Bull. Environ. Contam. Toxicol. 31, 501–511 (1983)

Environmental Disturbance and Estuarine Benthos Functioning

R. Warren Flint and Richard D. Kalke

The University of Texas, Marine Science Institute, Port Aransas, TX 78373

Until recently, the study of marine benthic communities has largely been devoted to the classical description and analysis of community structure. This approach has also been used in examining the effects of environmental disturbance on benthic habitats. Included in these descriptive studies are several evaluations of marine/estuarine benthic habitats of the northwestern Gulf of Mexico (FLINT & HOLLAND 1980, FLINT 1981, FLINT & YOUNK 1983). Very little is known, however, about many of the aspects of benthic community function, and we are only beginning to learn about how fauna influence processes such as energy transfer and nutrient regeneration. For example, typical environmental monitoring may detect benthic community change in a marine habitat due to a disturbance. We don't really know, however, what these structural changes represent to the dynamics of that habitat. Even though a change in fauna occurs, the biomass may still be produced for higher trophic levels. But what about other functional roles that the benthos plays in the ecosystem that may require specific kinds of fauna?

If functional aspects of the benthos such as biomass production for food sources (e.g. WOLFF 1977, ARNTZ 1980) and regulation of sediment nutrient regeneration in the maintanence of benthic-pelagic coupling dynamics (e.g. DAVIS et al. 1975, ROWE & SMITH 1977, ZEITZSCHEL 1980, FLINT & KAMYKOWSKI in press) are important to the marine ecosystem, then basic questions arise concerning the role of benthic fauna in these processes. The purpose of this investigation was to address some of these questions by testing the following hypotheses under controlled laboratory conditions:

1) changes in benthic macroinfaunal community structure alter fluxes of nutrients at the mud-water interface, and
2) macroinfauna are one component of the benthos required to maintain rates of benthic nutrient regeneration.

It was hoped that by testing these hypotheses and obtaining further information on functional aspects of the benthos we might redefine future environmental monitoring considerations in the evaluation of ecosystem disturbance effects. Now we rely upon detection of community structure changes which are often misleading. In addition, by using a chemical pesticide in our experiments that is commonly used in the south texas agricultural

region, we were able to determine the effect of this pesticide on the marine environment.

METHODS AND MATERIALS

To investigate for changes in benthic function related to macroinfaunal (> 0.05 mm) community structure changes benthic communities developed in the laboratory according to the methods of FLINT et al. (1982) were manipulated by chemical poisoning. The experiments started on 23 September 1980 with a 72 day period of sediment colonization using 32 sediment compartments, receiving 200 ml/min water flow from the Aransas Pass Inlet. On 5 December 1980, 15 replicate compartments were randomly selected (using a random numbers table) for treatment with the pesticide methyl parathion, an insecticide commonly used in south Texas agriculture. Methyl parathion was injected over the sediment surface of each estuarine benthic treatment compartment to equal 200 mg/l of pesticide in solution. After treatment the experiments continued until 26 February 1981.

Three replicate compartments were randomly chosen prior to treatment and examined for benthic fauna community structure according to methods of FLINT & HOLLAND (1980). Wet-weight biomass was measured on dominant fauna and the total community of each compartment. After treatment, random triplicate control and treated compartments were chosen for similar community structure examination on 18 December 1980, 5 January, 21 January, 5 February, and 26 February 1981. At the conclusion of the experiments triplicate 2.2 cm diameter sediment cores were taken out of two of the remaining control and treated compartments and sectioned every 2 cm sediment depth to determine vertical distribution of fauna in the different sediments. These sections were sieved with 0.06 mm mesh screen to include the meiofaunal organisms and then analyzed as above. Bacteria were not considered in these experiments.

To examine functional changes in the benthos of each compartment, both during colonization and after treatment, three variables were examined: depth of the redox potential discontinuity (RPD) layer (mv=0), sediment oxygen uptake (metabolism), and sediment nutrient regeneration (ammonia flux). These variables were measured in randomly selected compartments on 24 September, 16 October, 25 November, 18 December 1980, 5 January, 21 January, 5 February, and 26 February 1981. Eh measurements to detect the RPD layer were made at 10 mm depth intervals through the sediment with a Radiometer TTT-26 Eh/pH meter with a platinum/calomel electrode system. This was done to determine depth of the sediment mixed layer which is partially regulated by burrowing infauna (RHOADS et al. 1978) and influences other processes within the sediment such as metabolism and nutrient regeneration. Metabolism in each compartment was determined by a YSI Model 57 oxygen meter and probe which measured changes between initial and final oxygen in the water overlying the sediments after a 4 hr incubation period, during which time water flow was stopped and total darkness maintained. Oxygen concentrations were not allowed to decrease

below 2.5 ml/l in any compartment during incubation. Sediment ammonia regeneration was determined during the same incubation period by the difference between triplicate initial and final 60 ml samples taken from water overlying the compartment sediments using acid-washed syringes. These samples were immediately analyzed in the laboratory for ammonia according to the phenol-hypochlorite method of SOLÓRZANO (1969). The flux of ammonia out of the sediments and oxygen uptake by the sediments (rates) were calculated according to the methods of HARGRAVE & CONNOLLY (1978):

$$\text{flux} = \frac{V(C_o - C_t)}{A} \times \frac{10^4}{t}$$

where V is the volume of water (l) over the sediments, C_o and C_t are the dissolved concentrations (l^{-1}) of ammonia or oxygen before and after time t, and A is the sediment area (cm^2) enclosed.

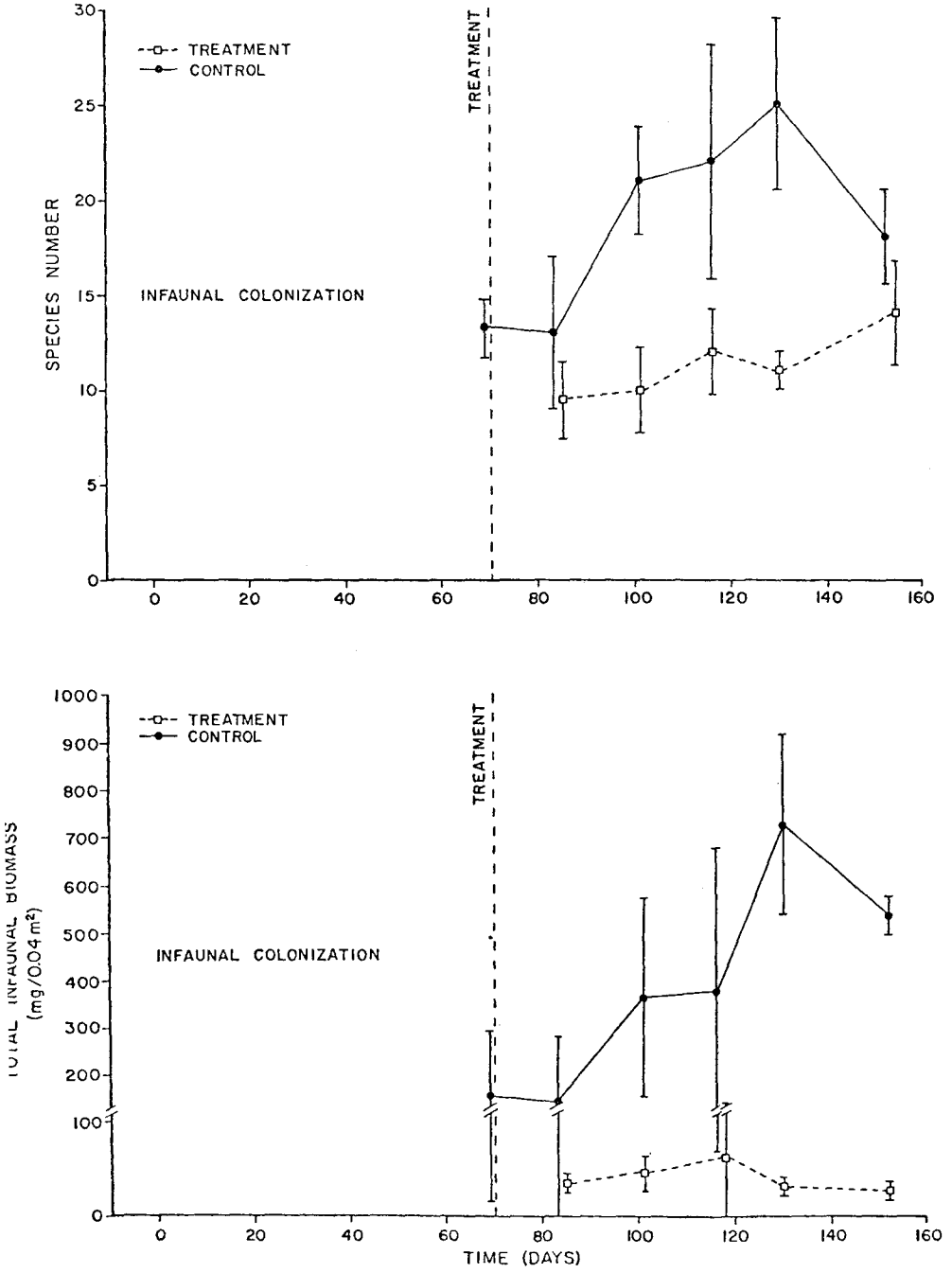
Species lists of each replicate control and treated compartment were compared using cluster analysis, employing the Canberra-Metric similarity index with flexible sorting strategy (FLINT & YOUNK 1983). Benthic community structure parameters and functional measures were compared for differences between treatments using two-way analysis of variance (ANOVA) with the factors of time and treatment both considered.

RESULTS AND DISCUSSION

After a period of 72 days of colonization well-developed benthic communities were established. A mean number of 13 macroinfaunal species were observed. Mean abundance was 120 individuals/0.04 m^2, and biomass averaged 155.8 mg/0.04 m^2. Following treatment of the sediments with methyl parathion there were significant ($P < 0.01$) decreases observed in both species number and biomass for treated compartments (Fig. 1). Similar changes were not observed for macroinfaunal abundance after treatment because methyl parathion had a preservative effect on dead fauna which could not be distinguished in our counting methods.

Cluster analysis results (Fig. 2) showed a difference in community structure between control and treated sediments at the 56% dissimilarity level. Treatment with methyl parathion significantly decreased macroinfaunal biomass and changed community structure of the benthos, the effect desired by treatment. This change continued through the entire experimentation period as indicated by differences (Fig. 2) between treated and control communities on 26 February (period 6).

During initial measurements of sediment metabolism and nutrient regeneration in azoic sediments, no oxygen uptake or ammonia flux was observed (Fig. 3). These variables showed a continual increase during the colonization period. Prior to treatment, metabolism reached its maximum value in control compartments and



igure 1: Macroinfaunal mean species number and total mean biomass for estuarine benthic communities allowed to colonize in the laboratory and then subjected to chemical poisoning. Bars around the means represent 95% confidence intervals.

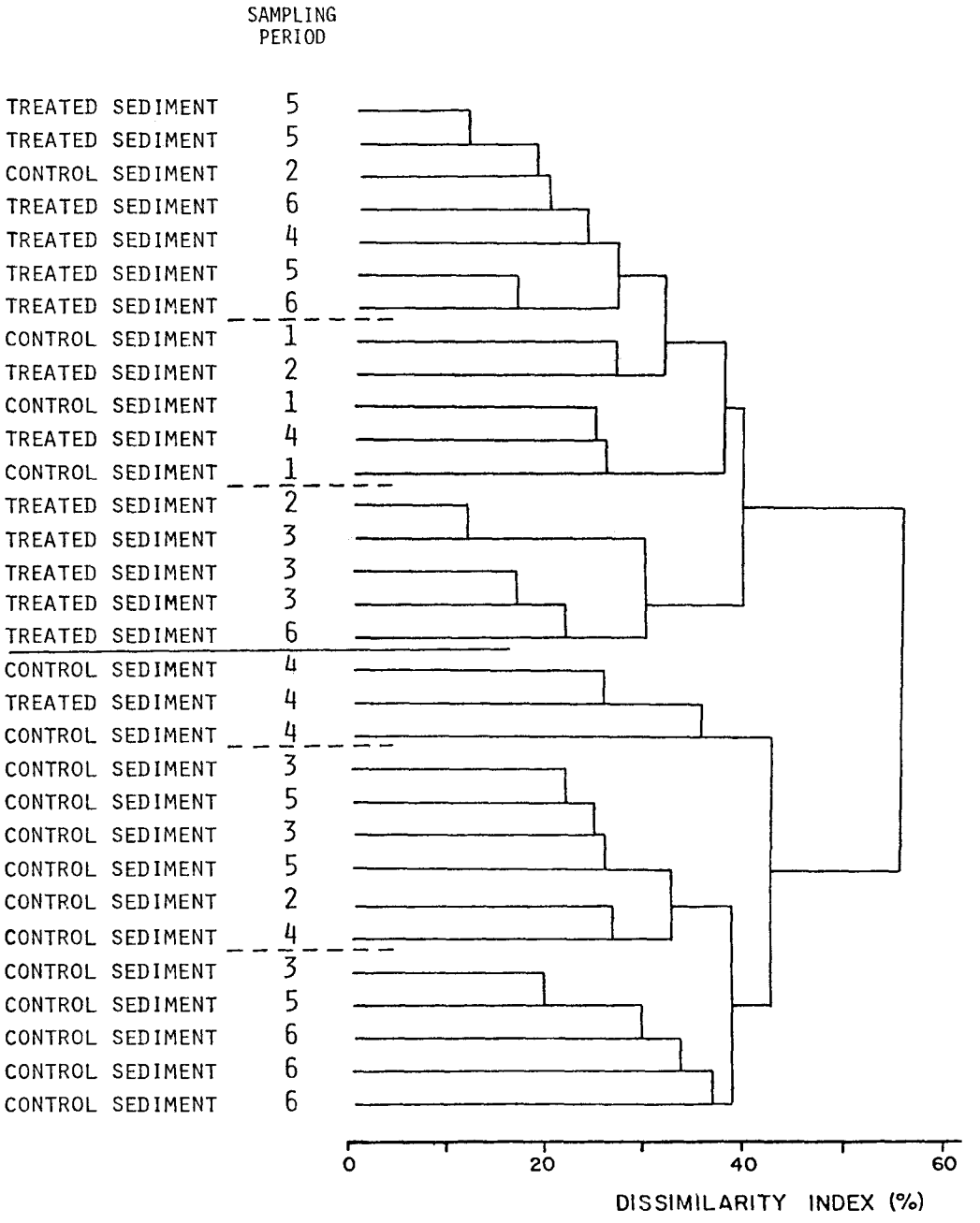
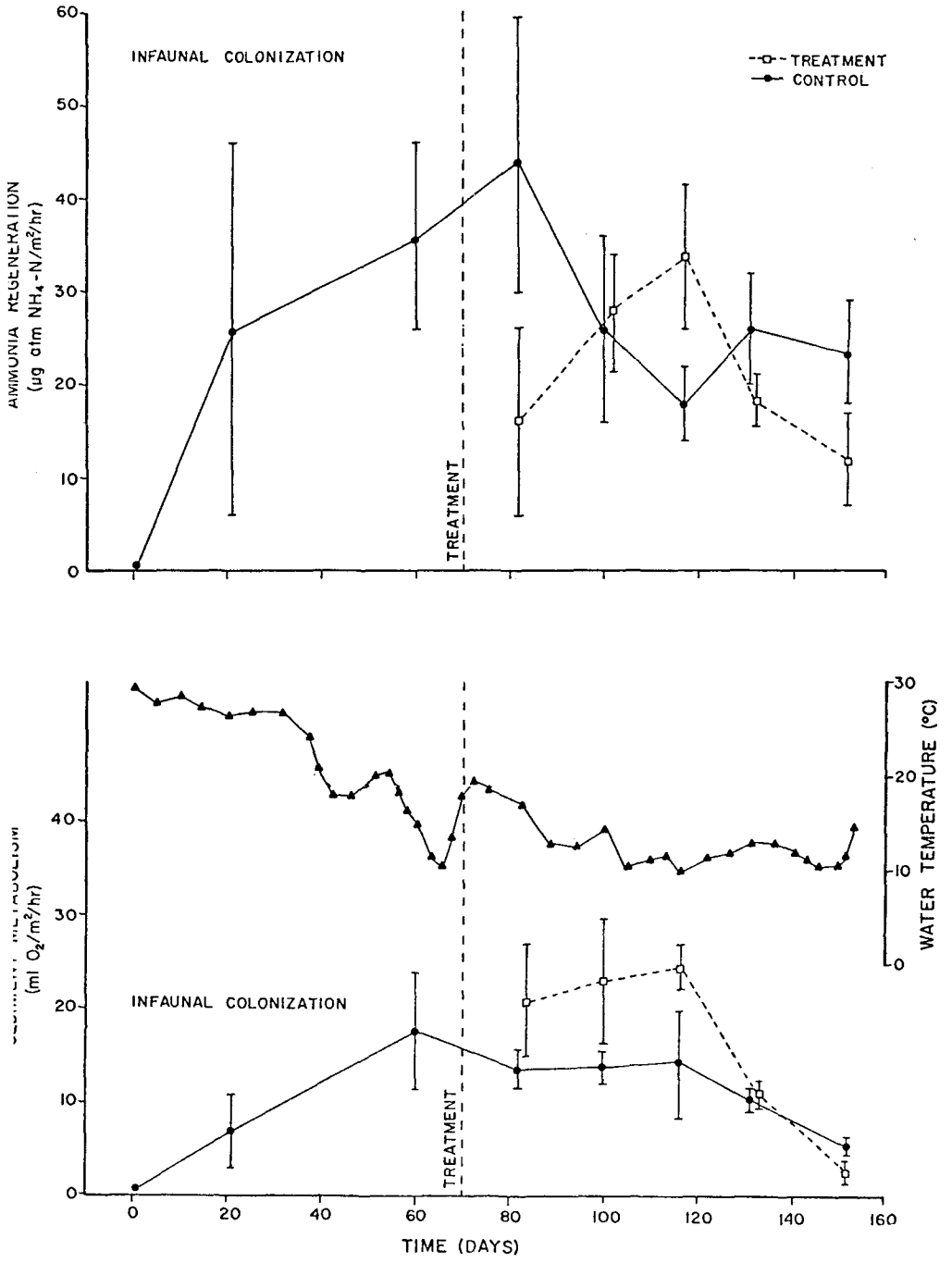


Figure 2: Cluster analysis dendrogram comparing benthic communi structure, based upon species biomass, for control an methyl parathion treated sediments. See text for sampling dates.



gure 3: Mean ammonia regeneration and metabolism rates for sediments subjected to methyl parathion poisoning. Bars around the means represent 95% confidence intervals.

exhibited a fairly consistent rate (12-15 ml $O_2/m^2/hr$) through most of the remainder of the experimentation period, except when water temperature dropped to around 10 °C (Fig. 3), which corresponded with metabolism decreases. After treatment nutrient regeneration decreased below control levels, showed a great deal of variation on successive sampling intervals, and exhibited significantly ($P < 0.05$) lower regeneration rates in the treated sediments at experiment conclusion (Fig. 3). Metabolism measures were initially higher in treated sediments but at experiment conclusion these rates were lower than in healthy control sediments.

Eh profiles (Fig. 4) illustrated changes that occurred in sediment structure related to RPD layer migration throughout colonization and the period of treatment. The compartment sediments did not show an oxygenated layer and anoxic zone together until 18 December because we began the experiments with azoic sediments devoid of organic matter and decomposing bacteria. After this date there was a difference between the depth of the RPD layer for control and treated sediments which was consistent throughout the remainder of experimentation (Fig. 4). The RPD layer was always shallower in the treated sediments than in the controls, meaning less of a volume of aerobic sediments was available for infaunal habitation in treated sediments.

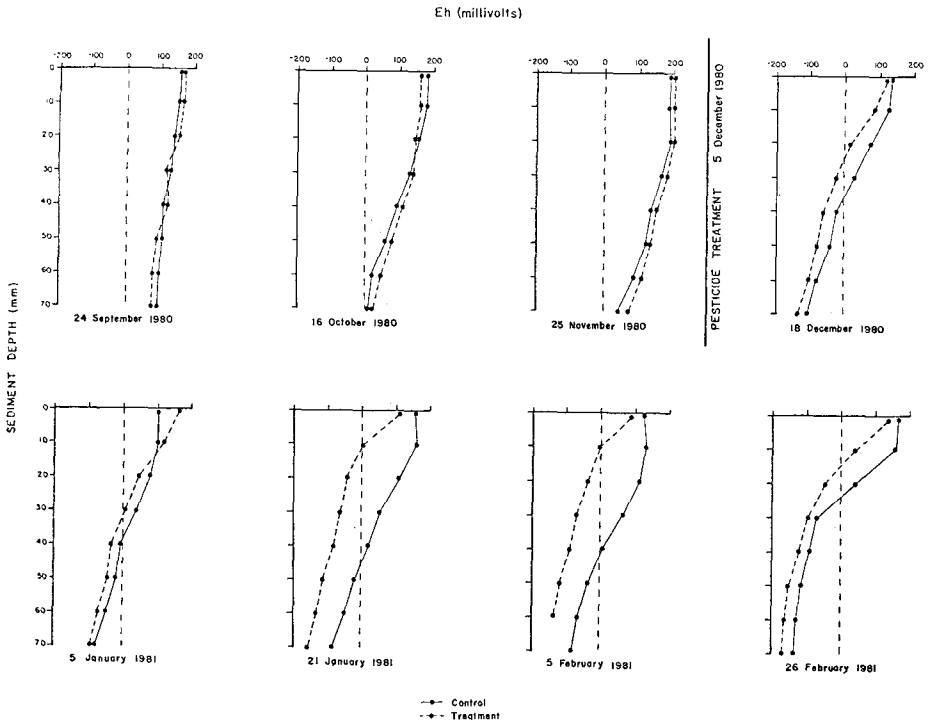


Figure 4: Average Eh (mv) profiles of control and methyl parathion treated sediments. Experiments started with sterile sediments on 24 September. RPD layer equals zero mv.

In the sediment cores taken from treated and untreated compartments at experiment conclusion, difference in RPD layer depth was also illustrated by difference in the depth of the blackened sediment zone, indicating start of anoxic sediments. Treated sediments exhibited this zone between 1-2 cm beneath the surface while untreated sediments showed the start of this zone deeper than 3 cm. The faunal analysis from these cores indicated that fauna inhabited the first 2 cm of sediment (Fig. 5). In untreated sediments, however, fauna were also present in the deeper sediment layers, whereas in the treated sediments they were not. This deeper penetration of fauna in untreated cores corresponded to observations of bioturbation (burrows) below the RPD layer in these cores, in contrast to treated cores where this deeper bioturbation was not observed.

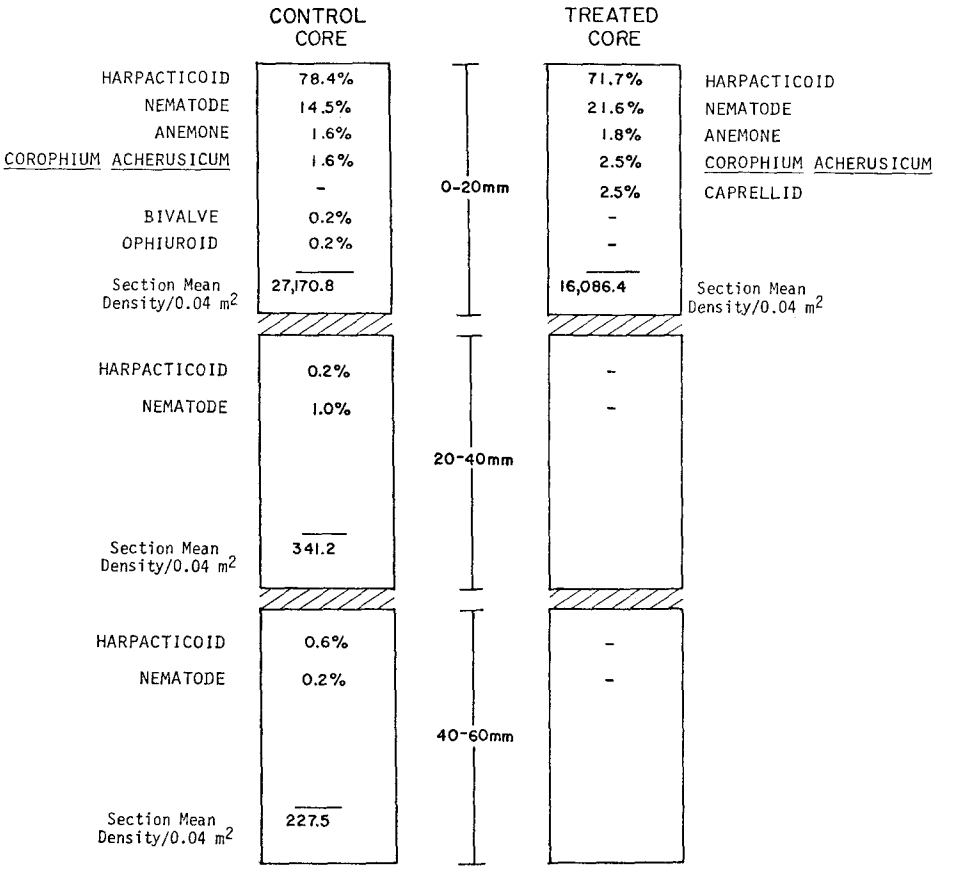


Figure 5: Mean faunal percent composition and total abundance for sediment cores taken from control and methyl parathion treated sediments at experiment conclusion. The RPD layer was located at approximately 3 cm depth in the control cores and 1-2 cm depth in the treated cores.

The goal of this research was to determine what changes occur in benthic nutrient regeneration when macroinfaunal community structure is altered through a disturbance such as chemical poisoning. Because we have had good success at mimicing natural benthic community structure with our laboratory flow-through colonization methods (FLINT et al. 1982), we chose to conduct the above experiments under laboratory conditions, to allow for easier treatment manipulation.

Unfortunately these experiments were not designed to evaluate what effects the treatment chosen had on bacterial populations in our laboratory sediments. Although our research question focused upon benthic infauna, we suspect that the treatment of methyl parathion had a significant impact on bacteria and their ultimate effect on some of the processes measured, such as nutrient regeneration and sediment metabolism. For example, methyl parathion is an organic pesticide which meant, besides adding a chemical poison we also added a significant amount of organic material to the treatment sediments. As Fig. 3 illustrates, the addition of this organic material resulted in initial higher sediment oxygen uptake after treatment, due primarily to the high biological oxygen demand (BOD) of both the added organic material and decomposing fauna killed by the poison. This was correlated with ammonia regeneration rates higher than the controls as the bacteria decomposed (remineralized) the excess organic material in the treated sediments. Thus, we feel that bacterial activities in our experiments probably had a major influence on initial responses we observed to treatment and should not be ignored in the future.

Eighty days after altering benthic infaunal community structure by treatment (Figs. 1 and 2), treated sediments exhibited significantly different metabolic rates from controls, indicating that the benthic community activity was different (e.g. different species, lower biomass). Ammonia fluxes observed from the treated sediments were approximately half the control rates. Fig. 5 illustrates that recolonized fauna in treated compartments did not burrow (bioturbate) as deep in the sediment as control fauna. Bioturbation and vertical mixing of sediments by burrowing macroinfauna affects the RPD layer (RHOADS et al. 1978). As we have observed in the Corpus Christi Bay estuary (unpubl. data), more deep-burrowing activity by such macroinfauna as *Balanoglossus* sp. forces the RPD layer deeper into the sediments. The deeper and more ventillated this layer is by burrows, the more nutrient reserves are exposed to oxygenated interstitial waters, which increases the potential for a greater mud-water interface flux of nutrients. This is confirmed by our observations 80 days after treatment where greater nutrient flux occurred, correlated with higher sediment metabolism (Fig. 3) and benthic biomass (Fig. 1), in control sediments that exhibited a deeper burrowing fauna (Fig. 5). In contrast, treated sediments, which were void of bioturbating fauna below 2 cm depth, showed (1) a shallower RPD layer at experimental conclusion and (2) a faster migration of the RPD layer towards the sediment surface during the progress of the experiments (Fig. 4). These sediments also exhibited significantly lower rates of nutrient regeneration (Fig. 3) at experiment conclusion.

The results of these investigations indicate that benthic community structure is one factor that plays a role in regulating processes of the benthos important in overall ecosystem functioning. If the benthos is inhabited by fauna that don't bioturbate the deeper sediments, nutrient regeneration rates from these sediments will be different than those that are deeply bioturbated. Therefore, we believe that although fauna may be altered by an environmental disturbance, this alteration itself tells us very little. It is impossible to predict the ultimate impact of this change on the ecosystem until some of the more subtle processes of the benthos are considered. For example, the fauna affected by the disturbance may be replaced by fauna that functionally perform the same way in the benthic habitat and thus no change would be noted in processes like benthic nutrient regeneration. The monitoring for only community structure change, however, would suggest that the disturbance had a negative impact because a change did occur in species.

Acknowledgements. Thanks are extended to L. Tinnin for help in manuscript preparation and S. Rabalais for aid in faunal taxonomy. This project was funded in part by a grant from the Caesar Kleberg Foundation to the University of Texas. This manuscript is University of Texas Marine Science Institute Contribution No. 588.

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Accepted June 27, 1983