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Planktonic Processes Affecting Establishment and Maintenance of Reef Fish Stocks

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U.S. DEPARTMENT OF COMMERCE
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INTRODUCTION

One of the most intriguing unanswered questions we face is how does an island, situated in the midst of a strong oceanic current, sustain itself of populations of animals which have pelagic early life stages? One obvious answer is from upstream sources, but when the upstream sources do not exist or when the length of the larval life does not coincide with current speeds this problem is complicated further. Since these questions impinge on arriving at suitable strategies for the management of reef resources, it is necessary to gain an understanding of the factors and mechanisms which control the recruitment of animals.

The purpose of this paper is to provide background material on this subject and to outline the types of experiments which need to be conducted to solve the problem. Two major components are involved - the biological factors of the species and the physical factors of the environment. These two aspects insure successful recruitment.

Biological Factors

In considering biological factors involved in this recruitment problem we need to know what species are involved and the basic life histories of these species - by basic I mean what mode of spawning do these species utilize, what is the fecundity of the parents, and do they subsequently care for the developing offspring? If the offspring are pelagic and uncared for, what are their major characteristics - length of larval life stages, swimming ability of these stages, depth distribution by age, food levels necessary for survival, and predation factors? As one investigates specific cases, this list of questions can be easily expanded.

One of the first interesting aspects of this problem is that one would expect fishes of shore waters to exhibit a great deal of parental care to insure that their spawning products would not be swept away. The opposite is true of the 66 families of bony fishes inhabiting coral reefs in the Caribbean listed by Randall (1968), 74 percent have pelagic eggs and 92 percent have pelagic larvae. These percentages are probably higher because there are several families where types of eggs and larvae are not known (Breder and Rosen, 1966). I have found pelagic larvae of many reef families to be major components of the pelagic ichthyoplankton in my studies in the Caribbean and Gulf of Mexico (Richards, ms; Richards, in press; Houde et al., 1979). In these studies, members of the families Scaridae and Labridae were two of the major components of the pelagic realm. Scarid larvae were in the top ten in both occurrence and number in both the winter and summer collections made in the Caribbean. Goby larvae are also very abundant, especially offshore in the Gulf of Mexico, although these goby larvae may not be reef gobies because the larvae have yet to be identified to specific taxa. In my Caribbean studies I found larval representatives of 50 of the 66 reef fish families listed by Randall (1968).

It has also been verified that many of these larvae remain in the plankton for a considerable length of time. From rearing studies, Houde and Potthoff (1976) showed that a sparid, Archosargus rhomboidalis, was planktonic for at least 16 days; Saksena and Richards (1975) showed that a pomadasyid, Haemulon plumieri, was planktonic for about 20 days; and Richards and Saksena (1980) have shown that a lutjanid, Lutjanus griseus, is planktonic for at least 26 days. The time durations found in laboratory rearing studies (and there are many more) have been confirmed by field observations by McFarland (1980). His field observations combine direct observations of field behaviors coupled with otolith ageing methods which provide information on daily growth. The daily growth increments on otoliths provide a very accurate method for ageing tropical fishes throughout all their life stages and also denote major changes in eco-behavior (Brothers, 1979). Lobel (1978) has hypothesized that reef fish spawning is associated with time of day and month to occur at peak ebb flows of tidal currents.

Physical Factors

Circulation patterns around islands are extremely complex, according to R.A. Berkley (personal communication). Not only the islands, but island groups, seamounts and banks, modify the environment in a number of ways: they perturb the flow, enhance mixing, cause upwelling which can enrich the photosynthetic layer, reflect or refract surface and internal waves, generate planetary waves, and may add materials such as fresh water, sediments and detritus. In addition, recent observations indicate that islands and other mid-ocean structures have wakes which may be vital factors in the distribution mechanisms of plankton. Physical factors control the movements of plankton and some recent studies of the Gulf Stream reveal interesting insights to the relation between planktonic communities and currents (Wiebe et al., 1976).

The current patterns in the Caribbean Sea are quite complex due in part to the antillean arc which intersects the westward flowing current into the Caribbean. Molinari et al. (1980) studied the movements of surface currents using Lagrangian drifters tracked by satellite, and they detected a complex system of meanders and eddies of various scales. Interestingly, some of their buoys remained in the Caribbean for over 5 months which indicates that long residence times are available for some planktonic forms. These meanders and eddies were found to be produced by advection in the surface wind drift layer and by geostrophic flow. Using pilot charts of surface drift velocity Richards and Goulet (1977) developed an operational surface drift model which also depicted meanders and eddies, however, their residence times were not as long as found with the buoys of Molinari et al. (1980). Both sources reveal very complex current systems. Local currents near shore must also be extremely complicated considering local wind effects, uneven bottom topography and deflections of tidal waves. Dynamic effects have also been noted recently in the water column. Proni et al. (1978) detected unusual particulate spires and walls in regions of current systems. The forces causing these events must also contribute to the distribution of larvae.

Proposed Solution to the Problem

As discussed above, the factors which affect the distribution of spawning products are many and varied. This problem was recognized in 1977 by a planning group which met at the direction of UNESCO. I was a member of that group, and a skeleton of a research plan was developed (UNESCO, 1977). This plan emphasized that closely integrated oceanographic-ichthyoplankton research was necessary. The purpose of the research was to investigate how nearshore fish populations are controlled and what are the mechanisms of recruitment to the fish stock; and in addition, to investigate the existing situation in the trap fishery of the Lesser Antilles and determine how scientific data may be used to assist rehabilitation and management. The research plan described areas which would be ideal plus aspects of the research needed. Subsequent to the meeting, several of us have inquired as to the best approach to carry out the plan. Basically this research is expensive which would require the dedication of a lot of ship time and personnel. To reduce the scope of the research would jeopardize the experiment. As of this date, it is still unclear if the project could be carried out. IOCARIBE has hired a project manager for this, and a planning meeting is scheduled for later this year.

This IOCARIBE plan is presented here because its original distribution was quite limited. The plan is as follows: Any efforts to rehabilitate and properly manage small island fisheries require in-depth knowledge of oceanographic factors that regulate reproduction, growth and recruitment of fish stocks. Such knowledge, when complete, should allow development of predictive ecosystem models necessary for long-term fishery management, including changes caused by the fishery itself. Necessary information included:

a) Circulation patterns affecting movement of fish eggs and larvae;

b) The availability of nutrients and the mechanism of their supply;

c) The amount of primary productivity providing energy to the ecosystem.

Such information can only be gained through an intensive interdisciplinary program co-ordinated with ongoing fishery programs in the region, which will collect the appropriate data.

It was agreed that the basic study of the trap fishery and its management must be conducted in an overfished area, and that WECAF would need to make a major input in relation to fishery problems.

It was agreed that two main areas should be designated for the study:

a) St. Kitts-Nevis. In this area the trap fishery is well developed and overexploited, but the interpretation and oceanographic data will be complex.

b) St. Lucia. In this area the trap fishery is less well developed and there are immediate plans for the collection of fishery statistics. Recruitment data will be relatively easy to obtain because the oceanographic regime is apparently less complex.

An important question to be answered in both areas is whether recruitment depends on the local stock or does it originate from some other source. In both areas it is considered necessary to collect data on fisheries, ichthyoplankton distribution and abundance, water transport, nutrient chemistry and productivity.

A simple outline of the proposal and divisions of responsibility is given below.

Program description

A) St. Lucia Project

1) Oceanographic (IOCARIBE)

a) St. Lucia Passage
- a) Circulation
- b) Ichthyoplankton
- c) Chemistry, primary production, zooplankton.

b) St. Vincent Passage
- a) Circulation
- b) Ichthyoplankton
- c) Chemistry, primary production, zooplankton.

c) Up-stream
- a) Circulation
- b) Ichthyoplankton
- c) Chemistry, primary production, zooplankton.

d) Down-stream
   1. Island wake
   2. West of island wake

a) Circulation
b) Ichthyoplankton
c) Chemistry, primary production.

2) Fisheries (WECAF Project and St. Lucia Fisheries Department)

   a) Catch/Effort (C/E) and assessment
   b) Spawning season and fecundity
   c) Nursery and recruitment information
   d) Maximum sustainable yield (MSY) and optimum yield (OY)

B) St. Kits/Nevis Project

1) Oceanographic (IOCARIBE)

   a) Circulation
   b) Ichthyoplankton
   c) Chemistry, primary production, zooplankton

2) Fisheries (WECAF Project and local Fisheries Departments)

   a) St. Kitts
      1 - C/E and assessment
      2 - Modify gear and methods
      3 - Monitor C/E

   b) Nevis
      1 - C/E and assessment
      2 - Monitor C/E and report assessment

The nature and type of data to be collected in each area is similar and is as set out in the following paragraphs.

C) Ichthyoplankton

Samples will be collected to determine horizontal and vertical distribution patterns and diurnal changes. Sampling will be undertaken upstream from the island, in the island shadow and to the west of the shadow. These will be related to water transport, nutrient chemistry, plankton and productivity.

Sampling must extend over at least one year at minimum intervals of three months. It may be necessary to increase the sampling effort during known seasons of fish reproduction.

Samples will also be used for total analysis of zooplankton and the potential food sources for fish larvae.

D) Water Circulation

A water-mass circulation study around the shelf of an island should consider the following environmental parameters:

1. Currents and net transport at different levels of the water column;
2. Tidal Variations;
3. Meteorological parameters (wind regime, precipitation and evaporation rates, etc.);
4. Wave regime;
5. Land drainage;
6. Bathymetric survey.

The investigation of the inter-relationship among these variables entails monitoring for at least fourteen continuous days during each season of the year. Measurements of the physical variables should be undertaken jointly with biological and chemical studies for the area. Sophisticated measuring methods should be employed to prevent data loss and waste of effort. The methods suggested are as follows:

1. Use of current meter systems (monitoring, release units, etc.) (Eulerian measures);
2. Lagrangian tracking by means of radio, or theodolite-tracked drogues, dye patches, and surface drifting objects;
3. _In situ_ meteorological and wave regime parameters monitoring buoys;
4. _In situ_ tidal gauges;
5. Bathymetric surveys from small and large boats depending on closeness to the shoreline (portable recorders close to shore);
6. Wherever possible, data acquired by satellite remote sensing equipment should be obtained as a part of the programme. This will include wave spectra, surface winds and currents.

The methods of analysis will be as follows:

1. Spectral analyses of waves, currents and wind regime (computer programmes);

2. Correlation analyses of wind, currents, tidal variations by means of statistical and diagrammatic methods (for example: progressive vectorial diagrams).

This investigation is specifically designed to support biological data necessary to elucidate the fisheries problems or solutions being sought (net transport to determine distribution patterns of larvae).

E) Chemistry, productivity

In situ C^{14} uptake primary production measurements in Atlantic and Caribbean sides in and out of island shadow and on island shelf.

Coincident measurement of nutrient and biochemical parameters including

NO^{-}_{3}, NO^{-}_{2}, NH_4^{+}, PO_4 = SIO_4 = ATP

ATP (for total microbial biomass)

Chlorophyll (plant biomass)

Dissolved and particulate organic carbon
Dissolved and particulate organic nitrogen
Temperature
Salinity
Dissolved oxygen
Alkalinity
Nitrogen fixation

An oceanic platform that will allow performance of amount of these analyses at sea will be essential.

Data on chlorophyll and sea surface temperature will also be acquired through satellite remote sensing systems.

F) Fisheries

The fisheries study will concentrate on an evaluation of the trap fisheries in the Lesser Antilles. Such evaluation can be based on estimates of catch, effort and area fished in the various islands as well as recruitment to the stock. Improved estimates would be obtained if it were possible to manipulate these fisheries. It is agreed that the WECAF Project should be requested to be the responsible agent for implementation of the programme.

The objective is to estimate the state of exploitation of the fish resources, in particular those caught in the trap fishery, and to estimate if there are any simple indices which can be used to estimate the state of exploitation for grounds for which little information is available, for islands in the Lesser Antilles with special emphasis in Santa Lucia, St. Kitts, Montserrat and Antigua.

The basis for this study will be a statistical sampling programme, designed by an expert in the field who also should ensure uniformity and standardization in the countries participating in the programme. The sampling programme should be designed to give sufficiently reliable results for a moderate cost and limited use of personnel. The UNDP/FAO/WECAF project could be requested to assist in the programme by providing a statistician.

The statistics should include catches by species or species groups, by fishing ground, some information on size composition, maturity, etc. The data should be analyzed at regular intervals in order to follow and eventually modify the programme if necessary.

G) Training, Education and Mutual Assistance in the marine sciences (TEMA)

Every effort will be made to include scientists and students from the region in the conduct of the programme including field work, data collection and data reduction.

H) Time Schedule

It is estimated that two years will be required for planning and that the programme should aim to commence on 1 January 1980. The group noted that it was not necessary for St. Kitts and St. Lucia parts of the programme to be conducted simultaneously and it would be possible to operate the programme on a phased basis.

I) Finance

The principal financial requirement is support for ship time and for personnel. ISTPM (France), NOAA (U.S.A.) NSF-IDOE (U.S.A.), Sevastopol Hydrobiological Institute (U.S.S.R.), NERC (U.K.), Royal Navy (U.K.), National Marine Fisheries Service (U.S.A.), Canadian Committee on Oceanography (Canada) might be approached for donation of ship-time.

In conclusion I present this plan again to make two points. First, the problem is very complex, and second, the solution will not come simply. The IOCARIBE plan will solve the problem, but it needs interest from the scientific community and support from funding agencies.

Literature Cited

Breder, C.M. jr. and D..E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, N.Y. 941 p.

Brothers, E.B. 1979. Age and growth studies on tropical fishes. Workshop on tropical small-scale fishery stock assessment. Univ. Rhode Island, Sept. 1979. 31 p.

Houde, E.D. and T. Potthoff. 1976. Egg and larval development of the sea bream. Archosargus rhomboidalis (Linnaeus): Pisces, Sparidae. Bull. mar. Sci. 26:506-529.

Houde, E.D., J.C. Leak, C.E. Dowd, S.A. Berkeley, and W.J. Richards. 1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Bureau of Land Management, 546 p. NTIS PB-299-839.

Lobel, P.S. 1978. Diel, lunal and seasonal periodicity in the reproductive behavior of the pomacanthid fish, Centropyge potteri and some other reef fishes in Hawaii. Pac. Sci. 32:193-207.

McFarland, W.N. 1980. Observations on recruitment in haemulid fishes. Proc. Ann. Gulf Caribb. Fish. Inst. (32):132-138.

Molinari, R.L., D.K. Atwood, C. Duckett, M. Spillane and I. Brooks. 1980. Surface currents in the Caribbean Sea as deduced from satellite tracked drifting buoys. Proc. Ann. Gulf Caribb. Fish. Inst. (32):106-113.

Proni, J.R., F.C. Newman, F. Ostapoff, and D.J. Walter. 1978. Vertical particulate spires or walls within the Florida Current and near the Antilles Current. Nature 276:360-362.

Randall, J.E. 1968. Caribbean reef fishes. T.F.H. Publications, Jersey City, N.J. 318 p.

Richards, W.J. MS. Kinds and abundance of fish larvae in the western central Atlantic.

Richards, W.J. In Press. Kinds and abundance of fish larvae in the Caribbean Sea (Extended Summary). Symposium on Early Life History of Fish. ICES.

Richards, W.J. and J.R. Goulet, jr. 1977. An operational surface drift model used for studying larval lobster recruitment and dispersal. Pages 363-374 in Stewart, H.B. jr. (Ed.). Cooperative Investigations of the Caribbean and Adjacent Regions II. Symposium on Progress in Marine Research in the Caribbean and Adjacent Regions. Caracas, Venezuela, 12-16 July 1976. Papers on Fisheries, Aquaculture and Marine Biology. FAO Fish. Rep. (200):547 p.

Saksena, V.P. and W.J. Richards. 1975. Description of eggs and larvae of laboratory-reared white grunt, Haemulon plumieri (Lacepede) (Pisces, Pomadasyidae). Bull. mar. Sci. 25:523-536.

UNESCO. 1977. Report of the IOCARIBE interdisciplinary workshop on scientific programmes in support of fisheries projects. Intergovernmental Oceanographic Commission Workshop Rep. No. 12.

Wiebe, P.H., F.M. Hurlbert, E.J. Carpenter, A.E. Jahn, G.P. Knapp, S.H. Boyd, P.B. Ortner, and J.L. Cox. 1976. Gulf Stream cold core rings: Large scale interaction sites for open ocean plankton communities. Deep Sea Res. 23:695-710.