THE ROLE OF LARVAL SUPPLY IN THE POPULATION DYNAMICS OF QUEEN CONCH AND THE NEED FOR METAPOPULATION ANALYSIS

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INTRODUCTION

The large gastropod Strombus gigas (queen conch) represents one of the most important fisheries of the Caribbean region with a total annual value of approximately $40 million US (Appeldoorn, 1994). Queen conch stocks have declined significantly throughout the region over the last 10-20 years, and various forms of catch and size limits have been imposed in most nations (Appeldoorn, et al., 1987; Berg and Olsen, 1989; Appeldoorn, 1994). Despite complete closure of the fishery in the United States in 1985, queen conch stocks have shown little sign of recovery (Berg and Glazer, in press). This lack of recovery is poorly understood, in part because of limited knowledge of early life history, larval abundance, and recruitment processes.

Detailed larval descriptions for identifying larvae of the different Strombus species (Davis, et al., 1993) and the first analyses of veliger abundance (Stoner, et al., 1992; Posada and Appeldoorn, 1994; Stoner, et al., 1994) appeared only recently. The recruitment problem is compounded by the fact that queen conch larvae spend approximately 3 weeks in the water column and may drift hundreds of kilometers from parental stocks before settling to the benthos. As a result, local populations are probably replenished from distant sources, and stock management for queen conch is a multinational problem (Berg and Olsen, 1989).

This report represents a preliminary analysis of the relationship between larval supply and population distribution and year-class strength. Full analyses are underway and will be reported in the future (e.g. Stoner, et al., in review). Because of important correlations recently observed between larval supply and population size in queen conch, it is critical to consider population dynamics in terms of larval ecology and metapopulation theory. These concepts are introduced.

METHODS AND MATERIALS

Plankton collections were made in queen conch nursery sites near Lee Stocking Island in the southern Exuma Cays, Bahamas, and in the Florida Keys during the primary reproductive season (June through September). In the Bahamas collections have been made at several nurseries since 1988, and in Florida since

1992. All larval collections were made by towing a simple conical plankton net (202 micron mesh, 0.5 m diameter) behind a small boat at approximately 100 cm/sec. All collections were made in the near-surface water during the daytime. Strombus species were sorted from the samples using a dissecting microscope, identified according to Davis, et al. (1993), and measured for shell length. Tow volumes were determined with a calibrated flow meter, and conch larval densities were standardized to number/10 m3.

RESULTS

Concentrations of queen conch veligers in the Florida Keys were generally low, with mean seasonal densities < 0.91 conch larvae/10 m3 at four nursery sites in 1992. Concentrations in 1993 (0.007-0.67 larvae/10 m3) were similar to 1992, except one mid-July collection in Looe Key National Marine Sanctuary yielded 161 larvae/10 m3, all very small individuals. Larvae in the Florida Keys occur in two primary size classes, newly hatched larvae representing local reproductive stock, and late-stage, competent larvae (near 1.0 mm shell length) that occur sporadically along the reef tract in apparent association with Florida Current meanders. Concentrations of conch veligers in nursery areas near Lee Stocking Island, Exuma Cays, normally averaging 1-4 veligers/10 m3 for the reproductive season, tended to be higher and more consistent through time than those in the Florida Keys.

Correlations between larval supply and juvenile population size occurred on a spatial scale (across different nursery habitats), as well as on a temporal scale (between different years). When larval concentration was examined at nine nursery sites in the Florida Keys and near Lee Stocking Island, where numbers of juvenile conch ranged from a few hundred to > 100,000 individuals, there was a direct positive correlation between juvenile population size and the mean concentration of larvae at each site. Furthermore, five years of sampling at one nursery site near Lee Stocking Island revealed a positive, linear relationship between the mean concentration of queen conch veligers and juvenile population size two years later.

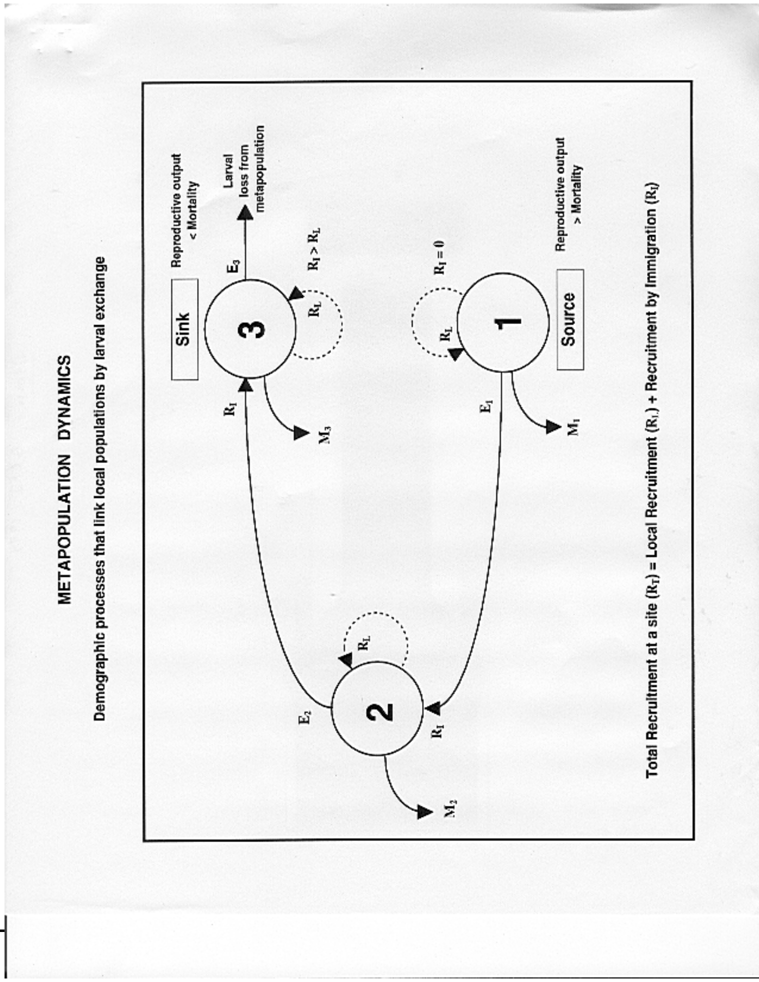

Figure 1: Conceptual model of metapopulation dynamics. The model assumes a general circulation of water carrying larvae from a Population 1 to 2 to 3. See text for definition of the model parameters.

DISCUSSION

Correlations between larval supply and juvenile population size over both spatial and temporal scales, along with data from transplant experiments to test juvenile growth (Stoner and Sandt, 1991; Stoner, et al., 1994; Ray and Stoner, 1994), suggest that populations of queen conch are recruitment limited, not habitat limited. Larval limitation implies that pre-settlement phenomena, such as mortality during planktonic stages and larval transport may be critical to population dynamics in queen conch. The positive relationship between larval supply and population size suggests that we need to understand transport processes and the mechanisms affecting larval supply to nursery grounds in order to understand recruitment process and year-class strength. The role of larval supply is frequently debated for commercially significant species, and relatively few data are available on the relationship between larval supply and population size for any species. For queen conch larval supply appears to be critical.

Because conch populations appear to be heavily dependent upon larval supply, it is particularly crucial to determine the sources of larvae and to conserve reproductive adults in upsteam areas. Biochemical data for queen conch indicate a high degree of gene flow among Caribbean populations (Mitton, et al. 1989; Campton, et al., 1992), undoubtedly maintained by drift of pelagic larvae. Although little is known about the abundance and transport of larvae of any species in the Caribbean region, it is unlikely that the reproductive sources for most populations in the region are local. This "open" nature of the populations requires that population dynamics be considered from a metapopulation perspective (see Gilpin and Hanski, 1991). In the theoretical model presented in Figure 1 there are three subpopulations connected by larval transport. Population 1 is maintained by local recruitment (RL) and has no recruitment by immigration from other sources (RI). Reproductive (larval) output from Population 1 is greater than local mortality (M), and some of that output is exported to downstream populations (E). In metapopulation terminology, this population is a 'Source'. Populations 2 and 3 are downstream from Population 1 and receive larvae both from local spawners (RL) and from upstream sources (RI). By definition, Population 3 is a 'Sink' because reproductive output is less than local mortality, and most larval production is lost from the system. Population 2 is a 'Source' for Population 3, but may also be a sink depending upon the relationship between RL and M2.

Examples of 'Sources' and 'Sinks' can be seen, or at least hypothesized, in the Caribbean region. The Windward Islands are probably 'Source' locations, analogous to Population 1 in the model because of the general east-to-west circulation of surface waters through the Caribbean Sea. In the eastern Caribbean, populations of queen conch and other species with pelagic larvae must be maintained by local recirculation patterns. Island-scale self-recruitment mechanisms have been discussed in general by Farmer and Berg (1989), and more specifically for Bermuda (Schultz and Cowan, 1994) and Barbados (Cowan and Castro, 1994) which are probably dependent upon local retention of fish larvae. Florida Keys populations may receive larvae from local spawning populations by retention in the Pourtales or Tortugas Gyres (Yeung and McGowan, 1991; Lee, et al., 1992). However, these retention mechanisms appear to be relatively inefficient, and the Keys may actually be a 'Sink' with heavy dependence upon upstream sources of larvae. This is supported by the fact that late-stage queen conch larvae are sparse in the shelf waters of the Florida Keys but abundant in the Florida Current. Competent larvae arrive along the reef tract in association with meanders of the Current (Stoner, et al., in review) and indicate that recruitment from the Caribbean may be important to population maintenance in the Keys. Important conch-producing locations such as Belize and Pedro Bank are probably more analogous to Population 2 in the model, with characteristics of both 'Sources' and 'Sinks'.

Position within the metapopulation structure can have important management consequences. For example, a source population will be highly vulnerable to recruitment overfishing and emphasis needs to be placed on maintaining an effective and sustainable reproductive stock quality. Downstream populations are also dependent upon larvae from these source populations. A sink-type population is more susceptible to management practices occurring in the upstream source locations than effected by local management practice. Recovery of depleted stocks requires an adequate source of larvae which may or may not be local. For these reasons, a strong effort should be made to identify the sources of larval recruitment for target populations, and stock management should be based upon the associated metapopulation structure. In the Caribbean region, management of the queen conch resource must be considered a multinational issue (Berg and Olsen,1989).

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