THE INTERRELATION OF WATER QUALITY, GILL PARASITES, AND GILL PATHOLOGY OF SOME FISHES FROM SOUTH BISCAYNE BAY, FLORIDA

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ABSTRACT

This study investigated monogenetic trematode infestation of the gills and gill pathology of yellowfin mojarra, *Gerres cinereus* (Gerreidae); gray snapper, *Lutjanus griseus* (Lutjanidae); and timucu (needlefish), *Strongylura timucu* (Belonidae) in relation to water quality in south Biscayne Bay, Florida. Two habitats of the three species in the bay, one in the southeast and the other in the southwest, differed in water quality whereas physical and environmental parameters were similar. The water in southwest Biscayne Bay contained high amounts of ammonia, trace metals, and pesticides which were not present in the southeast bay. The gills of hosts from the habitat with inferior water quality were heavily infested with the Monogenea (Platyhelminthes) *Neodiplectanum wenningeri* (on *G. cinereus*), *Ancyrocephalus* sp. (on *L. griseus*), and *Ancyrocephalus parvus* (on *S. timucu*) and suffered from excessive mucus secretion, epithelial hyperplasia, fusion of gill lamellae, clubbing and fusion of filaments, and aneurisms. Only light infestations and little or no abnormal tissue changes were noted in fish from the area of good water quality. The findings led to the conclusion that the pollutants in the water acted as an irritant, stressing the fish, and producing physical and physiological changes which reduced resistance to infestation by Monogenea.

Manmade pollution of coastal waters of southeast Florida has reached a critical level in the most populated areas, causing substantial environmental degradation (Carter 1974) and the loss of valuable fishing grounds, and making some areas unsuitable for recreation. In recent years, the pollution of Biscayne Bay, Fla. (Fig. 1) has become a major issue. The shore of north Biscayne Bay is bordered by Miami and Miami Beach, and lined by bulkheads. It receives a large amount of runoff water from the metropolitan areas (Waite 1976). Although the southwestern part of the bay still retains much of its natural shoreline and mangrove forests, it is broken by drainage canals intended to lower the water level in neighboring agricultural and urban areas. These canals therefore carry agricultural, industrial, and urban wastes into that part of the bay (Waite 1976). The southeastern shoreline of Biscayne Bay is formed by a chain of islands which is part of Biscayne National Park with no major direct sources of water pollution.

The purpose of this study was to investigate if differences existed in the ectoparasite fauna and possible gill pathology in the same three species of fish living in southwest Biscayne Bay in the entrances of three drainage canals on one hand and the relatively clean waters of the southeast bay in the National Park on the other. The effect of water quality on the incidence and intensity of infestation by ectoparasites was investigated along with the frequency and kind of abnormal tissue changes of the gills. Included were those ectoparasites that came close to 100% incidence on their hosts and had a direct life cycle. Three species of Monogenea of the suborder Monopisthocotylea fell into this category.

Monogenea (Platyhelminthes) of the gills are common in fish. Since parasites affect the health of fish, they can be the cause of or a contributing factor to host mortality and epizootics (Iversen et al. 1971). Disease and mass mortality in aquaculture, often occurring under crowded conditions, are known to have been caused by the genera *Gyrodactylus*, *Dactylogyrus*, and *Tetraonchus* (Wobeser et al. 1976). Since exchange of gases in the gills takes place through a single thin epithelial layer separating the blood from the external environment (Anderson and Mitchum 1974), parasites may cause extensive damage to host gill tissue.

Although many adverse circumstances weaken fish and make them more susceptible to diseases, presently available literature is mainly concerned with bacterial diseases (Pippy and

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Manuscript accepted November 1981.

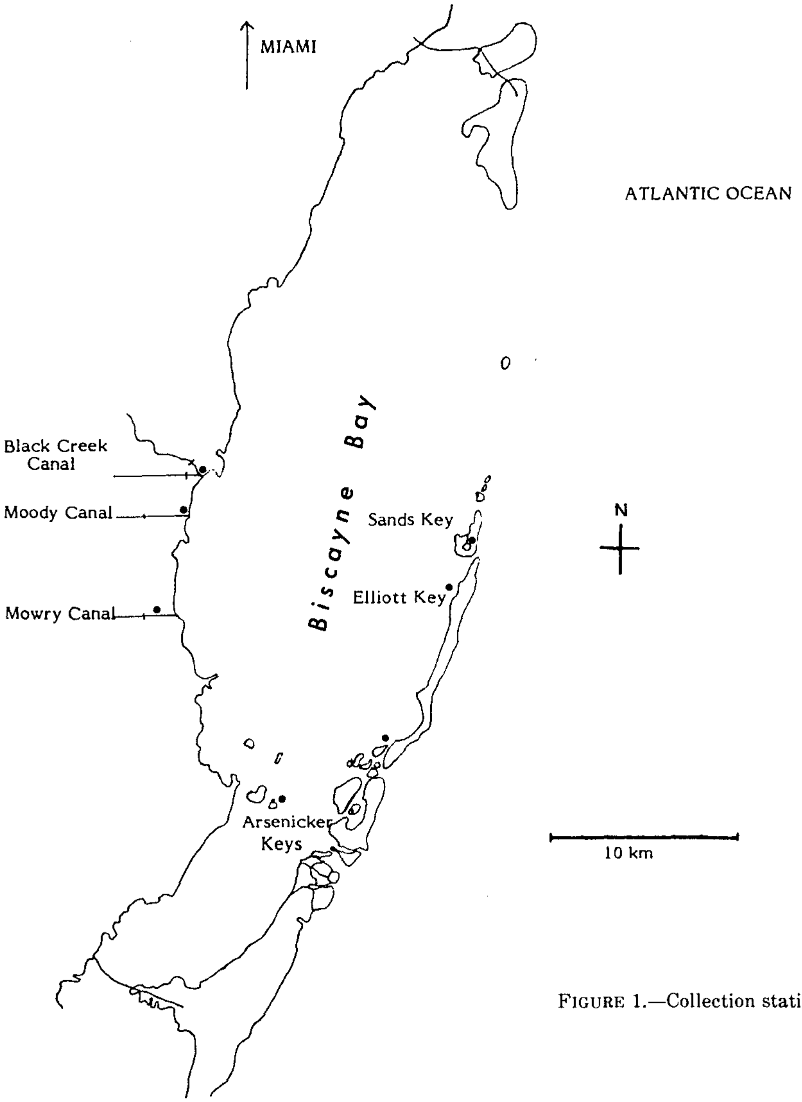

FIGURE 1.—Collection stations in south Biscayne Bay, Fla.

Hare 1969; Bullock et al. 1971; Burrows 1972; Snieszko 1974). Information concerning parasitic diseases in relation to water quality has been obtained in artificial situations such as aquaculture facilities rather than the natural environment. According to Hoffman (1976) eutrophication and pollution probably affect helminth parasites as well as the hosts, but no precise studies have been made. Deleterious effects on various marine biota due to manmade pollution have been investigated, among them disease of fishes and Crustacea (O'Connor 1976; Overstreet and Howse 1977; Sindermann 1979). Overstreet and Howse (1977) suggested that poor environmental conditions may favor parasitic infestation by stressing the host, causing disease and lowering resistance.

In pioneering literature on fish diseases, gill damage other than parasitic was described as due to exposure (Osburn 1911), industrial pollutants (Plehn 1924), and fertilizers (Schäperclaus 1954). More recent literature implicates phenols (Reichenbach-Klinke 1965), ammonia (Reichenbach-Klinke 1966; Smith and Piper 1975), pesticides (Lowe 1964; Walsh and Ribelin 1975), and environmental stress, defined as a change from the normal which reduces the chances for survival (Snieszko 1974). Damage to the gills in response to various toxins in the water was reported by Herbert and Shurben (1964), who suggested that "sublethal effects of each poison can sum within the individual fish and kill it." Minimal risk, hazard and lethal levels, and median lethal concentrations (LC_{50}, the concentration that kills 50% of the test organisms in 96 h) of certain pollutants in the marine environment are published by the National Academy of Sciences Environmental Studies Board (1972). Although both the National Academy of Sciences and conservation organizations have emphasized the need for ecological information on long-term effects of pesticides on wildlife at sublethal doses, most field studies are done after the animals have been found dead. Mitrovic (1972) asked for studies of subtle damage resulting from long-term exposure at subacute levels. Local studies are needed, since environmental conditions vary with location, and temperature, salinity, and pH play a part in the toxicity of poisons (Trussel 1972). Subtle indications of damage, according to Johnson (1968), may be a change in behavior caused by lowered efficiency of the organism. He suggested that the illustration of physiological and ecological effects of sublethal quantities of environmental pollutants will lead to a more realistic view in establishing tolerance levels for all toxic pollutants. This requires year-round monitoring to take into consideration seasonal variation, variation in drainage as a result of precipitation, runoff, and irrigation, as well as fluctuating physical or chemical factors.

MATERIALS AND METHODS

The study period extended from May 1975 to August 1976. The three host species were yellowfin mojarra, *Gerres cinereus* (Walbaum), a bottom feeder; gray snapper, *Lutjanus griseus* (Linnaeus), a predator; and timucu (needlefish), *Strongylura timucu* (Walbaum), a surface feeder, since they were available on both sides of south Biscayne Bay and remained in one locality for extended periods (Cervigon 1966; Randall 1968; Cressey and Collette 1971; Starck 1971).

Collection stations for the fish were the mouths of Black Creek, Moody, and Mowry Canals; the Arsenicker Keys; Elliott Key; and a canal in Sands Key (Fig. 1). South Florida Water Management District maintains salinity control structures a short distance inland from the southwestern shoreline of Biscayne Bay at Black Creek, Moody, and Mowry Canals. Directly upstream from the gates the water is brackish. The flood gates open automatically according to the difference in the water level on both sides when the water exceeds a certain height on the upland side. For many months during the study period the gates of the salinity structures remained closed because of the low freshwater table inland and the danger of saltwater intrusion into inland wells. Fish were collected downstream from the salinity control structures near the entrances of Moody and Mowry Canals into the bay, at the confluence of Black Creek and Goulds Canals where they enter the bay, in mangrove creeks and close to shore at Arsenicker and Elliott Keys, and in a manmade canal and lagoon in the interior of Sands Key.

Collections were made between April 1975 and August 1976 during three to five trips per week, depending upon weather conditions. The total number of fish collected was 356, of which 186 were from the southwest locations and 170 from southeast Biscayne Bay (Table 1). Only one species was collected on a given day from one area to prevent exchange of parasites from one host species to the other. The yellowfin mojarra were caught by gill net, 75 mm mesh size (stretch), and occasionally on hook and line; the gray snapper on hook and line; and the timucu (needlefish) on hook and line, and by beach seine. Collection trips to the stations were alternated regularly, depending on weather conditions and need. Because of the gear used, size ranges of fish were the same in both localities. Sex ratios were similar, with an average of 52% males and 48% females.

Fish were collected at depths between 0.5 m and 2.5 m. Water samples for the salinity readings were obtained from depths of 0.3 m, 1.0 m, and 3.0 m. An average of 2.5 salinity measurements per month were made at each station and each depth. To avoid contamination a closed, weighted plastic bottle was lowered to the desired depth where it opened and filled with water. Additional salinity data for the years 1975 and 1976 from Black Creek, Mowry, and Moody Canals downstream from salinity structures were made available by the U.S. Geological Survey (USGS) and South Florida Water Manage-

TABLE 1.—Numbers of fish hosts collected in the southeast and southwest locations in Biscayne Bay, Fla., between May 1975 and August 1976.

	S.E. Biscayne Bay	S.W. Biscayne Bay
Gerres cinereus	69	52
Lutjanus griseus	57	80
Strongylura timucu	44	54
Total	170	186

ment District (SFWMD) (unpubl. data). Temperature and dissolved oxygen measurements were taken at 0.3 m and 1.0 m depths. The average of two or three readings represent one measurement. The average number of measurements was two to three per month at each station. Data of hydrogen ion concentration expressed as pH were obtained from the Dade County Department of Environmental Resources Management (DERM) and USGS (unpubl. data).

DERM and USGS obtained routine monthly water quality data for Black Creek, Mowry, and Moody Canals downstream from salinity structures and made them available for this study. The DERM laboratory also made water quality analyses of eight southeast Biscayne Bay water samples collected at intervals of 2 mo. The samples, taken from slick-free water (see Discussion section), were kept in plastic bottles which contained a few milliliters of hydrosulfuric acid for preservation, and were refrigerated until arrival in the laboratory. Chemical analyses were made for total ammonia nitrogen, nitrite, nitrate, phosphate, and total organic carbon. DERM and USGS furnished data on heavy metals in Black Creek and Mowry Canals and pesticides in Black Creek Canal.

Fish were kept alive in an aerated plastic container until arrival and dissection at the laboratory. Body surface, fins, gills, gill covers, and mouth were searched for parasites; the gill arches and single parasites fixed and preserved; and the parasites identified and counted. When parasites were too numerous for total counts, estimations of numbers per gill arch were made from counts per gill filament. Formalin,[2] AFA (alcohol-formol-acetic acid) fixative, and Bouin's solution were used to fix whole gill arches and trematodes. They were preserved in 70% ethanol. For the purpose of identification whole mounts were made of Trematoda using Harris hematoxylin and Permount. Whenever possible, original descriptions of parasites were used for identification together with Yamaguti's (1963, 1971) keys for identification of trematode genera. Histological sections of 12 entire gill arches from 12 fish were examined. Arches were decalcified prior to embedding and cut at 8 μm. Sections were mounted, stained with hematoxylin and eosin (H&E) and Periodic Acid Schiff (PAS). Histological techniques were after the method described by Humason (1972). Statistical evaluation of all station salinity data consisted of calculations of standard deviation (Snedecor and Cochran 1967).

RESULTS

Water Quality

Variations in salinity occur in Biscayne Bay from year to year because of climatic conditions. The salinity readings of all stations were similar during the dry season of 1976, mainly January to June (Table 2). Maximum salinities in both the bay and canal entrances were 40-41‰ at this time. More freshwater discharge into the canals and Biscayne Bay during the rainy season in the fall accounted for a slight drop in salinity and some fluctuation mainly in the canals at that time. The lowest salinity reading from surface water samples from the entrance of Moody Canal in September indicated that freshwater discharge was more noticeable in this narrow canal than in the others. Some salinity measurements were taken immediately after freshwater discharge (see Table 2, footnotes). A typical reading showed that the fresh water flowed as a shallow surface layer about 30 cm deep out of the canals. During freshwater discharge, salinity at the surface varied from 5‰ to 15‰; at a depth of 30 cm it rose by 15-20‰, and at a depth of 1 m it was close to the reading before the discharge, indicating that there was little vertical mixing.

The statistical analysis of monthly averages of salinity data of all stations of 1.0 m depth showed that two-thirds of the values fell within one standard deviation of 1.85 on each side of the mean of 36.8‰. Temperatures reflected seasonal changes at all stations and were similar, with most values between 20° and 30°C (Table 2). Differences may reflect the time of day when readings were taken. Dissolved oxygen concentration fluctuated mainly at canal entrances. Values ranged from 4 ppm to above 8 ppm (Table 2). Values below 6.8 ppm did not occur in southeast Biscayne Bay.

Phosphates, ammonia, nitrites, and nitrates present at the collection sites from May 1975 to August 1976 are listed in Table 3. The southeast Biscayne Bay water quality data were similar to those of de Sylva[3] and Bader and Roessler[4]. In general, southeast bay values were low in all

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

[3] de Sylva, D. P. 1970. Ecology and distribution of post-larval fishes in southern Biscayne Bay, Florida. Univ. Miami

TABLE 2.—Monthly average of salinity, temperature, dissolved oxygen (DO) concentration and pH in southeast Biscayne Bay and southwest Biscayne Bay at Black Creek, Mowry, and Moody Canals, Fla. (at depth 1.0 m).

Location/ date	Salinity (‰)				Temp. (°C)				DO (ppm)	
	No.	Max.	Min.	Avg.	No.	Max.	Min.	Avg.	Avg.	pH
S.E. Biscayne Bay										
June 1975	1	34	34	34	2	30	30	30	7.5	—
July 1975	2	35	35	35	3	34	32	32	—	—
Aug. 1975	2	35	35	35	3	34	33	34	6.9	—
Sept. 1975	2	35	35	35	3	34	30	32	—	—
Oct. 1975	4	39	36	37	3	33	29	30	7.8	—
Nov. 1975	3	38	36	37	1	22	22	22	—	—
Dec. 1975	2	38	38	38	1	23	23	23	8.0	—
Jan. 1976	3	38	38	38	3	22	19	20	—	—
Feb. 1976	2	38	36	38	2	20	19	20	8.2	—
Mar. 1976	5	39	38	39	2	25	20	22	—	—
Apr. 1976	2	38	38	38	3	29	25	27	8.1	—
May 1976	3	40	38	39	3	31	24	27	—	—
June 1976	2	40	39	[1]40	3	31	28	29	7.8	—
July 1976	—	—	—	—	3	34	31	32	—	—
Aug. 1976	—	—	—	—	2	33	30	32	—	—
S.W. Biscayne Bay at Black Creek Canal										
May 1975	1	34	34	34	1	29	29	29	4.5	7.4
June 1975	2	37	35	36	1	29	29	29	4.5	7.3
July 1975	4	39	35	38	3	30	30	30	4.7	7.2
Aug. 1975	2	38	38	38	4	31	30	31	4.7	7.3
Sept. 1975	4	36	34	35	2	31	31	31	4.2	7.3
Oct. 1975	1	36	36	36	1	29	29	29	5.1	7.5
Nov. 1975	3	38	35	37	3	27	27	27	7.2	7.9
Dec. 1975	2	38	36	37	1	22	22	22	5.1	7.5
Jan. 1976	3	38	37	37	3	22	21	22	8.6	7.9
Feb. 1976	1	38	38	38	1	26	26	26	4.3	7.8
Mar. 1976	3	40	38	39	3	25	25	25	5.2	8.0
Apr. 1976	2	39	38	39	3	27	25	26	5.3	8.2
May 1976	2	40	39	40	3	28	25	27	3.6	7.4
S.W. Biscayne Bay at Mowry Canal										
June 1975	1	34	34	34	3	30	30	30	4.0	7.8
July 1975	2	35	34	[2]35	3	31	30	31	4.2	7.4
Aug. 1975	4	36	32	[3]35	3	31	31	31	—	7.5
Sept. 1975	2	35	35	35	4	31	30	31	6.2	7.8
Nov. 1975	2	37	36	37	3	30	28	28	7.4	7.8
Dec. 1975	—	—	—	—	2	23	23	23	8.0	8.0
Jan. 1976	1	35	35	35	1	21	21	21	6.5	7.7
Feb. 1976	3	36	35	36	4	22	21	21	7.5	7.9
Mar. 1976	2	40	38	39	3	26	22	25	7.6	8.1
Apr. 1976	2	40	37	39	3	27	25	26	5.2	8.0
May 1976	1	40	40	40	1	26	26	26	5.2	7.4
June 1976	2	38	36	37	2	29	29	29	4.0	7.4
S.W. Biscayne Bay at Moody Canal										
May 1975	—	—	—	—	2	29	29	29	4.0	7.8
June 1975	3	35	34	35	—	—	—	—	—	—
July 1975	—	—	—	—	1	29	29	29	4.2	7.5
Aug. 1975	4	36	36	36	2	31	31	31	4.2	7.5
Sept. 1975	—	—	—	—	1	30	30	30	4.8	7.5
Oct. 1975	1	35	35	35	3	31	29	30	4.5	7.4
Nov. 1975	1	36	36	36	2	29	25	27	6.0	7.8
Dec. 1975	2	38	30	[4]34	3	29	23	26	7.2	7.9
Jan. 1976	1	35	34	35	2	20	20	20	8.0	7.8
Feb. 1976	2	36	35	36	3	22	22	22	8.8	7.8
Mar. 1976	1	37	37	37	1	25	25	25	6.0	7.9
Apr. 1976	—	—	—	—	1	26	26	26	5.2	7.9
May 1976	1	41	41	41	1	26	26	26	4.8	7.8
June 1976	1	36	36	36	1	30	30	30	4.2	7.5

[1] 17 July 1976 salinity reading during rainstorm: 10 at surface, 36 at 30 cm depth, 39 at 1 m depth.
[2] 30 July 1975 salinity reading, gates open Mowry Canal: 15 at surface, 31 at 30 cm depth, 35 at 1 m depth.
[3] 5 August 1975 salinity reading, gates open Mowry Canal: 10 at surface, 27 at 30 cm depth, 32 at 1 m depth.
[4] 10 December 1975 salinity reading, gates open Moody Canal: 5 at surface, 20 at 30 cm depth, 30 at 1 m depth.

TABLE 3.—Monthly nutrient[1] values (mg/l) in southeast and southwest Biscayne Bay, Fla., locations (at depth 0.3-1.0 m) (Dade County Department of Environmental Resources Management unpubl. data).

Location/ date	PO_4	TOC	TAN	NO_2	NO_3
S.E. Biscayne Bay at Elliot Key					
July 1975	0.00	7.0	0.00	0.00	0.00
Sept. 1975	0.00	1.0	0.00	0.00	0.01
Dec. 1975	0.02	9.0	0.00	0.00	0.07
Feb. 1976[2]	0.05	12.0	0.00	0.003	0.002
Apr. 1976	0.00	—	0.00	0.00	0.002
June 1976	0.017	—	0.00	0.002	0.025
July 1976[3]	0.338	0.224	0.012	0.00	0.265
Aug. 1976[3]	0.380	0.336	0.012	0.00	0.168
S.W. Biscayne Bay at Black Creek Canal					
May 1975	0.32	7.0	0.10	0.01	0.01
June 1975	0.64	7.0	0.48	0.02	0.30
July 1975	0.12	4.0	0.72	0.21	0.48
Aug. 1975	0.48	—	—	—	—
Sept. 1975	0.40	6.0	0.59	0.10	0.56
Oct. 1975	0.25	4.0	0.45	0.06	0.43
Nov. 1975	0.09	—	—	—	—
Dec. 1975	0.25	4.0	0.44	0.24	1.5
Jan. 1976	0.00	4.0	1.0	0.30	2.1
Feb. 1976[2]	0.50	6.0	0.51	0.11	1.8
Mar. 1976	0.18	—	—	—	—
Apr. 1976	—	6.0	0.03	0.16	1.2
May 1976	—	1.0	0.32	0.03	0.36
Aug. 1976[3]	0.04	11.0	0.31	0.01	0.08
S.W. Biscayne Bay at Mowry Canal					
May 1975	0.02	—	0.48	0.01	0.00
June 1975	0.00	6.0	0.44	0.01	0.20
July 1975	0.00	1.0	0.30	0.02	0.12
Sept. 1975	0.00	1.0	0.10	0.01	0.02
Oct. 1975	0.01	3.0	0.05	0.02	0.68
Dec. 1975	0.01	1.0	0.04	0.01	0.50
Jan. 1976	0.11	3.0	0.04	0.03	0.59
Feb. 1976[2]	0.40	3.0	0.05	0.01	0.48
Mar. 1976	0.07	—	—	—	—
Apr. 1976	0.01	2.0	0.03	0.01	0.17
May 1976	0.05	3.0	0.04	0.02	0.70
Aug. 1976[3]	0.01	6.0	0.03	0.01	0.32
S.W. Biscayne Bay at Moody Canal					
May 1975	0.00	—	0.06	0.00	0.00
June 1975	0.02	1.0	0.04	0.00	0.01
July 1975	0.00	—	—	—	—
Sept. 1975	0.01	—	—	—	—
Oct. 1975	0.02	1.0	0.06	0.02	0.32
Dec. 1975	0.01	3.0	0.04	0.02	0.48
Jan. 1976	0.00	3.0	0.04	0.03	0.50
Mar. 1976	0.14	3.0	0.03	0.01	0.30

[1] TOC = Total organic carbon, TAN = Total ammonia nitrogen. The term "total" refers to the amount present both in solution and in suspension.
[2] Arsenicker Keys.
[3] Sands Key.

nutrients. Nutrient concentrations were considerably higher in the southwest, especially ammonia values. The water sample taken in April 1976 near Arsenicker Keys contained high total organic carbon compared with the other samples because of the proximity of an extensive mangrove coastline and the presence of mangrove detritus in the water. The two July 1976 water samples from Sands Key were taken in a canal and small lagoon inside the Key surrounded by mangroves and connected to the bay. At low tide, about two-thirds of the bottom muds of the lagoon were exposed, the canal was rich in fish, and wading birds fed in the flats at low tide. The somewhat higher content of ammonia, nitrates, and phosphates was due to decaying vegetation, the exposed mud flats, animal concentrations, and little flushing. Trace metals were present in water samples from the southwest locations only (Table 4). None were detected with standard methods in water samples from the southeast bay. Those pesticides either present or not detected in the water in Black Creek during the time of this study are shown in Table 5. None were detected with standard methods in the southeast bay. As in all the other southeast bay samples, no pesticides or heavy metals were detected in Sands Key samples. The junction of Black Creek and Goulds Canals and the south-

TABLE 4.—Potentially harmful trace metals (μg/l, total) in southwest Biscayne Bay locations of Black Creek and Mowry Canals, Fla., from May 1975 to May 1976 (USGS unpubl. data).

	Black Creek Canal				Mowry Canal				Hazard level to marine biota[1]	Minimal risk level to marine biota[1]	Source
	May 1975	Oct. 1975	Jan. 1976	Apr. 1976	May 1975	Oct. 1975	Jan. 1976	Apr. 1976			
As	2	2	—	2	—	1	1	1	50	10	Paints; pesticides; industry
Pb	4	7	19	20	—	7	9	38	50	10	Gasoline fuel; industry
Mn	4	20	0	0	—	0	0	0	100	20	Industry; paints
Hg	0.2	0.2	0.2	0.5	—	0.1	0.2	0.6	0.1	—	Pesticides; paint plastics and paper industry
Zn	2	2	20	0	—	—	—	—	100	20	Plating industry

[1] Natl. Acad. Sci., Natl. Acad. Eng., Environ. Stud. Board (1972).

Sch. Mar. Atmos. Sci., Prog. Rep. Fed. Water Qual. Admin., 198 p.

[4] Bader, R. G., and M. A. Roessler. 1971. An ecological study of south Biscayne Bay and Card Sound, Florida. Rosenstiel Sch. Mar. Atmos. Sci., Univ. Miami.

TABLE 5.—Pesticides (μg/l) in southwest Biscayne Bay location of Black Creek Canal, Fla., from July 1975 to August 1976 (USGS unpubl. data).[1]

Date	Diazinon[2]	2,4-D[3]	Silvex[4]	Parathion[5]
July 1975	0.02	0.00	0.02	—
Dec. 1975	0.06	0.00	0.00	0.02
Aug. 1976	0.00	0.27	0.10	0.00

[1] Pesticides not found present in Black Creek Canal water samples were: Aldrin, Chlordane, DDD, DDE, DDT, Dieldrin, Endrin, Ethion, Heptachlor, Heptachlorepoxide, Lindane, Malathion, Methyl-parathion, Methyltrithion, PCB, Toxaphene, Trithion, and 2,4,5-T.
[2] 0,0-Diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate.
[3] 2,4-Dichlorophenoxy (acetic acid).
[4] 2-(2,4,5-Trichlorophenoxy) propionic acid.
[5] 0,0-Diethyl-0-p-nitrophenyl phosphorothioate.

west bay was found to be the highest in nutrients and trace metals. Direct sources of pollution may have been waste discharge from boats, marinas, agriculture, suburban developments, and the nearby county dump. Slightly lesser amounts were found at the Moody and Mowry stations which were located some distance from inhabited areas. Pesticide data were not available from the Moody and Mowry stations, although chemical pest and weed control conducted at the time along the banks and in the vicinity of the canals would have been a direct source of pesticides in the water.

Parasites

The parasite fauna in both the southeast and southwest Biscayne Bay habitats was similar in kind for all three hosts, consisting mainly of previously reported ectoparasites of marine fishes of the same and related species or those sharing similar habitats. The three monogenetic gill parasites—*Neodiplectanum wenningeri*, *Ancyrocephalus* sp., and *A. parvus*—showed close to 100% incidence and were therefore suitable for this study. Incidence of infestation was as follows: *N. wenningeri* on *G. cinereus*, 97% in southeast Biscayne Bay, 100% in southwest Biscayne Bay locations; *Ancyrocephalus* sp. on *L. griseus*, 100% in southeast Biscayne Bay, 100% in southwest Biscayne Bay; *A. parvus* on *S. timucu*, 100% in southeast Biscayne Bay, 100% in southwest Biscayne Bay.

The difference in intensity of infestation of hosts by these parasites was striking, with few parasites on host gills from the southeast locations and extremely large counts on hosts from the southwest locations (Table 6).

Pathological Changes in Host Gills

Neodiplectanum wenningeri created comparatively little histological disturbance of the gills when infestation was light. Damage was often mechanical and gill lamellae were deflected. In severe cases of infestation, however, the lamellae were covered with *N. wenningeri*, and an increase in mucus production was noticed along with clubbing of filaments where parasites were attached. Similarly, when numerous, *Ancyrocephalus* sp. and *A. parvus* caused pathological changes at the site of attachment. Localized host reaction to the parasites' hooks included epithelial hyperplasia and heavy mucus production (Fig. 2), and the respiratory epithelium was lost in some instances. Often the side of the filament opposite the worm attachment was also affected

TABLE 6.—Averages of some nutrients, trace metals, and pesticides in water samples, and Monogenea and gill pathology of the three host species in southeast Biscayne Bay and southwest Biscayne Bay at Black Creek Canal from May 1975 to August 1976.

	Southeast Biscayne Bay				Southwest Biscayne Bay at Black Creek Canal			
Component	Min.	Avg.	Max.	No. of samples	Min.	Avg.	Max.	No. of samples
Total ammonia nitrogen mg/l	0.00	0.00	0.012	6	0.03	0.45	1.0	11
Arsenic μg/l	0.00	0.00	0.00	6	2.0	2.0	2.0	3
Lead μg/l	0.00	0.00	0.00	6	4.0	12.5	20.0	4
Manganese μg/l	0.00	0.00	0.00	6	4.0	6.0	20.0	4
Mercury μg/l	0.00	0.00	0.00	6	0.2	0.28	0.5	4
Diazinon μg/l	0.00	0.00	0.00	6	0.02	0.026	0.06	3
2,4-D μg/l	0.00	0.00	0.00	6	0.00	0.09	0.27	3
Silvex μg/l	0.00	0.00	0.00	6	0.00	0.04	0.10	3
Parathion μg/l	0.00	0.00	0.00	6	0.00	0.01	0.02	2
Neodiplectanum wenningeri no./gill arch	0.00	0.625	5	69	25	72.5	>100	52
Ancyrocephalus sp. no./gill arch	0.1	1.4	8	57	69	124.75	>500	80
Ancyrocephalus parvus no./gill arch	0.3	2.25	4.5	44	61	89.25	>200	54
Pathological changes[1]	None	None	Slight	170	Moderate	Severe	Severe	186

[1] Slight = mucus production above normal; moderate = heavy mucus production and epithelial hyperplasia; severe = fusion of lamellae, loss of structure.

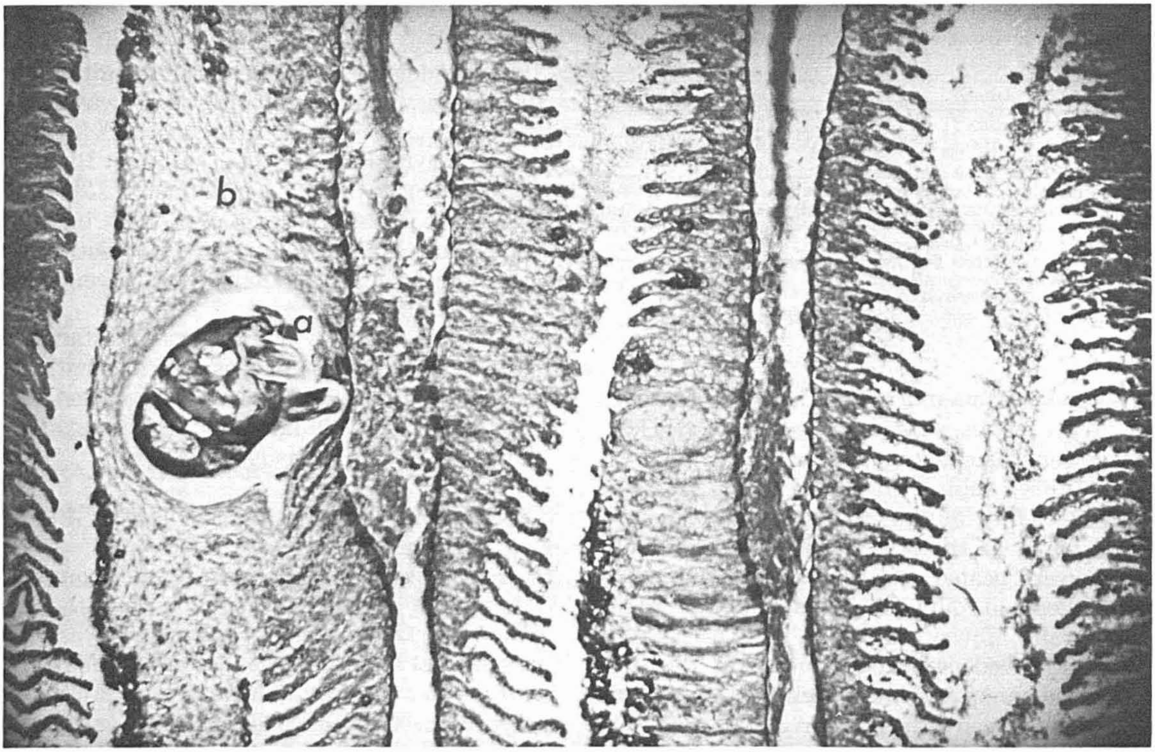

FIGURE 2.—Photomicrograph of *Ancyrocephalus* sp. on the gills of *Lutjanus griseus*, 22.0 cm SL, from southwest Biscayne Bay, Fla. (PAS, 75×) showing hyperplasia, loss of respiratory epithelium, excessive mucus, lamellar fusion, and aneurisms. a) parasite; b) mucus.

in a similar manner (Fig. 3). In addition to injury caused by the hooks of the parasite, the lamellae were deflected and adhered to each other, thus reducing the gill surface effective for gas exchange. In severe cases when a number of worms were attached to the tips of filaments, clubbing of filaments was almost always present, as was obliteration of normal filament structure. The affected filaments appeared white in fresh preparations and the gills were congested with mucus.

Histological changes of the gills not associated with parasites were found in hosts from southwest Biscayne Bay stations. Few southeast Biscayne Bay fish showed above-normal production of mucus in the gills. Increased mucus production was evident in all fish from the southwest locations, and pathological changes ranged from moderate to severe (Table 6). Abnormal color changes were frequent in southwest Biscayne Bay fish and were usually associated with overproduction of mucus which congested the gills. Histological sections of gills from these fish showed that whole filaments were lined with mucus and that it filled the spaces between the filaments. Additionally, mucus-producing cells were concentrated, sometimes in several layers, at the tips of gill filaments which had lost their normal structure. Fusion of gill lamellae along entire filaments, epithelial hyperplasia, clubbing of lamellae or obliteration of lamellar structure, aneurisms, and clubbing of filaments occurred frequently, along with proliferation of cells at the bases of lamellae.

DISCUSSION

According to Grundmann et al. (1976), helminth populations in a natural environment are well regulated to a point of host comfort. Although the results from the southeastern habitat in this study agreed with this statement, those from the southwest bay locations did not. Disease caused by parasites often requires exogenous as well as endogenous factors (Sindermann 1979). Exogenous factors, as defined by Cameron

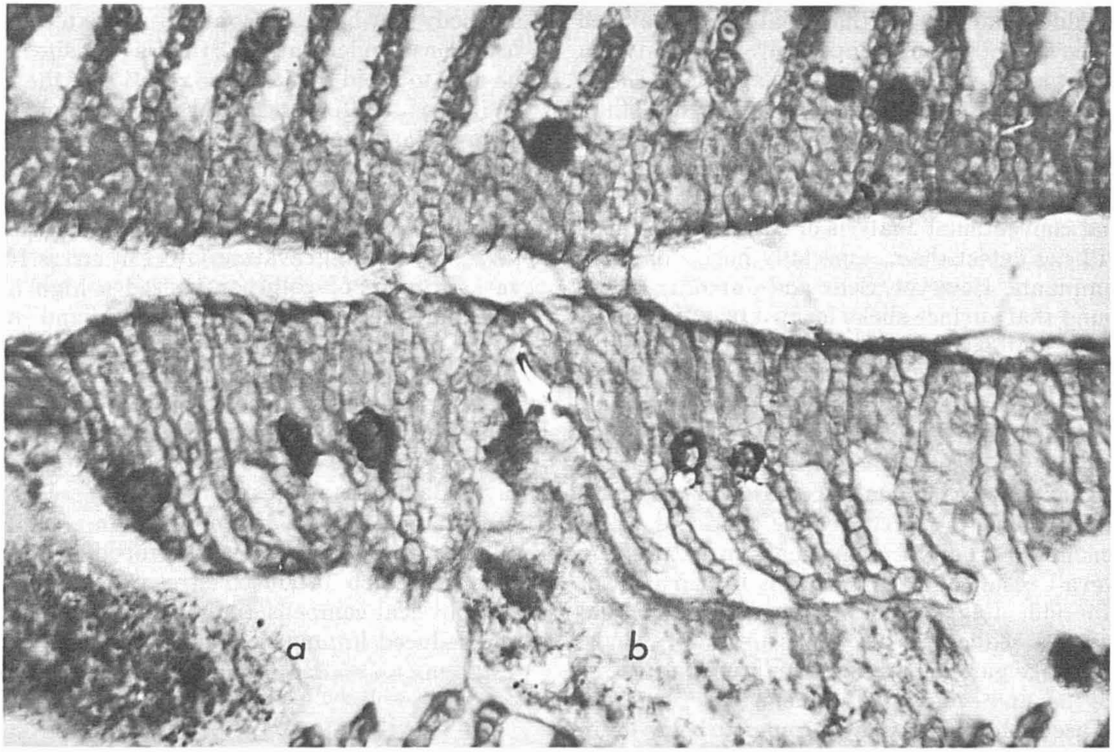

FIGURE 3.—Photomicrograph of two *Ancyrocephalus parvus* on the gills of *S. timucu*, 24.3 cm SL, from southwest Biscayne Bay, Fla. (PAS, 300×). Lamellae are deflected and obstructed. a) and b) parasites.

(1958), are alterations in the ecology of the parasites or hosts by some abnormal or unnatural event, most often manmade.

The most outstanding difference between the southeast Biscayne Bay and southwest locations was the difference in chemical water quality. According to Klontz (1972), fish are so intimately associated with their aqueous environment that physical or chemical changes in this environment are often rapidly reflected as measurable physiological changes in the fish. In general, reactions of fish gills to an irritant include inflammation, hyperplasia, lamellar fusion, excessive mucus production, clubbing of filaments or lamellae, and formation of aneurisms.

Aneurisms may be a specific tissue reaction due to injury or toxic substances, especially ammonia or herbicides in the water or food (Eller 1975). Ammonia frequently has been reported to cause extensive gill damage. Although much of the data on the degree of toxicity of ammonia is not satisfactory (National Academy of Sciences Environmental Studies Board 1972), it has been shown that the more toxic component of ammonia solutions is the unionized ammonia (NH_3). An increase in pH from the normal level increases the toxicity, because along with temperature it controls the degree of dissociation (Trussel 1972). A decrease in dissolved oxygen concentration increases the toxicity of unionized ammonia (National Academy of Sciences Environmental Studies Board 1972). Even low concentrations may cause pathological changes in marine and freshwater organisms (Doudoroff and Katz 1950; Flis 1968; Larmoyeux and Piper 1973). In addition to exhibiting gill damage, after exposure to NH_3 freshwater fish were susceptible to ectoparasites, according to Reichenbach-Klinke (1966). Prolonged exposure to nonlethal dosage of ammonia in salmon led to hyperplasia of gill epithelium and epizootic bacterial gill disease in a study by Burrows (1964).

Pollutants such as metals and pesticides show similar effects on fish gills (Gardner 1975). The LC_{50} and sublethal effects of pesticides are presently under scrutiny. According to Anderson (1971), for pollutants not to influence the physiology and behavior of fish, "safe" concentrations should be 0.01-0.05 of the lethal concentrations. Since a small rise in temperature or salinity can shift the LC_{50} by one order of magnitude (Eisler 1972), most pesticides may be more harmful than previously assumed. A synergistic effect of several sublethal concentrations of pollutants is possible. They may exist in such low concentrations that conventional analysis or collection methods will not detect them, especially herbicidal contaminants. However, Seba and Corcoran (1969) found that surface slicks formed by a film of organic matter concentrated pesticides in southwest Biscayne Bay to detectable levels, up to 137 times as much as slicks in the Florida Current.

Although the reaction of gill tissue to toxic chemicals appears to be nonspecific in regard to the particular chemicals present, and it is therefore difficult to indict any one particular component or group of components in nature, the overall result of gill damage is impairment of function. Regardless of cause, pathological changes reduce the useful respiratory surface and make gas exchange difficult, which stresses the fish and eventually weakens it.

Disease has been known to change behavior in fish (National Academy of Sciences 1973) and influence their chance for survival. Impaired function of an organ and reduced efficiency require expenditure of energy which cannot be used for other life processes such as feeding, reproduction, and predator avoidance. In case of gill damage, metabolic activity must be reduced to a minimum in order to reduce oxygen demand (Wedemeyer et al. 1976), and the fish become weakened and stressed. Selye's (1950) definition of stress was used in reference to fish by Wedemeyer (1970): "the sum of all the physiological responses by which an animal tries to maintain or reestablish a normal metabolism in the face of a physical or chemical force." Unfortunately, some of the metabolic changes may also contribute to increased susceptibility to disease (Wedemeyer et al. 1976).

When fish are weakened by environmental factors, chemicals, or poor nutrition, their resistance to infestation and infection by Monogenea, *Trichodina*, and bacteria is reduced (Schäperclaus 1954; Wedemeyer et al. 1976). These facts are well known to the aquaculture and aquarium industries. Most research on immune reactions is done in human and veterinary medicine, but parallels can be drawn since fishes' immune systems, although less advanced, resemble those of other vertebrates (Sindermann 1970). Mucus antibody may be active against some external infestations (Anderson 1974); thus, a parasite must be able to avoid the immune reaction of the host (Williams 1970). Stress-provoked physiological changes may cause a disturbance of the host's immune system, and damaged or irritated gills can then become heavily infested with parasites. Snieszko (1974) shared the belief of other scientists that the aggravating effect of stress from various types of pollution caused a high incidence of infectious disease in fishes, and mentioned that this belief, unfortunately, was not yet adequately documented. Sindermann (1979) summarized some of the recent supporting evidence that toxins have a deleterious effect on the immune response of fishes. This study of Biscayne Bay fishes suggests that, in the presence of sublethal quantities of pollutants in a natural marine environment, fish suffered from gill damage which produced stress, physiological and physical compensation, leading to weakening, reduced immunity, and heavy parasitic infestation.

ACKNOWLEDGMENTS

I thank Edwin S. Iversen, Eugene F. Corcoran, and Donald P. de Sylva of the Rosenstiel School of Marine and Atmospheric Science, University of Miami; and George T. Hensley and Lanny R. Udey of the School of Medicine, University of Miami, for their advice and assistance during this study.

Special thanks go to James T. Tilmant, Biscayne National Monument; James F. Redford, Jr., Dade County Commissioner; Henry J. Schmitz and Edward Gancher, Dade County Department of Environmental Resources Management; Robert L. Taylor, South Florida Water Management District; and Keith Dekle, Florida Power and Light Company, for help with field work and obtaining water quality data.

I am grateful to Fay Mucha, Rosenstiel School of Marine and Atmospheric Science, University of Miami; and Elaine Kraus, Medical School, University of Miami, for assistance with histological work and photomicrography.

Funds were provided by the Rosenstiel Fund, University of Miami, RSMAS. The Richard G. Bader Memorial Student Fund supplied a gill net and photographic material. This is a contribution from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149.

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