NOTES

Quantitative sampling of demersal plankton migrating from different coral reef substrates[1]

Abstract—Continuous quantitative sampling of demersal zooplankton rising from a Philippine coral reef reveals a distinct pattern of nocturnal vertical migration. Demersal plankton live within the reef by day and migrate into the water column by night. The amount of plankton rising from specific reef substrates is significantly related to the degree of three-dimensional structure of the substrates: branching coral provides the most demersal plankton and sand the least. Coral rubble resulting from dynamite fishing is comparable to sand in its plankton production.

Coral reefs are areas of high productivity and abundance of organisms in relatively nutrient-poor waters. Within the reef ecosystem there is a tight recycling of nutrients and a self-generated food web. The extent to which reefs influence the surrounding waters is of interest. Much of the zooplankton in waters immediately adjacent to coral reefs comes from the reef itself (Emery 1968; Porter 1974; J. Porter et al. in press). Demersal zooplankton, which live in the crevices of the reef by day and migrate into the water column at night, are predominately mysids, polychaetes, nematodes, cumaceans, amphipods, isopods, copepods, ostracods, shrimp, zoea, and larval forms. They are large in comparison with open water plankton and are the major food source for planktonic reef fish (Vivien 1973; Davis and Birdsong 1973; Vivien and Peyrot-Clausade 1974; Hobson 1975) and benthic predators such as corals (Porter 1974). With the exception of Krämer's (1897) extensive and surprisingly unquoted monograph on the subject, coral reef zooplankton have been overlooked until recently because they are not sampled by conventional plankton nets towed from boats in offshore waters.

Devices used to collect plankton near coral reefs include diver-pushed nets (Emery 1968; Porter 1974), drift nets (Johannes et al. 1970; Johannes and Gerber 1974), suction and airlift systems (Emery 1968; Steven 1961), light traps (Sale et al. 1976), and standard water samplers from small boats (Helm et al. 1972; Glynn 1973; Grahame 1974). Others were reviewed by K. Porter et al. (in press). Our vertical migration trap allows continuous quantitative sampling of demersal reef plankton rising directly from specific reef substrates. It is designed on the principle of traps used to sample emerging stream insects (Mundie and Morgan *cited in* Edmondson and Winberg 1971) and vertically migrating freshwater cladocerans (Whiteside and Williams 1975).

The trap consists of sets of 1.5-m-high cones of 6 mil (0.15 mm) polyethylene sheeting attached to meter-square frames of 0.5-inch (1.3 cm) PVC pipe that are tethered just above the reef surface. A trap with four adjacent cones is shown in Fig. 1. Each cone is topped with a cutoff polyethylene bottle neck and a 3-cm-ID clear plastic tube leading two-thirds of the way up into a 2-liter polyethylene catch bottle. The catch bottle contains a small amount of air (3–4 cc) to keep the system upright and has a capped vent on the top with a 64-μ plankton netting across it. The vent is opened at the time of collection and water from the cone is squeezed up into the catch bottle for a complete sampling of the system. Narcotizing agents such as $MgCO_3$ can be injected into the bottom of the catch bottle to prevent predators from decimating prey, but care must be taken to determine that these agents do not discourage animals from entering the catch bottle. The trap is sampled at desired in-
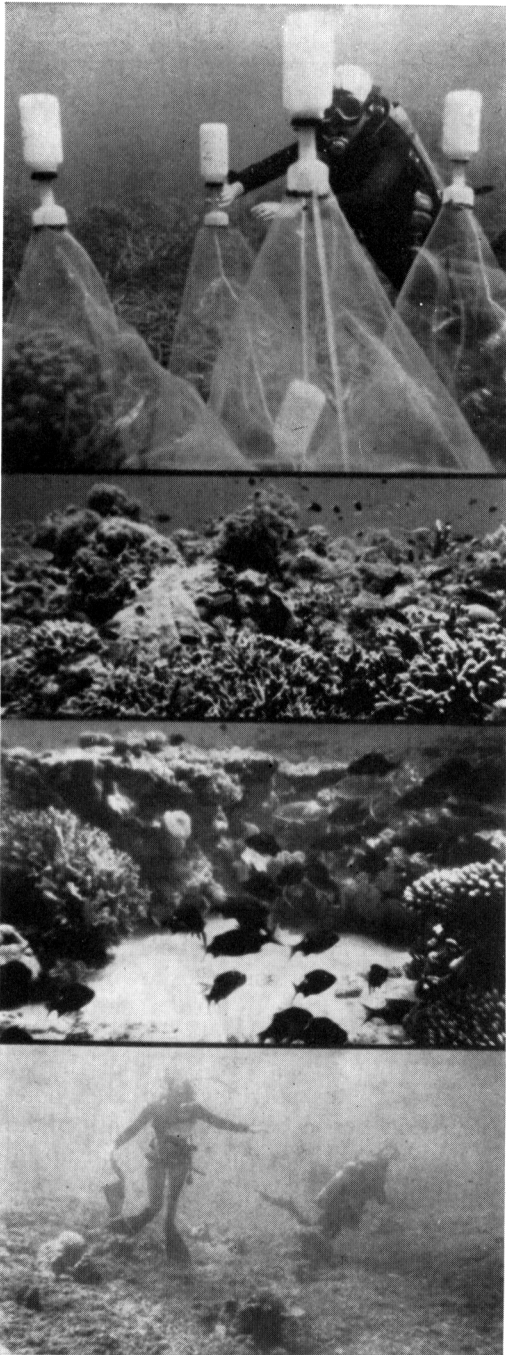
Fig. 1. Top: vertical migration trap in place over stand of branching coral. Upper middle: reef surface showing branching and plating coral substrates. Lower middle: coral sand adjacent to reef. Bottom: dynamited *Anacropora* rubble. Bohol, Philippines, September 1975.
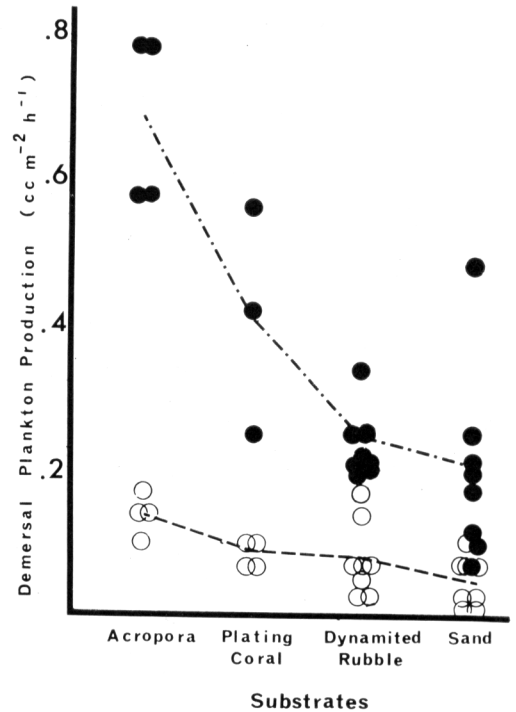

Fig. 2. Production of demersal plankton from reef substrates, Bohol, Philippines, 20–25 September 1975. Day samples (○) are hourly averages for wet settling volume of plankton collected continuously between 1000 and 1600 hours; night samples (●) collected between 1600 and 1000 hours. Lines connect means.

tervals by removing and replacing the catch bottle and tube. Contents of the catch bottle are brought to the surface, sieved through 64-μ plankton netting, and preserved in a final concentration of 5% buffered Formalin.

Figure 2 presents data from collections taken over four substrate types on the outer barrier reef, Bohol, Philippines, from 20–25 September 1975. Traps were placed on the reef at 1000 hours; bottles were collected at 1600, replaced with empty bottles and collected again at 1000 the following day. Samples from the 1000–1600-hours period are called day samples. Those from the 1600–1000-hours period are called night samples. Samples were immediately quantified as wet settling volumes and expressed as hourly rates of emergence per unit of

substrate (cc m^{-2} h^{-1}). This nondestructive quantification of the samples allows them to be counted by species later (J. Porter et al. in press). More frequent collection of the bottles will allow a finer pinpointing of the times of emergence of demersal zooplankton from the reef surface. Other studies suggest that the major movement of demersal plankton from the reef occurs at dusk (K. Porter et al. in press). Substrates (Fig. 1), in decreasing order of structure, are 1-m-high stands of branching *Acropora cuneata*, plates of mixed coral species, *Anacropora* coral rubble produced by dynamite fishing, and coral sand. All substrates are within 8 m of one another at a depth of 10 m.

Comparison of day and night emergence rates from each substrate shows the distinct nocturnal vertical migration pattern. A significantly greater amount of plankton leaves each substrate during the night than during the day, as determined by Wilcoxon two-sample tests comparing night and day samples for each substrate ($P < 0.05$ in all comparisons). This vertical migration pattern is probably a behavioral antipredation device. At night, when tactile benthic predators are active, demersal plankton move into the upper water column where visual predation is reduced by darkness. Demersal plankton are large and have highly visible swimming movements, making them easy prey for visual daytime predators such as planktivorous reef fish. Silversides and *Chromus* immediately feed on demersal plankton collected the night before and released into the water the next day. Nocturnal movement into the water column also allows demersal plankton to utilize planktonic food sources, to mate, and to migrate to new settling or feeding sites.

The volume of emerging plankton is greatest over branching coral and least over rubble and sand. The following differences in demersal plankton production exist among substrates during the day: *Acropora* > plating coral = dynamited rubble = sand; and during the night: *Acropora* > plating coral > dynamited rubble = sand. All differences are significant at the $P < 0.05$ level as determined by Wilcoxon two-sample tests comparing substrates within each time period. The relationship between plankton production and reef three-dimensionality is expected because demersal plankton live within the interstices of the reef by day.

Unfortunately, the data do not meet the assumptions required to apply a two-way analyses of variance, which would allow determination of interaction effects between time of day and substrate productivity. However, visual examination of Fig. 2 suggests a greater difference among substrates at night than during the day; this is expected because vertical migration occurs during the night.

The severe reduction of demersal plankton production in areas of dynamite fishing indicates that this practice not only destroys resident fish populations (Ronquillo 1950) and the reef surface but may also slow rate of reef ecosystem recovery by reducing the plankton supply which provides food for the regeneration of reef corals and reef fishes.

James W. Porter

School of Natural Resources
University of Michigan
Ann Arbor   48109

Karen Glaus Porter

Division of Biological Sciences
University of Michigan

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Changes in the activity of epiphytic bacteria of *Elodea canadensis* and *Chara vulgaris* following treatment with the herbicide, paraquat[1]

Abstract—The heterotrophic activity of the bacterial epiphytes of *Elodea canadensis* and *Chara vulgaris* was studied by measuring the mineralization of ^{14}C-glucose in situ. In a field experiment in which the plants were treated with the herbicide, paraquat, there was an increase in both V_{max} and $K + S_n$ of the epiphytic bacteria of *Elodea* and turnover time remained fairly constant. The epiphytic bacteria of *Chara*, which was resistant to paraquat, did not show any appreciable change in these parameters.

The values for the mean V_{max} per bacterium calculated from acridine orange counts, viable counts, and autoradiographic counts of bacteria labeled with ^{3}H-glucose showed greater increases after herbicide treatment for *Elodea* than for *Chara*.

Aquatic macrophytes release soluble organic matter during healthy growth (Wetzel 1969; Allen 1971). It is likely that this excretion increases as the plant ages (Mann 1972) and that on death much organic matter is lost through autolysis and leaching (Otsuki and Wetzel 1974; Mason and Bryant 1975). Ramsay (1974) showed that the numbers of bacteria metabolizing glucose on *Elodea canadensis* could increase as much as ninefold as the leaves became senescent, but changes in the activity of epiphytic bacteria as aquatic plants die have not been reported.

Previous work on the microbial changes associated with herbicide treatment of aquatic macrophytes has involved study of population changes of bacteria in the water and sediment (Petruk 1965; Fry et al. 1973); neither epiphytic bacteria nor their activity have been studied. There is however limited evidence that aquatic macrophytes killed with paraquat release dissolved organic materials (Dodge 1971) to which epiphytic bacteria may respond.