Spiny Lobster Recruitment in South Florida: Quantitative Experiments and Management Implications

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ABSTRACT

Understanding recruitment and identifying factors critical to that process are imperative if adult spiny lobster *Panulirus argus* stocks are to be conserved and properly managed. The goal of our research has been to obtain ecological information linking inshore postlarval spiny lobster recruitment to later life stages, thereby providing the basic framework for assessing and predicting adult stock. Since 1983, we have investigated various aspects of spiny lobster recruitment including: postlarval time-to-metamorphosis, postlarval/juvenile habitat selection and selection cues, postlarval/juvenile crypticity and susceptibility to predation, juvenile food preference and emigration, juvenile sociality, and the effect of habitat degradation (*i.e.*, siltation) on postlarval/juvenile habitat selection and mortality. From this research we have established many of the basic biological and ecological determinants of the so-called "missing stage" of the spiny lobster (*i.e.*, settlement through first 3-4 months of benthic life). Currently, we are conducting quantitative field experiments evaluating:

1. The relationship between surface collector catch (a standard measure of recruitment), postlarval settlement in algal clumps, and benthic juvenile abundance, and
2. The relative importance of settlement versus habitat carrying capacity in determining local lobster abundances.

This research is ongoing, but preliminary results suggest that in Florida Bay:

1. Settlement is patchy and highest near the keys.
2. Surface collectors are poor indicators of local settlement or recruitment.
3. Suitable habitat may limit recruitment to the postalgal juvenile stage more than settlement.

INTRODUCTION

Recruitment can be defined as the number of progeny surviving to a subsequent life stage (Campbell, 1986). For the spiny lobster fishery, recruitment generally reflects the number of planktonic larvae that settle in shallow nursery habitats and survive to a catchable size. Factors relevant to spiny lobster recruitment include: the size of the brook stock (*i.e.*, number of eggs or larvae), larval (phyllosome) distribution by oceanic currents during the

6-9 month long larval period, and the subsequent mortality, growth, and movement of juveniles during their 2-3 year development. Identification of the parental stocks of western Atlantic spiny lobster, *Panulirus argus*, for any location remains uncertain (Lyons, 1986) and quantifying oceanic distributions lies beyond practical study. Yet, understanding the magnitude and mechanisms of recruitment from the point at which postlarvae enter nearshore waters is now subject to research and promises to "...substantially improve the predictive capabilities of population models and benefit fisheries management" (Campbell, 1986).

Since 1983, our Sea Grant-sponsored research has concentrated on diagnosing the ecological conditions regulating postlarval settlement, and the mortality and dispersal of subsequent juvenile benthic stages. Together with prior research on postlarval distribution and behavior (Little, 1977; Little and Milano, 1980; Sweat, 1968; Calinski and Lyons, 1983; Marx and Herrnkind, 1985a, 1985b; Herrnkind and Butler, 1986; Herrnkind *et al.*, 1988), we can now accurately portray a significant portion of the recruitment period.

Once the phyllosome larvae metamorphose into the postlarval stage, the postlarvae migrate from the open ocean to the inshore nursery area, which in Florida is primarily Florida Bay. During this migration, postlarvae are active and swim at night, but are quiescent and lie buried in the sand by day (Calinski and Lyons, 1983; Butler and Herrnkind, pers. obs.). Postlarvae are subject to a variety of predators during their inshore migration, the most important of which are nocturnally active fishes that feed in the water column (*e.g.*, yellowtail snapper, squirrelfish). Pelagic feeding predators are approximately twice as effective at preying on postlarvae than are day-active benthic predators (Butler and Herrnkind, unpub. data), although postlarvae have been found in the stomachs of some benthic fishes (Garcia and Lozano, 1980). If the postlarvae survive the threat posed by fish predators (most of which inhabit the offshore reefs and shallows), they are carried on flooding night tides into Florida Bay through inter-island channels, the influx peaking each month near the new moon (Little, 1977). Postlarval abundance is seasonally greatest in spring, but lunar peaks occur throughout the year. In nearshore waters, the postlarvae settle selectively among architecturally complex vegetation, especially the ubiquitous red algae *Laurencia* spp. (Marx and Herrnkind, 1985a; Herrnkind and Butler, 1986). Dark, complex structures are a critical requirement for settlement. Although food abundance does not influence postlarval habitat choice, benthic juveniles prefer habitats repelte with high prey concentrations (Herrnkind and Butler, 1986).

Once postlarvae reach Florida Bay, they metamorphose to the benthic juvenile phase within 7-10 days. Time-to-metamorphosis appears to be under strict physiological control and uninfluenced by the presence of any particular habitat or structure (Butler and Herrnkind, 1991). Settled postlarvae metamorphose into first benthic instars about 5-7 mm in carapace length (CL), which remain associated with algae for up to several months. These algal-dwelling juveniles feed on the abundant algal epibionts, especially gastropods, isopods, and amphipods (Marx and Herrnkind, 1985a; Herrnkind *et al.*, 1988). Algal-dwelling juveniles are asocial and usually reside solitarily within algal clumps, which combined with their cryptic coloration reduces their susceptibility to predation (Butler and Herrnkind, unpub. data); exposed juveniles are rapidly consumed by predators (Herrnkind and Butler, 1986; Smith and Herrnkind, in press). Although juveniles forage nomadically about contiguous vegetated substrates, their movements are deterred by patches of open substrate, a behavior that presumably reduces their risk of predation (Herrnkind and Butler, 1986). At 15-18 mm CL, the habitat preference of the juveniles changes and the postalgal-dwelling juveniles seek daytime shelter among sponges and seawhips, or within coral or rock crevices (Andree, 1981; Herrnkind and Butler, unpub data). At dark the postalgal juveniles emerge to forage over adjacent substrates, feeding on molluscs and crustaceans of correspondingly larger size (Andree, 1981). By the time the postalgal lobsters reach 25-30 mm CL, they lose the last vestiges of the algal-phase coloration and take up the nomadic lifestyle typical of late-stage juveniles and adults (Davis and Dodrill, 1980; Kanciruk, 1980).

LOBSTER RECRUITMENT IN SOUTH FLORIDA: RESEARCH IN PROGRESS

Quantifying Settlement-Recruitment Relationships

Among several problems crucial to understanding and quantitatively estimating lobster recruitment in Florida waters, is determining the pattern and density of settling postlarvae, as well as the factors regulating settlement. The scarcity of newly settled lobsters together with their cryptic appearance, small size, and propensity to settle in massive beds of algae (Marx and Herrnkind, 1985a) make direct field censuses or sampling of this stage difficult and impractical. Previous sampling efforts using floating "Witham-type" collectors (Witham *et al.* , 1964) on the Atlantic side of the Florida Keys have indicated that postlarval influx into Florida Bay is highly variable (Marx, 1986). Moreover, the relevance of these postlarval catches from floating artificial collectors, deployed on the oceanside, to local settlement in the bay nursery is uncertain. We have found that bayside-deployed surface collectors typically catch small numbers of postlarvae and that collector catch in several regions of Florida Bay are not necessarily indicative of the postalgal juvenile abundances in those areas (Herrnkind *et al.* , 1988). If postalgal habitat is sufficient, juveniles generally do not roam more than 100 m during the postalgal stage (Butler and Herrnkind, unpub. data). Thus, local postalgal juvenile abundances, particularly individuals 15-25 mm CL, are probably derived from local settlement. Surface collectors alone may be inadequate indicators of benthic settlement, which depends on postlarval planktonic abundance, substrate suitability, and probably other unknown factors (Herrnkind and Butler, 1986; Butler and Herrnkind, 1991; Herrnkind *et al.* , 1988). Predicting recruitment requires quantitative sampling of not only planktonic postlarval abundance, but of newly settled benthic recruits and postalgal stage juveniles. Until such sampling is accomplished and density relationships between these stages established, the essential phase of spiny lobster recruitment will remain unquantified and predictions of future fishable stock impossible. Thus, we are examining stage-specific abundance relationships to determine if a stock-recruitment relationship can be detected among young lobster life stages.

To quantitatively determine planktonic postlarval abundances we used oceanside and bayside surface collectors, and plankton nets deployed in inter-island channels. Postlarval settlement was measured with benthic algal collectors, and recruitment to the postalgal-phase by diver censuses. By situating arrays of benthic algal collectors (30 clumps of algae spaced 2 meters apart in a 5 x 6 array) at several sites in the bay at increasing distances from inter-island channels, we can examine the spatial pattern of postlarval settlement and the effect of tidal currents on postlarval dispersal. We also deployed surface collectors and conducted a census of benthic juvenile densities at each algal collector site. Thus, by simultaneously incorporating data from surface collectors, plankton nets, benthic collectors, and benthic surveys at several sites over several months we can evaluate correlations between postlarval planktonic abundance, settlement, and recruitment to the postalgal-juvenile phase.

We have completed a preliminary trial of this experiment and some interesting results have surfaced. For example, postlarval settlement was significantly patchy and decreased linearly from shore, despite similar habitat at all three experimental sites. Twenty-eight postlarvae settled at our first benthic algal array located two kilometers from an inter-island channel, eight settled at our second site 5 kilometers from the channel, and only 3 settled at our most distant site 8 kilometers from the channel. Although postlarvae typically do not metamorphose for 7 to 10 days after they enter Florida Bay, most settled close to shore suggesting that nearshore areas may be particularly productive nursery grounds. Although quantitative correlations among various recruitment predictors are not possible before we complete a full-scale experiment, it appears that benthic algal collectors provide a better measure of recruitment to the postalgal stage than do surface collectors. Incorporating the more mobile and widespread adult stocks into this relationship will require monitoring settlement throughout Florida Bay to account for geographic variation in settlement. This effort will necessitate a standard, quantitative, and logistically simple means of monitoring benthic settlement. Although past efforts to develop a benthic settlement sampler were unsuccessful (Sweat, 1968), new information and encouraging preliminary results suggest that we may be able to develop this technology in the next year or two.

Settlement Versus Habitat Carrying Capacity

Many regions in Florida Bay are covered by extensive algal beds intermixed with seawhip- and sponge-dominated hardbottom areas - prime habitat for postlarval settlement and subsequent juvenile lobster residency (Andree, 1981; Marx and Herrnkind, 1985a; Marx, 1986; Herrnkind and Butler, 1986; Herrnkind *et al.* , 1988). Despite this, many of these areas contain few juvenile lobsters. We hypothesized that postalgal juvenile lobster abundance in these areas was primarily recruitment limited and wanted to test whether apparently good habitat can actually support and protect substantially greater numbers of juvenile lobsters. This project has direct relevance to the application of lobster "ranching" programs and was basically designed to determine if the abundance of postalgal-phase juvenile lobsters in an area is regulated primarily by settlement or the support capacity of the local environment.

To answer this question we enhanced settlement at three sites (approximately 0.10 hectare in area) in Florida Bay by "seeding" the sites with approximately 500 algal-dwelling juvenile lobsters (5-7 mm CL). Based on previous estimates of natural settlement (Marx and Herrnkind, 1985a), the results of our preliminary settlement experiment (see above), and surface collector catches at our nine experimental sites we estimate that we tripled settlement at our settlement enhancement sites. We also determined if postalgal habitat abundance influences local juvenile lobster densities by enhancing postalgal habitat (*i.e.*, small concrete blocks which mimic rock crevices) at three sites and comparing lobster abundance there with unmanipulated natural control sites. We also added blocks to the seeding sites to permit evaluation of settlement enhancement irrespective of habitat enhancement. Thus, if settlement limits local abundances - and if ranching efforts are viable - we expected an increase in postalgal juvenile densities at the seeding (plus habitat addition) sites as compared to the habitat enhancement sites. Because we added first stage algal-phase juveniles to the sites but could only census postalgal animals, we predicted a 2-3 month lag in the treatment response - time enough for the algal-phase juveniles to grow to postalgal size. This experiment was conducted from May - October 1988 and only preliminary analysis of the data are complete.

During the course of the experiment, the mean number of postalgal-phase juveniles increased significantly where settlement and habitat were enhanced as compared to natural control sites. However, enhancing settlement had no effect over and above that attributable to postalgal habitat enhancement alone. These data include all lobsters less than 40 mm CL, but the results are identical if only recently settled lobsters less than 25 mm CL are considered. Results from a tagging study conducted in conjunction with this study indicate that juveniles 15 - 40 mm CL generally remained within each experimental site and did not move between sites, which were approximately 100 m apart. Thus, the addition to postalgal habitat probably did not attract lobsters from surrounding areas, but instead decreased mortality of postalgal juveniles. The results of this experiment suggest that while enhancement of postalgal juvenile habitat increases local postalgal juvenile abundance, tripling settlement has no effect on postalgal juvenile density. We suspect that while enhanced settlement may temporarily increase the number of algal-phase and early postalgal-phase juveniles (*i.e.*, 5 - 18 mm CL), it is the abundance of appropriate postalgal shelter that limits recruitment to the later postalgal stages. Further analysis of these data is needed, but preliminary indications suggest that the anticipated success of lobster ranching programs may be suspect. A few ranching projects are currently underway in the Caribbean, primarily in regions where postlarval densities are high (as determined from surface collector catch rates) but adult stocks somewhat depauperate. This relationship alone suggests that settlement may not be limiting in some regions and our data support this hypothesis.

To summarize, preliminary analysis of our recent field experiments dealing with recruitment suggest that there are a number of ecological factors that can intervene to decouple the relationship between planktonic postlarval abundance, as measured by surface collectors, and recruitment to the postalgal juvenile stage. In general, we found that settlement in Florida Bay was greatest near the seaward islands and while the local abundance of small juvenile lobsters (< 20 mm CL) may be influenced by settlement rates, continued recruitment to later juvenile stages may be dependent on adequate postalgal juvenile habitat. Habitat support capacity probably involves a complex interaction among factors such as the availability of food, shelter, and settlement habitat. A better understanding of habitat-juvenile lobster relationships is necessary if lobster ranching programs are to be successful.

CONCLUSIONS

The results of our five years of research on various aspects of postlarval and juvenile spiny lobster biology have yielded a clearer quantitative portrayal of spiny lobster recruitment in Florida Bay, and better defines the impact of various ecological conditions on this process. Our most recent comparisons of simultaneous catches from various collector types (*i.e.*, surface, planktonic, and benthic), each sampling different parts of the recruit's environment, potentially will reveal predictable relationships between postlarval influx, settlement, and recruitment. These relationships must be established if a feasible, routine sampling technique is to be developed. Evaluating benthic artificial collectors represents a necessary first step to designing a suitable monitoring technique that would be applicable regionally. Yet, inferences from our studies in the middle Florida Keys need to be assessed regionally and over longer time scales, especially where environmental conditions differ geographically (*e.g.*, Gulf of Mexico, other Caribbean regions) or temporally (*e.g.*, fluctuations in year-class recruitment).

Irrespective of good conservation and fishery practices designed for the preadult and reproductive stages, regional fishery potential depends on postlarval recruitment. Thus, we must recognize the importance of basic ecological and life history information on postlarval and juvenile lobsters, and incorporate those data in empirically-based models predicting settlement-recruitment relationships. We hope that the information and techniques we develop relative to lobster recruitment may be used for just this purpose. We believe that understanding the basic biological phenomena underlying major applied problems represents a necessary component in the overall development of effective fishery management practices. Unfortunately, we have only begun quantitative research in these areas and more research effort should be directed towards answering these questions. We have been counting postlarvae on surface collectors for 20 years and must move beyond that approach if we are to advance our knowledge of spiny lobster population biology.

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