Using Knowledge of Microhabitat Selection to Maximize Recruitment to Marine Fishery Reserves (MFR)

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ABSTRACT

Marine fishery reserves (MFRs) offer advantages for the management of tropical and temperate fisheries that can effectively augment conventional management programs. The effectiveness of MFRs to support fisheries in surrounding environments depends 1) on their ability to maintain or rebuild spawning stock biomass; and 2) upon the rate of export of propagules and/or adults out of the reserve. Inherent protection of important fish habitats within the reserve should help sustain ecological structure and function. Various ontogenetic stages of both fishery and non-fishery species have been shown to use particular habitats, presumably because they offer some evolutionary advantage. Habitat characteristics have been shown to influence settlement rates and control post-settlement survivorship by affecting growth and predation rates. In this study, newly settled white grunts, *Haemulon plumieri*, are shown to select natural habitats composed of small *Acropora cervicornis* coral heads in a shallow seagrass bed rather that either artificial reefs in the same seagrass bed or natural substrates available in the surrounding areas. These preferred microhabitats should be identified for other fishery species and included within MFR boundaries to preserve these habitats and to hasten the rate of increase in the spawning stock biomass within the reserve.

KEY WORDS: Marine Fishery Reserves, habitat, *Haemulon plumieri*, white grunt

INTRODUCTION

Marine Fishery Reserves (MFRs) can be valuable tools for the management of tropical and temperate fisheries. With proper design and site selection, MFRs can augment conventional fisheries management to address many of the failings or uncertainties of conventional management programs. Although research is far from complete at this date, there are some generalities that can be stated about the benefits that have been, or can be, gained from establishment of MFRs. They can build stock abundance and biomass by protecting subadults and adults, thus increasing spawning-stock biomass. Increases in size and number of spawners should increase reproductive output and subsequent recruitment. Migrations out of the reserve and dispersal of propagules will enhance fishery yields in adjacent areas and support fish populations in both adjacent and distant habitats. A source of unfished spawners should serve as a buffer against stock collapses or in severe cases of stock depletion, hasten recovery of harvestable stocks. The protection from fishing damage within MFRs will preserve intact habitats and communities that can provide valuable research insights to better understand the ecological processes that maintain sustainable fisheries and preserve ecosystem productivity. MFRs are simple for affected parties to understand, easy to enforce and are particularly well suited as a precautionary approach to management in tropical fisheries where the lack of data makes it extremely difficult and expensive to manage these multi-gear, multi-specific fisheries (Bohnsack, 1996; Plan Development Team, 1990).

MFRs have traditionally met with resistence from many fishing communities as well as some fishery managers. However, where reserves have been established, such as Hol Chan in Belize (Polunin and Roberts, 1993), Apo Island and Sumilon Island in the Philippines (Russ and Alcala, 1996), the success of these areas in rebuilding fish assemblages has enhanced support from both fishery managers and local fishers. Early success is important to gain or conserve popular support for an MFR and to enhance local protection and enforcement.

Initial support for MFRs can be generated by working within the fishing community to explain the potential benefits to the user groups and involve them in the decision-making process as was done in La Parguera, Puerto Rico (Garcia, in press; Hill and Garcia, in press). However, continuing support is dependent on the demonstration of effectiveness in meeting the MFR goals. For fishers, this is the increase in harvestable fish and the support of sustainable fisheries in adjacent fishing grounds; these properties depend on the increase in spawning-stock biomass within the MFR. Since habitats have been linked to enhanced growth and survival, it is essential to identify optimal habitats that maximize settlement and recruitment success.

This paper presents information on the settlement of white grunt post-larvae to a shallow backreef seagrass habitat. Settlers showed preferential settlement and colonization of small natural coral heads over both larger coral clusters or artificial substrate located in the same seagrass bed. Additional monitoring of small coral heads in deeper water off the forereef and sites on the reef face further supported the conclusion that the presence of post-settlement grunts on small acroporid coral heads in the seagrass bed reflected selection of a preferred microhabitat. Preliminary data on the numbers of sites of each type selected by the settlers, the duration of local survival, and the average abundance are reported for a nine month period, December 1995 - September 1996. Selection of habitats by commercially or ecologically important species is suggested as a criterion for establishing boundaries of MFRs.

METHODS

Information for this analysis was gathered in conjunction with other studies on the white grunt, *Haemulon plumieri* (Lacépède) (Pisces: Haemulidae). Those studies investigated ontogenetic habitat shifts (Appeldoorn *et al.*, in press a), migration/mortality rates and examined settlement and post-settlement dynamics. Preliminary studies included broad scale visual surveys of the shallow water habitats off La Parguera on the west end of the south coast of Puerto Rico. It encompasssed seagrass beds, coral reefs and mangrove habitats. Analysis of this survey, related distributions of life stages of juvenile, subadult and adult white grunts to discrete habitat types (Appeldoorn *et al.*, in press b). During that survey, areas of persistent settlement of post-larval grunts were recorded and one of these sites, Las Pelotas reef was selected as a site for further experimentation.

Las Pelotas is a small coral-mangrove key located on the inner reef platform. The emergent portion of the key is at the south end of the reef complex. Its near-emergent reef crest runs NNE to SSW (~250 m) parallel to the coast. Immediately north of the coral-mangrove is a small cut through the forereef that opens onto a shallow (0.3 - 2.5 m) backreef lagoon that is covered with a moderate density of *Thalassia* spp. seagrass. Generally near the center of the seagrass lagoon there are clusters of *Acropora cervicornis* (2 m diameter) that support schools of medium sized (~8 - 13 cm TL) juvenile grunts, *H. plumieri* (white), *H. sciurus* (bluestriped), *H. flavolineatum* (french), and *H. aurolineatum* (tomtates). Scattered around these clusters in the seagrass bed are spherical or elliptical *A. cervicornis* coral heads (1 m diameter). The small coral heads support heterospecific schools of grunts numerically dominated by white grunts and french grunts; during this study white grunts were most numerous. Small artificial substrata, consisting of 2 - 3 concrete construction blocks, were placed interspersed among the coral heads to provide an alternative substrate choice for new settlers in the seagrass bed. Minimum distance between sampling replicates was 3 m.

These small coral heads (n = 44) and small block stacks (n = 22) were the primary experimental replicates for monitoring settlement dynamics. This site was monitored from December 1995 - September 1996 at which time Hurricane Hortense disrupted the spatial integrity of the coral heads. Replicates were visually surveyed using snorkel or SCUBA as close to daily as was possible, although that proved to be a lofty goal. At each replicate, the numbers of fish were enumerated and size was estimated by comparison with a ruled slate. For individuals 0.8 - 10.0 cm length was estimated (rounded up) to the nearest 0.5 cm total length (TL); fish over 10 cm were estimated to the nearest 1 cm TL. All fish were identified to species when possible; small post-larvae that could not be identified with some confidence were labeled simply as PL-1 (post-larvae, ~1 cm.). Periodic sampling of small grunts with hand nets was used to confirm size estimates and species identifications.

In addition to visually sampling the replicates in the seagrass bed, periodic searches of the mangrove roots, the reef face, the windward and leeward reef crest, *A. cervicornis* coral heads in deeper water (4 m) at the base of the reef face and sites in an adjoining seagrass bed were made. For this paper, a comparison was made of the selection between the various microhabitats available.

RESULTS

The data presented here represent a preliminary assessment of settlement data in the Las Pelotas backreef *Thalassia - A. cervicornis* complex. Table 1 displays the monthly totals of sites that were occupied by grunts during each month of the study. During the study different grunt species were identified by juvenile characteristics (K. Lindeman, drawings and pers. comm.). For the analysis reported here, all species are grouped.

Table 1. Numbers of settlement microhabitats occupied at any time during each month. (Actual data recorded per lunar month).

Microhabitat	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Acroporid coral heads (≤1 m dia)	17	18	24	22	18	23	19	24	22
Concrete block	0	6	5	1	0	3	1	2	2
Acroporid clusters (>1 m dia)	0	0	0	0	0	0	0	0	0

Of the 22 concrete block habitats, six received new settlers within the first month after they were deployed. Maximum abundance for any of these block sites was 3 new settlers; average duration of local survival was less than 6 days. No grunts larger than 3 cm TL colonized a block site. Maximum recruitment to a block site occurred to a single site in August. A maximum of 22 settlers accumulated and survived on the site for 21 days.

Of the 44 replicates of the acroporid coral heads, the average numbers of occupied coral heads ranged from 17 in December to 24 in both February and July with a mean of 20.4. Unoccupied coral heads were frequently colonized by juvenile grunts 3 - 3.5 cm TL. The total abundance per coral head ranged from 1 to 320. Average local survival exceeded 30 days with the maximum of 90 days.

No new settlers were ever found on the larger acroporid clusters in the Las Pelotas backreef seagrass bed. Whether the settlers avoided these sites because of the presence of older juveniles and other potential predators or because they failed to survive is unknown.

No settlers were observed on the forereef proper. Two settlement events occurred in August during periods of high recruitment onto habitats in deeper waters immediately outside the cut through the forereef. One occurred onto *A. cervicornis* about 3 m deep and consistently mainly of french grunts; the other onto an algal covered boulder coral in about 2 m situated right in the cut.

DISCUSSION

The differences seen in habitat usage in the Las Pelotas complex are attributed to microhabitat selection by newly settling grunts. Concrete block stacks were obviously not appropriate settlement sites for post-larval grunts. This was supported by the earlier work of Shulman (1984) in St. Croix where concrete blocks attracted no settling french grunts compared to small reefs formed from queen conch shells or branched corals. In the Las Pelotas complex small acroporid coral heads were obviously a preferred settlement site and/or offered increased local survival. Other researchers have analyzed distributions of settlement in coral reef fish with varying degrees of attention to microhabitat selection. Finn and Kingsford (1996) found distinct differences between the distributions of different size classes of Apogonids, *Apogon doederleini* and *Cheilodipterus quinquelineatus* that follow a similar pattern to recruitment in the white grunts. They propose that recruitment occurs in two phases: settlement to marginal reef habitats (coral rubble and patch reefs) and subsequent movement to continuous reef habitat. Masterson *et al.*, (1997) analyzed settlement of *Thalassoma bifasciatum*, the bluehead wrasse, in the Virgin Islands. Their analysis assumed constant post-settlement survivorship among diverse sample sites. Caselle and Warner (1996) compared the recruitment of *T. bifasciatum* on the north and south shores of St. Croix. They identified processes working at two different scales that explained the distribution of recruits, larger scale hydrodynamics that delivered recruits to specific sites along the coast and the small scale process of selection of particular habitats within those sites. Victor (1984) discerned larval patches of *T. bifasciatum*, apparently composed of several cohorts, that settled more or less simulataneously over a broad area at similar habitats. Many other taxa preferentially use particular habitats especially for early life stages: groupers (Eggleston, 1995), flatfish (Burke, 1995), damselfish

(Danilowicz, 1996; Robertson *et al.*, 1988), queen conch (Ray and Stoner, 1995), blue crab (Perkins-Visser *et al.*, 1996), spiny lobster (Herrnkind and Butler, 1986), and shrimp (Kenyon *et al.*, 1995). Ontogenetic habitat shifts have been suggested as trade-offs between available food resources and refugia from predation (Werner and Gilliam, 1984). The widespread use of settlement or nursery habitats that are distinct from adult habitats suggests that this selection offers some evolutionary advantage. The use of the branched acroporid as early settlement microhabitat for white grunts with an ontogenetic shift to larger acroporid clusters in the same seagrass bed (mesohabitat) follows this pattern.

Hixon and Beets (1989, 1993) identified habitat structure and the availability of appropriate size refuges (holes) as important in mediating predation and enhancing post-settlement survival for tropical reef species. Carr and Hixon (1995) identified predation by resident predators and transient predators as major structuring forces that decouple propagule production and recruitment among coral reef fish assemblages. This preliminary report on the local survival of newly-settled grunts, a maximum of 21 days on concrete blocks vs >90 days on *A. cervicornis* coral heads, suggests that the choice of microhabitat does enhance survival. Choice of appropriate habitat should enable the post-larval grunts protection while they grow large enough to achieve release from predation pressure from size-selective predators. Increased survival of settlers may increase cohort size which has been shown to be important in contributing to stock size for commercial fisheries.

Marine fishery reserves are important tools to conserve and enhance assemblages of commercially important fishery species. However, the demonstration of success in supporting fisheries in adjacent or distant areas can be contingent upon the output of both propagules and migrants. These properties depend on the abundance and size structure of spawners within the reserve. Spawning-stock biomass within MFRs can be increased by growth of fish that are inside the reserve at the time of closure, additions to the adult populations from adjacent areas and settlement or recruitment of larva and/or juveniles with subsequent growth. Following closure of the Sumilon Island reserve to fishing, Russ and Alcala (1996) observed that increases in biomass lagged behind increases in abundance, demonstrating that the population increases within the reserve resulted from the immigration of small fish or increases in recruitment (or settlement). I would suggest that exploring ways to enhance recruitment is important for demonstrating the short term success of MFRs and increasing popular support of MFRs. Public support is critical both to the initial establishment of MFRs and to the continued support from user groups for the maintenance or expansion of MFRs.

One effective way to generate support for MFRs is to work within the fishing community to explain the potential benefits to the user. This is well demonstrated in La Parguera, Puerto Rico as documented by Garcia (in press) and Hill and Garcia (in press). The concepts and potential benefits to be gained through establishment of an MFR were explained to the La Parguera fishing community and the fishers were involved throughout the assessments of potential sites. When the results of the background assessments were completed, the fishers selected the reef area to be designated as an MFR. Their choice, the Turromote reef platform, was the best alternative. Turromote is a reasonably unimpacted reef that supports adult populations of the important fishery species (Hill and Garcia, in press). It is up-current from most of the La Parguera fishing grounds, thus providing the potential to serve as a source of propagules to replenish down-current areas. Turromote is also somewhat isolated and is, therefore, lightly fished compared to other nearby fishing grounds. One point of contention has been the fishers' belief that if they are restricted from using the area, other user groups, such as the dive charters, should be restricted as well. From a "marketing" standpoint, it is important for observers, whether fishers, divers or others, to see increases in fish stocks to maintain fisher support.

Of the many advantages that MFRs offer to augment conventional management regimes (Bohnsack, 1996 and references therein), the benefits that will garner support among fishers depend largely upon the reserves' abilities to increase spawning-stock biomass. Continuing support for an MFR will depend on the users' beliefs in the benefits to them. For fishers this means increases in harvestable fish that are attributable to the MFR. At present, some of the best support for the hypothesis that MFRs can support fisheries in adjacent areas comes from the fishing community itself as evidenced by the intensity with which the reserve boundaries are fished and the popular support of reserves by those fishers (Russ and Alcala, 1996). Research currently suggests that closures may be slow to demonstrate increases in stock size and abundance. The fishing pot ban in Bermuda (B. Luckhurst, pers. comm) and the restriction of fishing of red hind spawning aggregations in the USVI (J. Beets, pers. comm) have taken 5 - 7 years to show increases in protected fish assemblages or populations.

Design criteria for MFRs should consider the scope for stock rebuilding in establishing reserve boundaries. Reserve designers should consider the surrounding environment and be aware of exogenous influences that can suppress productivity (Hill, in press). Reserves should include key habitats that will contribute to the rapid rebuilding of spawning stocks for both commercially and ecologically important species. Further research that can enhance reserve effectiveness should continue to investigate microhabitat requirements of commercially and ecologically important species, investigate the time lags between predator and prey population changes, examine the dynamics of habitat overlap between settling habitats and adult habitats, and monitor temporal variations in settlement as the configurations of the microhabitats grow and change (e.g., the acroporid coral heads in this research).

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