Factors Regulating Population Size in the Caribbean Spiny Lobster, *Panulirus argus*, and Sustainable Resource Use With Artificial Shelters

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INTRODUCTION

The Caribbean spiny lobster, *Panulirus argus* (Latreille), is experiencing increased fishing pressure and regional overexploitation due to greater demand from the United States and Caribbean nations, higher market value, and an expanding fishing fleet (U.S. Agency for International Development, 1987). Moreover, reductions in spiny lobster landings have occurred without significant increases in fishing effort (Miller, 1989). Hence, the use of artificial habitats such as "casitas Cubanas" (Figure 1) to alleviate the impacts of overfishing and possibly enhance local stocks of spiny lobster is an appealing proposition. Interest in the application of this technology is steadily increasing throughout the Caribbean. For example, the use of casitas to concentrate and possibly enhance spiny lobster populations originated in Cuba over two decades ago, where there are well over 200,000 casitas in use (Cruz *et al.*, 1986). In the late 1960s or early 1970s, this technology was inaugurated in the Mexican Caribbean off the Yucatan Peninsula, and presently supports several fisheries, with over 75,000 casitas in use (Miller, 1989). In the Bahamas over the past two to three years, casita use has expanded dramatically, with conservative estimates yielding over 200,000 casitas in the northern Bahamas alone. The sudden adoption of this unconventional mode of fishing based on artificial shelters portends an unprecedented change in the character of the Caribbean spiny lobster fishery. This transformation can lead either to long-term sustainable resource use of one of the most valuable fisheries in the Caribbean, or to a decline and eventual collapse of the fishery, with far-reaching consequences for all Caribbean nations.

Sustainable resource use of commercially important species requires a thorough understanding of the patterns, processes and factors regulating

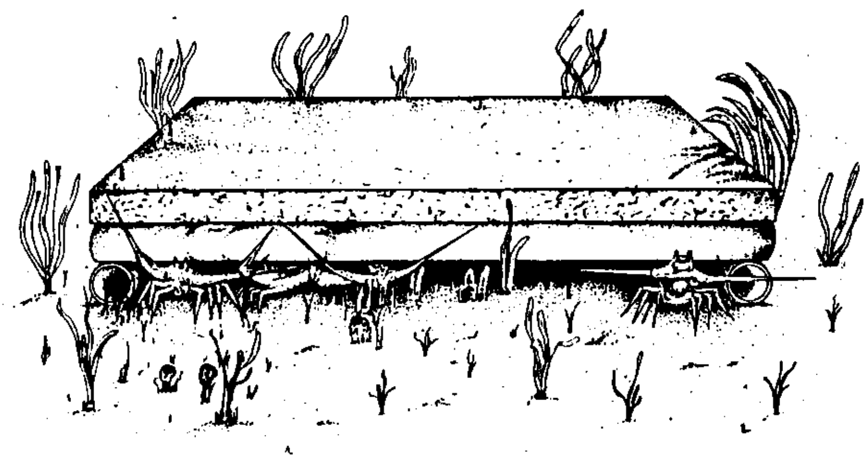

Figure 1. A large casita (artificial lobster shelter) constructed with a frame of PVC-pipe and roof of cement (177 cm length X 118 cm width X 6 cm height of opening).

population variability. Recent studies have stressed the importance of recruitment processes on the population dynamics of marine species, particularly that of planktonic larval or postlarval supply, settlement rates in suitable habitats, and post-settlement movements and mortality rates (Gaines and Roughgarden, 1985; Underwood and Fairweather, 1989). The underlying rationale for stock enhancement with artificial shelters is the production hypothesis (sensu Bohnsack, 1989): that artificial reefs provide critical shelter which increases the environmental carrying capacity and eventually the abundance and biomass of lobsters.

In this progress report, we compare and contrast the results from a series of field shelter enhancement experiments performed simultaneously in Florida Bay and the central Bahamas. We also quantified spiny lobster postlarval influx and settlement substrate availability in both geographic locations to identify factors other than shelter, which could be limiting population size. Our results suggest that for a casita-based fishery to be sustainable, not only must sensible management practices such as a closed-access fishery be applied (Miller, 1989), but casitas must be located in habitats with adequate postlarval supply and settlement substrate availability.

METHODS AND RESULTS

In 1990, we initiated field experiments in both the Florida Keys and Bahamas that directly tested if shelter was limiting the local population size of *P. argus*. The experimental design involved placement of casitas in replicate locations (Figures 2a and 2b), each with three randomly selected sites: one control site without casitas, one site with eight casitas, and one site with sixteen casitas (Figure 3). Spiny lobster abundance increased significantly over twelve months in replicate experimental sites augmented with eight or sixteen casitas within Florida Bay seagrass meadows, but not in control sites; up to 264 spiny lobsters were collected from a single artificial habitat (Figure 4). Moreover, the casitas provided shelter for nearly the full size range of juvenile and adult spiny lobsters, ranging from 17-114 mm in carapace length. Independent quantitative data on spiny lobster feeding in experimental and control sites confirmed that there were adequate amounts of food to support nearly 1000 lobsters per hectare (Figure 5). Thus, populations of Caribbean spiny lobster within the vicinity of our sites in Florida Bay appear to be limited by shelter for juveniles, rather than by food, or postlarval supply and settlement substrate availability.

The majority of spiny lobsters using casitas in the Bahamas were located at only one of four experimental sites (Figure 6). Moreover, the number of lobsters residing beneath casitas in Florida Bay was an order of magnitude higher than in the Bahamas (compare Figures 4 and 6). We hypothesized that differences in the number of spiny lobsters between our experimental sites in the Bahamas and Florida Bay were due either to (1) higher postlarval influx into Florida Bay, or

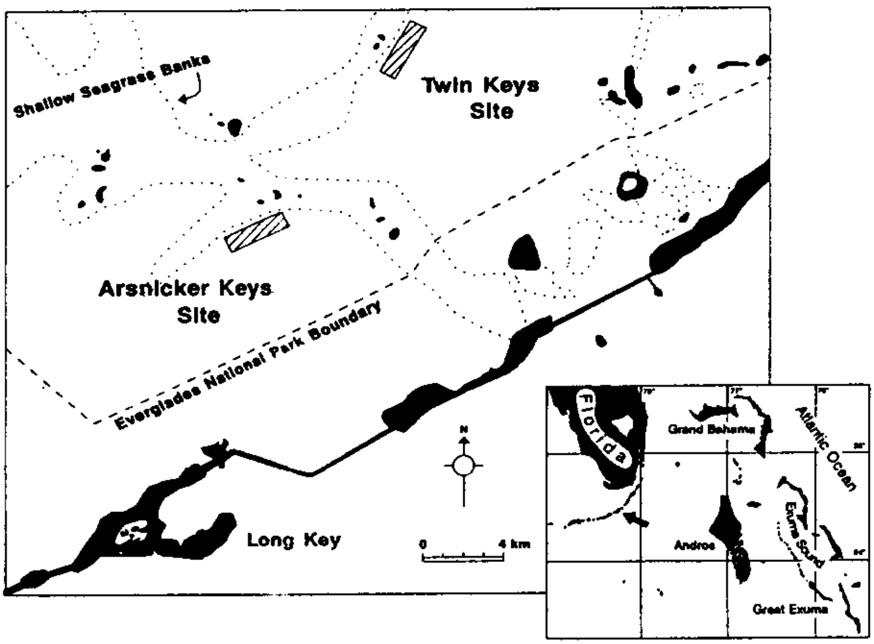

Figure 2a. Study sites in Florida Bay, USA.

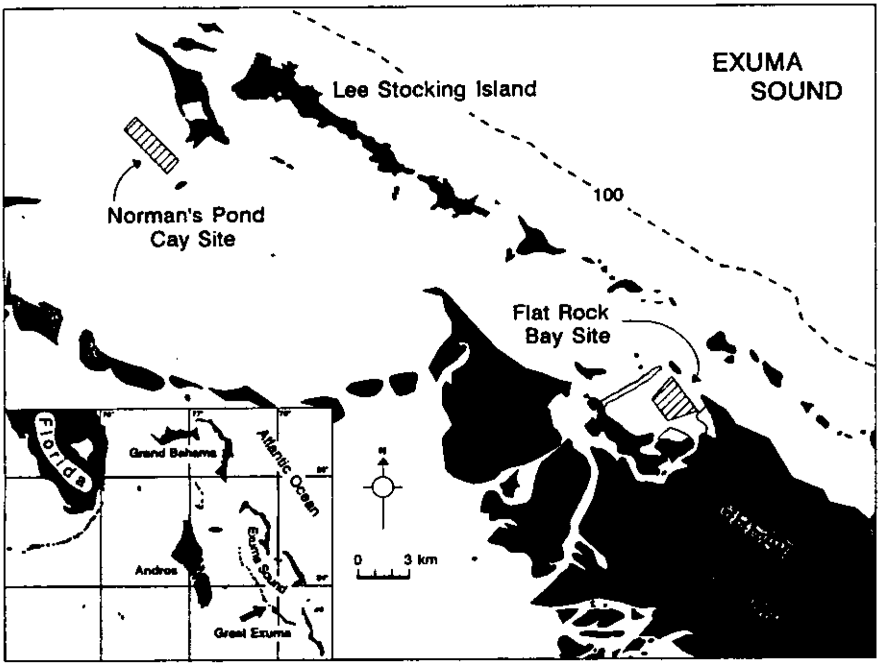

Figure 2b. Study sites in the Exuma Cays, Bahamas.

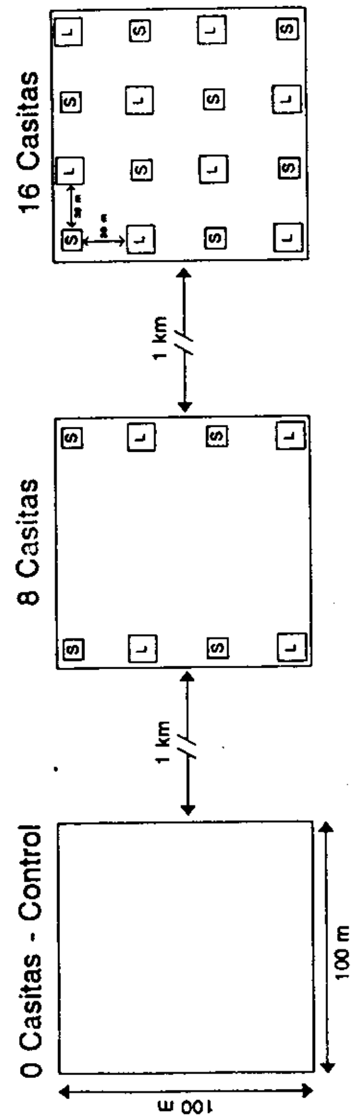

Figure 3. Schematic representation of experimental design for the shelter enhancement experiments. L = large casita (see Figure 1) and S = small casita (157 cm length X 105.1 cm width X 3.8 cm height of opening). We chose to use small and large casitas to provide shelter for the full size-range of juvenile and adult spiny lobster (Eggleston and Lipcius, 1992).

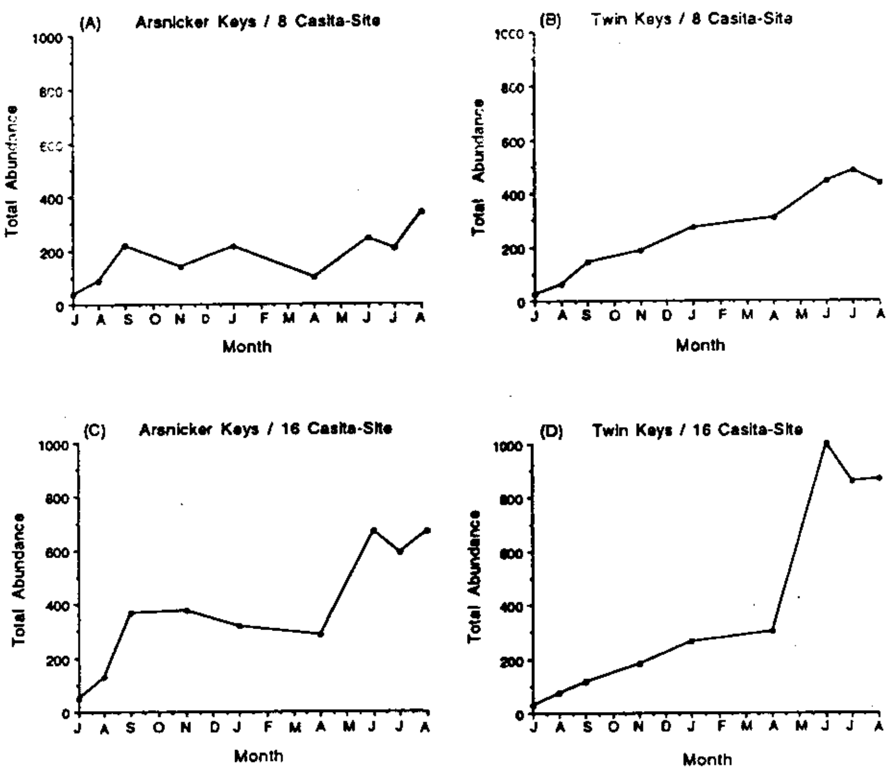

Figure 4. Spiny lobster abundance in the casita sites at Florida Bay. (A) Arsnicker Keys, eight-casita site; (B) Twin Keys, eight-casita site; (C) Arsnicker Keys, sixteen-casita site; (D) Twin Keys, sixteen-casita site. Data were collected by visual surveys. Results for the two control sites are not depicted because there were rarely more than ten to twenty lobsters observed per site in the control sites.

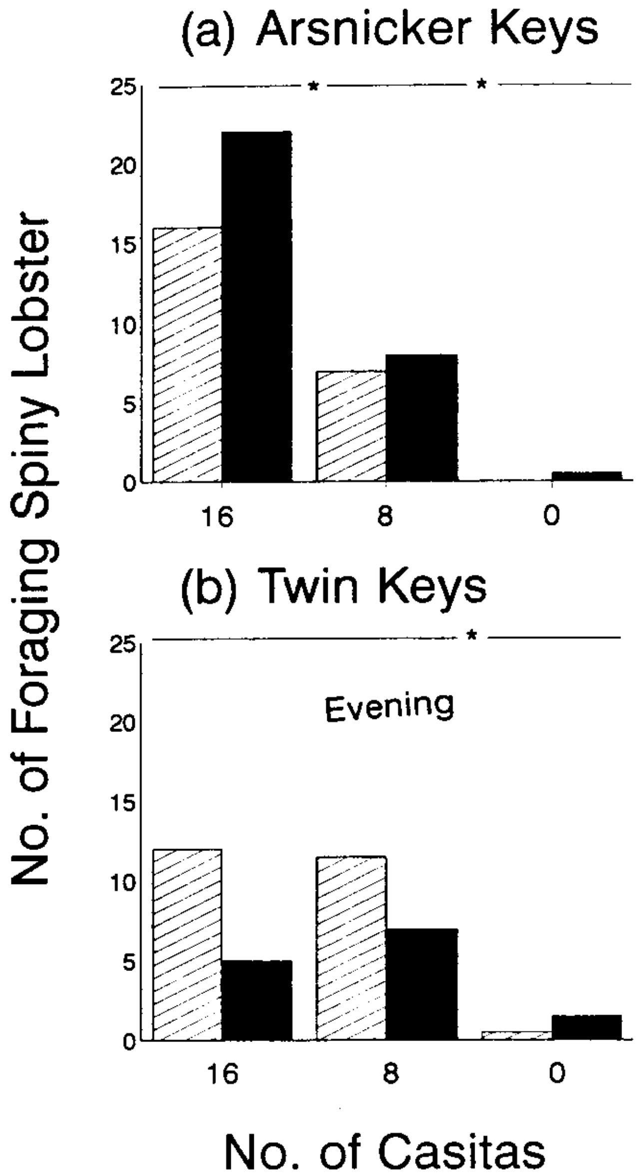

Figure 5. Spiny lobster foraging activity in Florida Bay as a function of the number of casitas per site; control sites = 0 casitas. (a) Arsnicker Keys; (b) Twin Keys. Horizontal lines above each graph reflect results of the Ryan's Q multiple comparison procedure; those levels separated by an asterisk differ significantly at the 0.05 level.

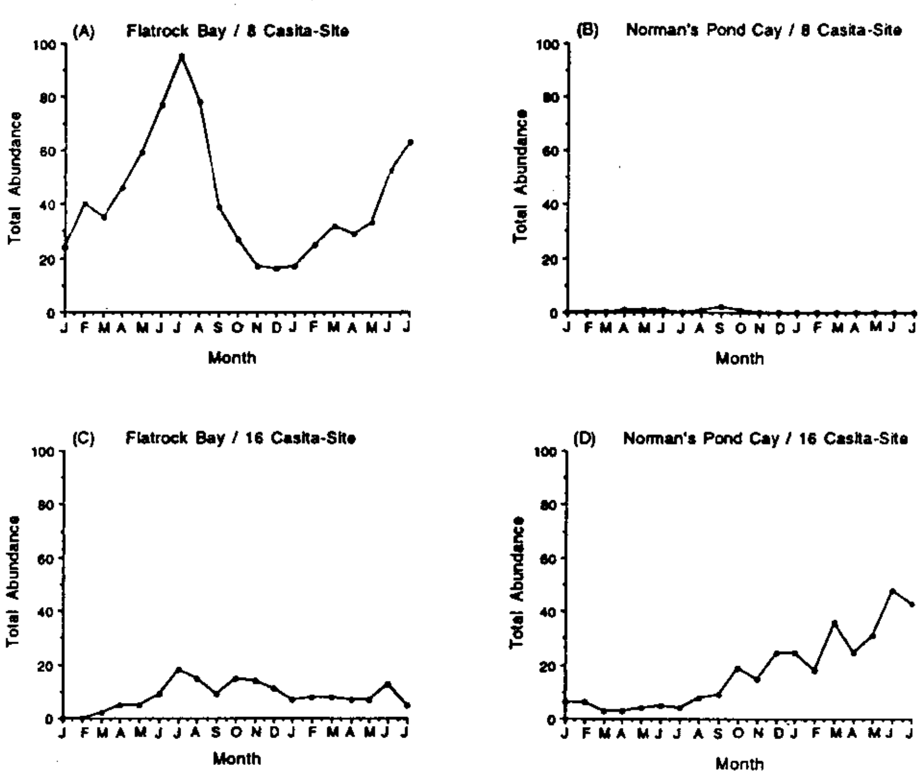

Figure 6. Spiny lobster abundance in the casita sites in the Bahamas. (A) Flatrock Bay,eight-casita site; (B) Norman's Pond Cay, eight-casita site; (C) Flatrock Bay, sixteen-casita site; (D) Norman's Pond Cay, sixteen-casita site. Data were collected by visual surveys. Results for the two control sites are not depicted because no lobsters were observed on any given sampling date. Note difference in the y-axis scale with Figure 4.

(2) greater amounts of settlement substrate (*Laurencia* spp.) in Florida Bay. Therefore, during the summer of 1990, we simultaneously monitored postlarval settlement on "Witham"- type artificial settlement substrates positioned at our experimental and control sites at both geographic locations. Contrary to our expectations, settlement was significantly higher in the Bahamas than in Florida Bay (Figure 7). These results suggest that postlarval supply was not limiting spiny lobster population size within the vicinity of our experimental sites in the Bahamas. Therefore, during the fall of 1991, we measured percent floral substrate cover at our sites at both geographic locations. The results indicated that although both locations possessed similar amounts of *Thalassia*, green algae, (*Udotea* spp., *Penicillus* spp., etc.) and sand, an average of 10% of the substrate in Florida Bay was covered by *Laurencia*, whereas no *Laurencia* was found at our sites in the Bahamas (Figure 8). These results suggest that although adequate numbers of *pueruli* are entering our system in the Bahamas, they are likely suffering extremely high predation-induced mortality due to inadequate amounts of settlement substrate. Conversely, *pueruli* may be simply passing through the system and not settling due to the absence of a strong settlement cue. We assume the former hypothesis is true since we have observed high numbers of postalgal-phase juveniles (25 - 35 mm CL) within the vicinity of Flat Rock Bay. We are currently testing both hypotheses by manipulating shelter and settlement substrate availability at various habitats that differ naturally in the rate of puerulus influx, and by measuring postlarval supply at the entrance and exit to the Flat Rock Bay system in the Bahamas (Figure 2b).

DISCUSSION

The collective abundance, size-frequency and foraging data indicated that placement of casitas in Florida Bay seagrass and algal systems enhanced Caribbean spiny lobster abundance in these habitats through the provision of a limiting resource—shelter. After asymptotic abundances were realized in the four experimental sites at six to twelve months since the initiation of the experiment, significantly more spiny lobster resided in the experimental sites than control sites at both Arsnicker Keys and Twin Keys (Figure 4). The results further demonstrated that spiny lobster not only resided in the artificial habitats, but that they also foraged in the associated seagrass and algal beds. Spiny lobster were neither abundant nor actively foraging in control sites lacking artificial shelters. We, therefore, conclude that shelter is a limiting resource in the expansive seagrass systems of Florida Bay, which apparently harbor a wealth of spiny lobster prey, and consequently that the artificial reef systems have enhanced spiny lobster abundance. Apparently, food, settlement substrate and postlarval supply were not limited to a significant degree in these habitats (Marx and Herrnkind, 1985), though they may be limited sporadically in space and time. The results from our shelter enhancement experiments and measurements of settlement substrate availability in the Bahamas were strikingly different from Florida Bay. Lobster abundance in the four experimental sites in the Bahamas reached an asymptote six to eight months after initiation of the experiment, and no lobsters were seen in the control sites at both Flat Rock Bay and Norman's Pond Cay. In Florida Bay, lobster abundance increased in proportion to the amount of shelter available (ca 400-500 lobsters at the eight casita sites versus 800-1,000 lobsters per hectare at the sixteen casita sites; Figure 4). Conversely, in the Bahamas, the highest number of lobsters occurred at the Flat Rock Bay-eight casita site (95 lobsters per hectare), compared to approximately twenty lobsters per hectare at the sixteen casita sites (Figure 6). Only one to two lobsters per hectare were observed on any given sampling date at the eight casita site at Norman's Pond Cay (Figure 6). We attribute the high numbers of lobster observed at the Flat Rock Bay-eight casita-site to the proximity of this site to a juvenile lobster migratory route. We commonly observed juvenile lobsters migrating out of a channel leading from a nursery habitat at night, and along a sand/seagrass boundary which intersected the Flat Rock Bay-8 casita site. These results suggest that casitas are attracting and concentrating lobsters as lobsters search for shelter at dawn, and that knowledge of local movement patterns are critical to the successful placement of these structures in the field. Our measurements of postlarval influx and settlement substrate availablity suggest that postlarval supply is adequate in both Florida Bay and the Bahamas, and that settlement substrate (*Laurencia* spp.) is limiting population size in the Bahamas.

By performing a geographical comparison of the relative importance of shelter, postlarval supply and settlement substrate availability, we conclude that different systems are likely to be unique in the factors that limit spiny lobster population size, and caution against the general assumption of shelter limitation. It is also important to realize that spiny lobsters have been implicated as key predators in a variety of benthic habitats, and their selective predation is apparently responsible for profound effects on species composition and size-frequency distributions of prey populations (Tegner and Levin, 1983; Edgar, 1990). Given the observed activity patterns of lobsters on the foraging grounds surrounding our casita sites (Figure 5), it is likely that large-scale deployment of casitas could dramtically alter benthic community food webs. It is unknown if benthic prey populations can sustain high numbers of foraging lobsters (1000 lobsters/hectare) over the long-term. Moreover, the light shadow created by casitas destroys seagrass and algae underneath it; large-scale deployment of casitas could also dramatically alter the ecological function of large seagrass systems. Thus, Caribbean nations contemplating the large-scale use of casitas for stock enhancement of spiny lobster, should verify that targetted habitats contain adequate postlarval supply, settlement substrate and food resources, and that casitas be placed on hard-bottom areas to minimize destruction of seagrasses.

LITERATURE CITED

Bohnsack, J. A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation of behavioral preference? *Bull. Mar. Sci.* **44**: 631-645.

Cruz, R., R. Brito, and R. Lalana. 1986. Ecologia de la langosta (*Panulirus argus*) al SE de la Isla de la Juventud. I. Colonization de arrecifes artificiales. *Rev. Invest. Mar.* **7**:3-17.

Edgar, G. J. 1990. Predator-prey interactions in seagrass beds. III. Impacts of the western rock lobster *Panulirus cygnus* (George) on epifaunal gastropod populations. *J. Exp. Mar. Biol. Ecol.* **139**:33-42.

Eggleston, D. B., and R. N. Lipcius. 1992. Shelter selection by spiny lobster under variable predation risk, social conditions, and shelter size. *Ecology* **73**:992-1011.

Gaines, S. D., and J. Roughgarden. 1985. Larval settlement rate: a leading determinant of structure in an ecological community of the marine intertidal zone. *Proc. Nat. Acad. Sci.* (USA) **82**: 3707-3711.

Marx, J. M. and W. F. Herrnkind. 1985. Macroalgae (Rhodophyta: *Laurencia* spp.) as habitat for young juvenile spiny lobsters, *Panulirus argus*. *Bull. Mar. Sci.* **36**: 423-431.

Miller, D. L. 1989. Technology, territoriality and ecology: the evolution of Mexico's Caribbean spiny lobster fishery. Pages 185-198 in F. Barkes, ed. *Common property resources: ecology and community-based sustainable development*. Valhaven Press, London.

Tegner, M. J. and L. A. Levin. 1983. Spiny lobsters and sea urchins: analysis of a predator-prey interaction. *J. Exp. Mar. Biol. Ecol.* **73**: 125-150.

Underwood, A. J., and P. G. Fairweather. 1989. Supply-side ecology and benthic marine assemblages. *Trends in Ecology and Evolution* **4**: 16-20.

United States Agency for International Development. 1987. Caribbean marine resources: opportunities for economic development and management. U.S. Agency for International Development, Washington, D.C. 53 p.

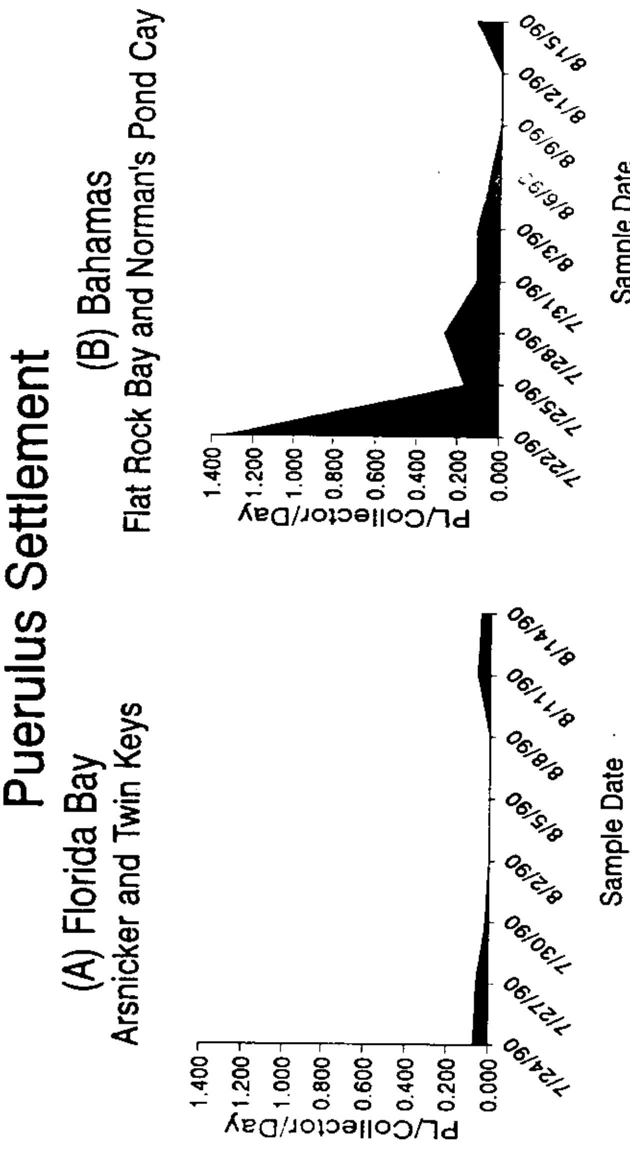

Figure 7. Spiny lobster puerulus (postlarval) settlement on floating, "Witham"-type artificial settlement substrates in Florida Bay and the Bahamas. Settlement associated with each sample date is the mean of twenty artificial substrates located in experimental and control sites within a geographic location (Arsnicker and Twin Keys pooled).

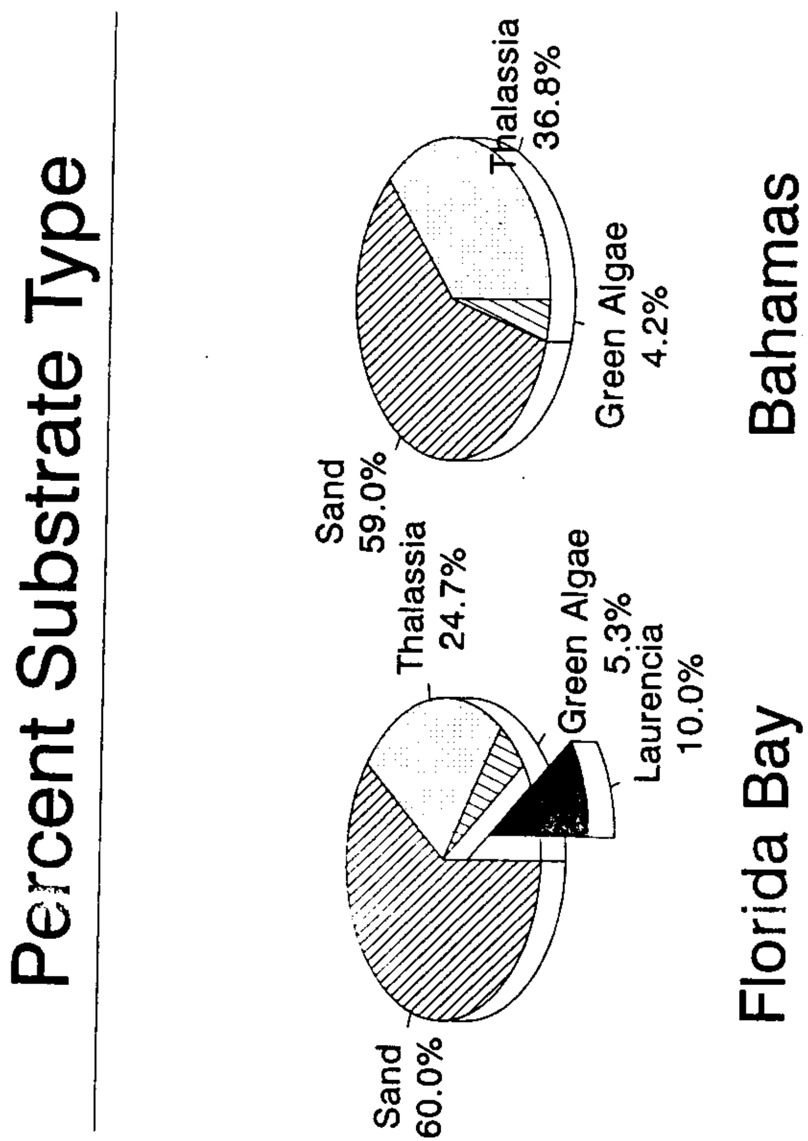

Figure 8. Mean percent substrate type from visual estimates of floral cover within 0.25 m^2 quadrats in the vicinity of the experimental sites in Florida and the Bahamas (N = 6).