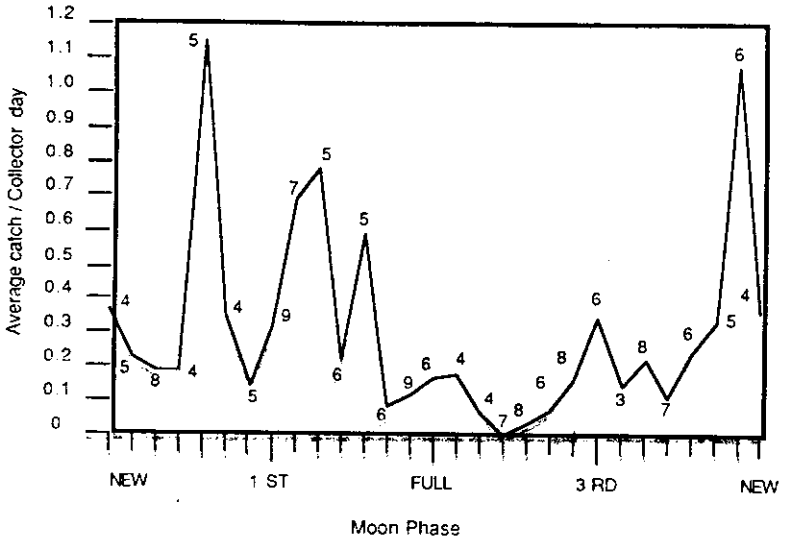
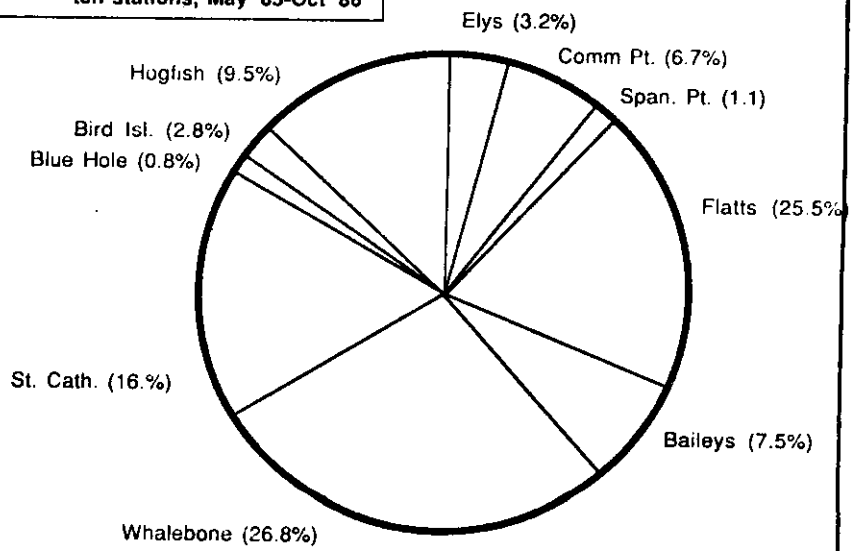


Fig. 4
Average Lunar Cycle of Puerulus
Settlement. All Stations, 1983-85



NOTE: Data lables indicate number of samples taken on the corresponding lunar date

Fig.5 Distribution of settlement ten stations, May '85-Oct '86



seasonality of these larvae at Bermuda (Farmer *et al.*, 1985) have failed to demonstrate larval retention. However it does appear as though local larvae may dominate in the plankton (Farmer *et al.*, 1989). Given the extended nature of the phyllosoma phase and the fact that Bermuda is downstream of the Caribbean region it seems likely that Bermuda shares this oceanic pool of larvae with other countries. Furthermore, the year round presence of mid to late stage larvae in the Bermuda area (Sutcliffe, unpub. data; Farmer *et al.*, 1989) supports the concept of multiple points of origin whilst suggesting that the seasonality of settlement observed during this study may be as much a function of environmental factors as that of late stage larval abundance. Bermuda's annual range of oceanic water temperature is approximately 18-28° C, far greater than that of most of the range of the species. The bulk of recruitment at Bermuda occurs from June through October when the local temperature is within the annual range of the Caribbean region (24—30° C, NOAA oceanographic analysis charts). The seasonality of recruitment recorded during this study (Figure 3) is far more pronounced than that recorded in Florida by Little and Milano (1980). Although Florida's annual range of inshorewater temperature (Little, 1977) is similar to that of Bermuda's oceanic waters, the offshore waters of the Florida area are buffered by the Gulf Stream. The puerulus stage is apparently well suited to sustained swimming over considerable distances (Phillips and McWilliam, 1986) and serves as the transition link between oceanic larvae and coastal-dwelling juveniles (Lyons, 1980). Studies of the pueruli of *P. cygnus* have demonstrated that they swim 40—60 km across the shelf prior to settling in the shallow coastal reefs (Phillips *et al.*, 1978; Phillips, 1981). If thermal effects on the metamorphosis to this stage exist, the oceanic rather than coastal temperature would be of importance. The cooler oceanic waters around Bermuda in winter may act to inhibit this metamorphosis; however, more sampling of the late stage phyllosoma larvae would be necessary to accurately assess the seasonality of this stage in order to test this hypothesis.

The relationship between average CPUE and lunar phase is shown in Figure 4. As has been found elsewhere (Little, 1977; Phillips, 1977; Little and Milano, 1980; MacDonald, 1986) peak recruitment occurs during the first half of the lunar cycle. Phillips (1975) found that postlarvae cease to settle on collectors when moonlight intensity rises above 10% full moonlight. In the present study, settlement was recorded from the time of full moon and a time lag between the time of maximum lunar illumination and that of minimum settlement was found. Assuming that light is the main lunar cue perceived by lobsters, the time lag between the period of maximum lunar illumination and that of minimum settlement may be of significance. As recruitment was regularly observed during the period of full moon it appears as though the pueruli are active despite elevated light levels. This may be a reflection of the puerulus stage being poorly suited to extended pelagic life and being highly vulnerable until the safety of the benthic inshore habitat is reached. As the present study reports on the results obtained from a weekly sampling programme, some of the observations may be as much a reflection of the sampling regime as of the lunar effect. To refine statements on the effect of lunar phase a shorter sampling period is needed.

The data show that certain stations regularly receive more recruits than others (Figures 2 & 5). The fact that the majority of the settlement was recorded

from the northeast coastline may be largely due to localized environmental factors and the current structure of the area. Oceanic waters flood around the eastern tip of the island mass into this area (personal observation). Little (1977) and Little and Milano (1980) found that collectors deployed in channels received fewer recruits than did those set in less fast moving waters adjacent to the channels. Although few data on currents around Bermuda exist, 3 years of personal observations of flow at the stations sampled during this study provide a basis for general comments. At none of the original 5 stations sampled were strong currents observed. Of the additional stations, those at St. Catherine's and Hogfish commonly exhibit strong currents whilst Commissioner's Point and Bird Island are sites of moderate flow. The two most productive stations were those at Whalebone Bay and Flatts Inlet. Although perceptible currents are rare at both these stations they are adjacent to major channels through which large volumes of water pass (Figure 1). The next two productive stations were in areas of high flow at the ends of the land mass. Nested midway between the Flatts and Whalebone sites is Bailey's Bay where only moderate settlement rates were recorded. This is supportive of the idea that areas proximal to major channels where modest but continual flow occurs may receive the most recruitment. It is logical that some flow will increase settlement to a site and that there exists an optimum rate above which settlement is reduced.

Large or meso-scale oceanographic events can affect phyllosoma distribution (Phillips and Sastry, 1980) and are correlated with puerulus recruitment rates (Phillips and Pearce, 1985). Gulf Stream eddies may exert such effects at Bermuda. Eddies may entrain larvae and transport them from the Gulf Stream to the Bermuda area. Evidence of this occurring comes from the peak of settlement observed in August of 1983. This peak coincided with the presence of a Gulf Stream eddy in the Bermuda area (NOAA oceanographic analysis charts, 1983). This eddy is the suspected vector for the transportation of the pathogen of the long-spine sea urchin Diadema antillarum to Bermuda. The mass mortality of this species was observed to progress through the Caribbean Sea following the prevailing currents and was first observed in Bermuda's waters in August of 1983 (Lessios *et al.*, 1984). Gulf Stream eddies impinging on Bermuda during the winter when local conditions appear to be unfavourable towards recruitment are less likely to stimulate settlement than are those which occur in the summer.

SUMMARY

Seasonality of puerulus settlement at Bermuda is more pronounced than in Florida. Low settlement observed during the winter months may be related to the relatively low sea water temperature of the Bermuda area. Most of the recruitment at Bermuda occurs during the period when local sea water temperature exceeds 24° C. Lunar periodicity in recruitment to Bermuda is marked and follows the pattern recorded for spiny lobsters throughout the world. The majority of settlement occurs during the first half of the lunar cycle. Consistent, large scale differences in settlement levels occur between collector stations with the majority of the recruits being observed along the northeast coastline. The two most productive stations are adjacent to channels which feed large inshore basins. The largest peak in settlement occurred in August 1983 during which time a Gulf Stream eddy impinged on Bermuda. It

appears as though such eddies may transport larvae of foreign origin to the Bermuda area.

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