A Restored Seagrass (*Thalassia*) Bed and Its Animal Community

by

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INTRODUCTION

During August 1973, seedlings of *Thalassia testudinum* König (Turtle-grass) were planted in two parallel 'corridors' (150 m × 6 m) in an area adjacent to Florida Power and Light Company's plant at Turkey Point, Biscayne Bay, and located on a shallow subtropical estuary about 20 miles (32 km) south of Miami, Florida (Thorhaug, 1974). The 'corridors' were a part of a relatively large area that had been denuded (Fig. 1) by thermal effluents from one of the plant's discharge canals (Roessler, 1971; Thorhaug *et al.*, 1973; Thorhaug, 1974). A total of 6,000 seedlings (initially) were implanted by divers, and within four years these seedlings had extended their rhizomes to such an extent that the 'corridors' could be considered as 'restored' from a botanical viewpoint (*see* Fig. 2 and cf. Thorhaug, 1979). The need for, and value of, such restoration of plant communities, both terrestrial and aquatic, has clearly been recognized (e.g. Hutnick & Davis, 1973; Thorhaug & Austin, 1976; Thorhaug & Roessler, 1977).

FIG. 1. *Underwater photograph of bottom sediment during period of thermal effluent from fossil-fuel power-plant at Turkey Point, Biscayne Bay, Florida, 1971. Area denuded of pre-operational seagrass at time of effluent release. Effluents diverted in 1973. Control areas in present study were not restored and remained barren as in the photograph.*

FIG. 2. *The same area at Turkey Point 4 years after 6,000 seeds of* Thalassia testudinum *were planted on barren bottom and after effluents were diverted offstream. Such restored areas were major animal study-stations. The seagrass blades average about 40 cm in length.*

In the marine environment, the value of *Thalassia* and other 'seagrasses'—both as primary producers and as providers of essential ecological niches for a variety of animal species—is well documented (e.g. Phillips, 1960; Stephens, 1966; Kelly *et al.*, 1971; Thorhaug *et al.*, 1973; Brooks, 1975; Thorhaug & Roessler, 1977). Many qualitative and quantitative studies have been made of benthic animal communities, particularly in areas which may be affected by Man's activities (e.g. Jones, 1950; Hedgpeth, 1954; Sanders, 1956, 1960; Iverson & Roessler, 1969; Bader & Roessler, 1971, 1972; Roessler & Tabb, 1974; Roessler *et al.*, 1975; Young *et al.*, 1976); however, few have been concerned with such communities following abatement of pollution (Dean & Haskin, 1964; McNulty, 1970; Linton & Cooper, 1971).

The study reported on here was undertaken to ascertain whether the recolonizing animal community associated with a restored seagrass bed would establish itself with a similar community-structure to that of 'natural' communities in unpolluted areas. Two approaches are used most frequently as a base in the study of benthic communities: (1) emphasis on biomass and productivity, with concern for assemblages of organisms

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Environmental Conservation, Vol. 10, No. 3, Autumn 1983—

in terms of energy and matter; or (2) emphasis on community structure, and analyses of communities as complexes of individuals belonging to different taxa. This latter approach has been used to assess some effects of thermal effluent discharged from the power-plant at Turkey Point (Anon., 1971; Roessler *et al.*, 1975), and is also used in the present study.

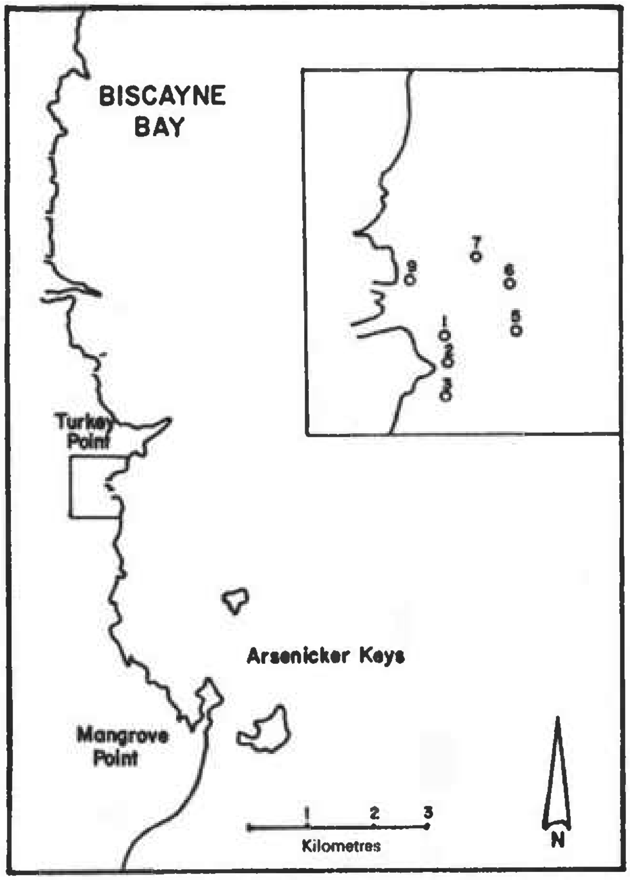

FIG. 3. *Sketch-map of South Biscayne Bay, Florida, in the vicinity of Turkey Point. Inset indicates the locations of the sampling stations (stations 1, 5, and 7, in restored corridors; 2 and 6 in unrestored* Halodule, *and 9 barren; 3 = control).*

From July 1968 through June 1970, the last-cited group collected approximately 288,000 benthic animals from the area in the vicinity of the power-plant (Roessler *et al.*, 1975). The most abundant taxa were molluscs and crustaceans, with the former group exhibiting a high degree of diversity. However, in the area of the thermal effluent, approximately 300 acres (121.5 ha) showed a marked decline in animal abundance. It was predicted that, in the 50 acres (20.25 ha) which were exposed to the highest temperatures of the effluent (4°C or more above ambient), recovery would occur very slowly, if at all, as a result of the death of the *Thalassia* rhizomes and accompanying changes in the sediments (Anon., 1971).

In an early study of Biscayne Bay, Roessler (1965) found that samples collected at night had significantly greater numbers* of fishes than had those collected in daytime; however, in the studies made at Turkey Point, comparisons of day and night catches showed no significant differences (Roessler & Tabb, 1974). Roessler *et al.* (1975) did, however, find significant differences in the numbers of crustaceans and molluscs caught in day and night samples; but no species were taken in the night samples that were not also present in the day samples.

MATERIALS AND METHODS

Seven sampling stations were selected—three of them in the restored seagrass 'corridors' in shallow, medium, and deeper, water, respectively, three in the unrestored area representing parallel depths, and one control station in an area that had not been affected by the original thermal effluent (Fig. 3). With due consideration of the data obtained by Roessler & Tabb (1974) and Roessler *et al.* (1975), that showed no significant differences in species diversity between day- and night-collected samples, the results of our study have been based exclusively on day samples.

The sampling was carried out quarterly (i.e. July, October, January, and April), using two types of sampling gear. The epifauna was sampled by means of a 1-metre (diameter) bottom trawl with a ⅛-inch (3.2 mm) stretch-mesh bag; three 10-metres' tows were taken at each station. In the restored corridors the tows were made parallel with the corridor, on either side of the designated station in order to remain within the restored area. In the unrestored and control areas, tows were made parallel and perpendicular to the designated stations. The infauna was sampled by means of a 15-cm square (bottom surface area) 'Grab' sampler, similar in design to a post-hole dipper (cf. Zimmerman *et al.*, 1971). Five replicates were taken around each station buoy, except in the case of No. 9 where the bottom was of coral rock.

Field procedures used in the July processing of the epifaunal and infaunal samples differed from the subsequent sampling periods. Each epifaunal sample collected during the first quarter's sampling was preserved in 10% buffered formalin—in its entirety, in the field. During subsequent sampling periods, each replicate was placed in a large tub and covered with sea-water. The plant material was thoroughly washed by agitation and then drained and weighed. A portion of each plant sample was preserved; the excess plant material was returned to Biscayne Bay after its weight had been recorded. The animals and remaining plant material from each replicate were preserved in buffered formalin. In instances where plant material was sparse, the entire sample was preserved. As was the case with the epifaunal samples, in July all the infaunal replicates were preserved in their entirety. During subsequent sampling periods, each replicate was washed through a 0.5-mm-mesh screen in the field to remove excess silt and mud before being preserved in buffered formalin.

In the laboratory, each sample was washed with fresh water in a large 0.5 mm-mesh sieve. During this washing, as much plant material as possible was removed and transferred to 70% ethanol. The remainder of the sample was then washed through a series of graded sieves, the final sieve sizes being 1.0- and 0.5-mm, respectively. All

* A referee points out that species identity can be most important.—Ed.

animals retained by the 1.0-mm and larger mesh-sieves were sorted out of the sample; the animals retained in the 0.5-mm fraction were transferred to 70% ethanol and retained, but were not sorted or enumerated. During the washing process, all large animals were removed, counted, recorded, and preserved in ethanol. The remaining portion of the sample was either sorted completely or an aliquot was sorted, using the low-power magnification of a stereomicroscope. Aliquots were obtained either by sample-weight or by volume.

Statistical comparisons between the results of completely-sorted and aliquot-sorted samples showed no significant differences in total numbers of animals actually sorted and the estimated total numbers determined from aliquots. Specific identifications of animals were made for the majority of crustaceans, molluscs, and fishes. Other major taxa such as the Annelida, Echinodermata, Sipuncula, etc., were classified only to generic or higher taxonomic levels. Individual species of copepods were not removed regularly from the samples, though estimates were made of their relative abundance, and representatives of the various species were selectively sorted out of each sample.

Results

A total of 115,427 animals were sorted from the trawl samples; annelids, molluscs, and crustaceans, were the dominant groups at all sites. The unrestored site contained both barren areas and areas in which a natural growth of *Halodule wrightii* (Aschers) had returned. As may be seen from Table I, the barren area of the unrestored site was appreciably poorer in animal abundance than any of the other areas. An analysis of variance test for differences in total animal abundance indicated significant differences among the sites. When the Newman-Keuls Multiple Range Test for significant differences between mean abundances was applied to the data, the results showed that there were no significant differences between the barren and *Halodule* unrestored site and the control, nor between the restored site, the control, and the *Halodule* area of the unrestored site. However, there was a significant difference between the restored site and the barren area of the unrestored site. Seasonal variations in total abundance were also quite evident (Table I), with the numbers of animals considerably lower during the autumn and winter sampling periods than the spring and summer ones.

Of the dominant major taxa, the annelids were not identified further. In general, greater percentages of polychaetous annelids occurred in association with the *Halodule* area than with either the *Thalassia* or the control site.

The crustaceans were common to the control and restored sites and to the *Halodule* area of the unrestored site, but tended to avoid the barren area. Surprisingly, very few reptant decapods were collected during the entire study. *Pagurus* n. sp. (= *Pagurus bonairensis* of earlier Biscayne Bay studies, but not *Pagurus bonairensis* Schmitt), a common seagrass-bed inhabitant, was present in appreciable numbers only in April. A few specimens of *Callinectes ornatus* Ordway were collected, but none of the commercially important species of crabs.

Among the natant decapods, three species dominated the catches (Table II). The Pink Shrimp, *Penaeus duorarum* Burkenroad, was present throughout the year, but in very low numbers during the January and April sampling periods. Virtually all the specimens collected were juveniles or subadults. The two common grass shrimps, *Hippolyte pleuracanthus* (Stimpson) and *Thor floridanus* Kingsley exhibited somewhat similar seasonal patterns. Because of the extreme variations in population densities, analysis of variance tests for differences in mean abundances showed no significant differences between sites (Tables II and III). However, it is apparent that all natant decapods showed preference for the vegetated areas.

Some 80 species of molluscs were identified from the samples, and were predominantly gastropods. However, the pelecypod *Carditamera floridana* Conrad was the dominant species at the control site and in the *Halodule* area, followed in abundance by the gastropods *Caecum pulchellum* Stimpson and *Cerithium muscarum* Say. While relatively few molluscs were collected in the barren area, the dominant species were the gastropods *C. muscarum* and *Bulla striata* Bruguiere. In the restored site, *B. striata* was the dominant species, followed by *C. muscarum* and *Modulus modulus* (Linnaeus).

Although not among the major taxa in animal abundance or even biomass, fishes were commonly taken by the trawl. No commercial species were present; the samples were dominated by *Lucania parva* (Baird), comprising 58% of the total number of fishes caught. *Gobiosoma robustum* accounted for another 30% of the catch of fishes.

A general trend towards higher diversity was observed at the control site, and several groups which were relatively uncommon occurred more frequently in that area than the others. The nebaliacean *Paranebalia longipes* (Willemoes-Suhm), found only in the control site, often comprised as much as 5% of the non-decapod crustaceans in the samples. Anthurid isopods were also found mainly at this site. Other, less common taxa that tended to occur primarily in the control area included cumaceans, caprellid amphipods, and tanaids. One species of isopod, *Cymodoce faxoni* (Say), seemed to show a markedly higher frequency of occurrence at the restored site. Studies from the west coast of Florida (Treat, 1979) have indicated that this species may be restricted in its habitat selection. Conversely, a species of the isopod genus *Bagatus* showed a marked paucity in the restored area.

Grab samples have provided quantitative data on the infaunal populations of the study area. Although these data are limited in their applicability to the principal question of animal-community recolonization in restored seagrass beds, they do afford an alternative means by which ecological parameters can be evaluated. As previously indicated, grab samples in the barren area could not be taken because of the hardness of the substrate. Therefore, only the *Halodule* area of the unrestored site has been compared with the restored and control sites.

TABLE I

Average Abundance of Animals Collected per Trawl versus *Vegetation Types at a Four-years' Restored Seagrass Site at Turkey Point, Florida.*

	UNRESTORED		RESTORED	CONTROL
	Barren	*Halodule*	*Thalassia*	
JULY				
Annelida	47	1,562	2,457	*
Coelenterata	0	10	1	*
Crustacea	3	278	432	*
Echinodermata	0	86	34	*
Fishes	7	23	37	*
Mollusca	114	670	477	*
Other	1	71	204	
OCTOBER				
Annelida	41	354	206	685
Coelenterata	0	7	3	2
Crustacea	6	270	575	562
Echinodermata	0	3	1	6
Fishes	10	82	164	44
Mollusca	84	244	344	313
Other	2	104	33	310
JANUARY				
Annelida	0	386	43	253
Coelenterata	0	1	1	2
Crustacea	1	98	80	295
Echinodermata	0	2	0	4
Fishes	2	35	43	23
Mollusca	1	103	158	98
Other	78	56	10	137
APRIL				
Annelida	160	2,860	419	1,490
Coelenterata	0	6	1	10
Crustacea	0	223	61	108
Echinodermata	0	50	2	5
Fishes	0	22	107	24
Mollusca	27	966	547	390
Other	169	222	53	267
Total Numbers Collected	1,018	46,298	42,015	26,096 *
Mean	145.4	3,561.4	2,334.2	2,899.6
Standard Deviation	85.9	2,892.1	2,933.0	1,513.4

Summary of Analysis of Variance for Differences in Abundance of Total Animals

Source	Df	MS	F
Site Types	3	18,431,137.6	2.9909†
Error	43	6,162,396.9	
Total	46		

Summary of Newman-Keuls Multiple Range Test for Differences Between Mean Abundance of Total Animals. [Means connected by a line are not significantly different at the 90% significance level.]

Barren   Control   *Halodule*   Restored

* No samples taken in July.
† Significant at 95% level.

The major taxa collected by the grab sampler are annelids, sipunculids, molluscs, and non-decapod crustaceans (Table IV). Analysis of variance and pair-wise comparisons of means show that the July samples were significantly higher in abundance than the samples from the other quarters of the year. No significant differences among restored, unrestored, and control, sites were found when all the major taxa taken by this method were considered; however, when only the annelids were tested, the restored site was significantly lower in population density than either the control or the unrestored sites. In considering total catch, it may be sensed from Table IV that no significant differences between vegetative types could be distinguished. These results are not, however, unexpected in view of the fact that the grab is not sampling the epifaunal communities associated with the vegetational types.

Discussion

Data obtained from this study have been compared, as far as possible, with the results of studies conducted during the period of thermal discharge at this same site ('Grand Canal') (Roessler *et al.*, 1975); however, as procedural techniques differed between the studies, comparisons can be made only in general terms. Moreover, sampling stations in our study do not correspond precisely with the stations of the earlier operational study; but three stations in the area affected by the thermal effluent, and one outside the affected area, do correspond sufficiently well for broad comparisons to be made. Data from the three affected stations (Bader & Roessler, 1971, 1972) have been combined and are compared with data from our unrestored site. Data from Bader & Roessler's unaffected station are comparable with our control station in the same vicinity, and all stations are compared with the combined stations from the restored *Thalassia* corridors (Table V, p. 254).

Surprisingly, the results indicate that certain taxa—those with high temperature tolerances, and thus able to withstand elevated temperatures, e.g. decapod crustaceans—were much more abundant during the thermal discharge period than subsequently. In contrast, molluscs and fishes appear to have returned to the restored areas in greater numbers than had been present during the earlier study. A shift in species, however, has occurred. Roessler & Tabb (1974) report that *Lucania parva*, *Micrognathus crinigerus* (Bean & Dresel), *Opsanus beta* (Goode & Bean), and *Gobiosoma robustum*, were the dominant fishes, comprising 23, 16, 14, and 24, per cent of the fishes caught, respectively. As previously stated, *L. parva* and *G. robustum* were the dominant fishes in our samples, with *O. beta* and *M. crinigerus* accounting for only two and two-tenths per cent, respectively. *Lutjanus griseus* (Linnaeus), also common in the earlier study, comprised only five-tenths per cent in the current study.

Table II

Average Abundance of Natant Decapods Collected per Trawl versus *Vegetation at a Four-years' Restored Seagrass Site at Turkey Point, Florida.*

	UNRESTORED		RESTORED	CONTROL
	Burren	*Halodule*	*Thalassia*	
JULY				
Penaeus duorarum	1	19	24	*
Hippolyte pleuracanthus	7	32	66	*
Thor floridanus	2	48	22	*
Caridean juveniles	0	17	10	*
OCTOBER				
Penaeus duorarum	8	46	132	5
Hippolyte pleuracanthus	0	40	222	22
Thor floridanus	0	146	218	495
Caridean juveniles	1	3	9	17
JANUARY				
Penaeus duorarum	0	2	5	2
Hippolyte pleuracanthus	0	10	26	7
Thor floridanus	1	50	29	282
Caridean juveniles	0	0	0	0
APRIL				
Penaeus duorarum	0	3	2	3
Hippolyte pleuracanthus	0	1	5	3
Thor floridanus	0	36	12	22
Caridean juveniles	0	0	3	1
Total Numbers Collected	20	2,078	4,303	2,568 *
Mean	3.3	148.4	253.1	321.0
Standard Deviation	3.3	224.1	340.6	588.1

Summary of Analysis of Variance for Differences in Abundance of Total Natant Decapods

Source	Df	MS	F
Site Types	3	144,791.0	1.0003†
Error	41	144,744.2	
Total	44		

* No samples taken in July.
† No significant difference.

TABLE III

Average Abundance of Penaeid Shrimp (Penaeus duorarum) *Collected per Trawl* versus *Vegetation at a Four-years' Restored Seagrass Site at Turkey Point, Florida.*

	UNRESTORED		RESTORED	CONTROL
	Barren	*Halodule*	*Thalassia*	
July	1	19	24	*
October	8	46	132	5
January	0	2	5	2
April	0	3	2	3
Total Number Collected	9	361	914	29
Mean	1.5	25.8	53.8	3.6
Standard Deviation	2.8	71.0	186.0	5.0

Summary of Analysis of Variance for Differences in Abundance of Total Penaeid Shrimp

Source	Df	MS	F
Site Types	3	6,752.6	<1†
Error	41	16,184.8	
Total	44		

* No samples taken.
† No significant difference.

Except in the barren area, most of the molluscs reported in the earlier study also occurred in our samples; however, *Cerithium eburneum* Bruguiere, the most abundant gastropod at the unaffected station during the operational sampling, was completely absent from our samples. Also notable in their absence were species of the echinoderm genera *Leptosynapta* and *Lytechinus* and the sponge genus *Chondrilla*. *Pagurus* n. sp. was the dominant decapod in the earlier samples but was relatively abundant only during one period in our study. Other reptant (creeping) decapods that had been common during the operational study, e.g. *Menippe mercenaris* (Say) and *Neopanope packardii* (Kingsley), were completely absent from all our sites. All three major natant decapods in our samples were also common during the operational study and showed similar seasonal peaks, but *T. floridanus* was relatively much more abundant in the earlier study.

Few definitive conclusions can be drawn from this study because of its relatively small scale (e.g. quarterly sampling from few stations); however, certain trends are apparent. The unrestored areas adjacent to areas that remained unaffected by the original thermal effluent are being slowly recolonized by mixed, successional seagrasses and Algae. *Thalassia* in these areas has increased during the study period but still is much more sparse than in the restored corridors. The area at the mouth of the discharge canal is still virtually barren in terms of both plant and animal life.

No study of bottom types was made, but field observations suggest that more peat may now be exposed at most of the stations than was reported by Roessler & Tabb (1974). Changes in the dominant members of the faunal communities may in some cases be related to this change in surface substrate. The shift in species dominance among fishes certainly could be related to substrate. *Opsanus beta* requires submerged cover and attaches its eggs to a firm substrate, whereas *Lucania parva* is not substrate-dependent. *Gobiosoma robustum* also attaches its eggs to a firm substrate, but is able to seek cover in mud as well as loose sand.

There are insufficient ecological data available for most of the molluscan species to permit speculation on reasons for shifts in population dominance. The decline in *Pagurus* n. sp. from being the most abundant species to a rank of generally less than one per cent is probably correlated with the absence of *Thalassia*, as this hermit crab is typically found clinging to the seagrass blades. The drastic decline in brachyuran decapods is thought also to be related to changes in the substrate.

The differences between the area with restored *Thalassia* and that of only residual *Halodule* is less clearly defined than might be hoped for—especially with regard to the larger motile forms, though this may be because the stations were within 10 metres of one another. In addition, the restored *Thalassia* has a high standing-crop of *Halodule* within it. A supplemental study of a successional *Halodule* community with no restored *Thalassia* is clearly necessary as an additional control.

In general it can be concluded that the restoration of *Thalassia* beds by replanting hastens the recovery of a denuded area. Although *Thalassia*, in itself, cannot alter or stop changes in the substrate, this seagrass is known to help stabilize existing substrates (Thorhaug, 1974) and help to guard them against erosion (Wanless, 1976). To return an area to its prepolluted state, after pollution abatement, it thus seems desirable to refurbish the substrate simultaneously by restoring the *Thalassia* beds.

ACKNOWLEDGEMENTS

The Authors gratefully acknowledge the National Oceanographic and Atmospheric Administration's Sea Grant Program administered through the Sea Grant

TABLE IV

Average Abundance of Animals Collected per 'Grab' versus Vegetation at a Four-years' Restored Seagrass Site at Turkey Point, Florida.

	Unrestored	*Restored*	*Control*
JULY			
Annelida	63	58	74
Sipuncula	16	<1	43
Mollusca	11	15	17
Non-decapod Crustacea	22	31	40
Decapod Crustacea	1	<1	3
Other	8	3	3
OCTOBER			
Annelida	27	29	44
Sipuncula	3	1	12
Mollusca	8	11	9
Non-decapod Crustacea	7	17	13
Decapod Crustacea	0	<1	1
Other	0	1	<1
JANUARY			
Annelida	24	13	31
Sipuncula	8	<1	2
Mollusca	7	10	10
Non-decapod Crustacea	11	8	16
Decapod Crustacea	1	<1	3
Other	0	<1	2
APRIL			
Annelida	31	26	48
Sipuncula	10	0	11
Mollusca	11	11	9
Non-decapod Crustacea	26	13	7
Decapod Crustacea	0	0	0
Other	0	0	0
Total Number Collected	1,429	1,090	1,196
Mean	84.1	68.1	99.7
Standard Deviation	51.7	45.7	56.9

Summary of Analysis of Variance for Differences in Abundance of Total Animals

Source	Df	MS	F
Site Types	2	3,441.6	1.317†
Error	42	2,612.2	
Total	44		

† No significant differences.

programmes of the Florida State University System and the University of Miami. The Univerity of Miami Sea Grant Program and the US Department of Energy are also gratefully acknowledged for their support, with matching money provided by Florida Power and Light Company, for the *Thalassia* restoration effort. Thanks are also due to Mr Henry Schur for providing his boat and capable seamanship, while Messrs Neil Gillies and Rolando Soto assisted in the sampling programme.

SUMMARY

Quarterly sampling of animals in a restored seagrass (*Thalassia*) area in south Biscayne Bay, Florida, was undertaken to determine whether the recolonizing animal community would be similar in structure to a *Thalassia* community that had never been impacted by thermal effluents or restored. Samplings by 1 m bottom trawl (⅛ inch = 3.2 mm stretch-mesh), 3 replicates at each of 9 stations, and a 15-cm² grab (5 replicates at 9 stations) were sorted as to species for most groups and quantified. Strong seasonal differences were found. The results were compared with data from previous work in the area which had been done during thermal emissions from a power-plant.

Significant differences were found between the abundance and species of animals in restored areas and a nearby barren area that had never recovered from impact, though differences in species and abundances between the restored *Thalassia* sites and an unaffected control site were not statistically different. Populations of certain groups such as the commercial Pink Shrimp (*Penaeus duorarum*), caridean shrimps, and juvenile fishes, were numerically far higher in the restored area than in control or naturally reestablishing successional seagrasses, and at least an order of magnitude higher than in barren areas that had never recovered from impact.

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TABLE V

Comparisons, in Percentage of Total Abundance, of Major Taxa Collected During Operational Sampling Period and During Four-years' Restored Seagrass Sampling Period.

	AFFECTED**	UNRESTORED† Barren	UNRESTORED† *Halodule*	RESTORED†	UNAFFECTED**	CONTROL†
FISHES						
July	5.0	0.2	0.8	1.0	5.0	*
October	—	0.3	7.7	12.0	1.0	2.0
January	4.0	0.1	4.9	3.0	1.0	13.0
April	4.0	0	0.5	9.0	2.0	1.0
MOLLUSCA						
July	74.0	6.9	20.1	13.0	43.0	*
October	28.0	2.5	21.5	25.0	27.0	16.0
January	50.0	<0.1	13.9	47.0	37.0	12.0
April	29.0	0.3	20.7	46.0	38.0	17.0
DECAPOD CRUSTACEA						
July	21.0	0.1	9.9	12.0	55.0	*
October	67.0	0.2	23.8	43.0	55.0	29.0
January	50.0	0.7	13.3	24.0	30.0	36.0
April	21.0	0	5.0	5.0	30.0	5.0
ANNELIDA (Polychaeta)						
July	—	2.7	5.3	67.0	—	*
October	—	1.2	31.8	16.0	—	36.0
January	36.0	1.2	51.8	13.0	28.0	31.0
April	44.0	0.8	62.2	35.0	23.0	65.0

† Based on trawl samples only.
— No data available.
* Station not sampled.
** Data from Bader & Roessler (1971, 1972) & Roessler *et al.* (1975).

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