FISHES, MACROINVERTEBRATES, AND HYDROLOGICAL CONDITIONS OF UPLAND CANALS IN TAMPA BAY, FLORIDA[1]

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ABSTRACT

Faced with statutory restraints that prohibit dredging and filling of estuarine bottoms, coastal developers have turned to alternate methods of providing water front property for homesites. One method, recently used in Tampa Bay, Fla., is the construction of access canals that lead from open water to upland acreage.

This paper presents biological and hydrological data from new upland canals together with some comparative data from older upland canals and bayfill canals. In all types of canals, as presently engineered, stratified, stagnant water causes low levels of dissolved oxygen in summer months, resulting in mortality or emigration among resident organisms. Means of alleviating the problems are discussed.

Among Florida's 322,000 ha of estuarine habitat less than 2 m deep, about 24,000 ha have been filled by coastal developers (Marshall, 1968). Public indignation over indiscriminant and unregulated exploitation of these areas has stimulated legislative action designed to conserve and protect natural resources in estuarine areas that remain (Linton and Cooper, 1971). Faced with statutory restraints, coastal developers have, in some instances, abandoned plans for further bay filling and now seek alternate ways to create premium homesites that will satisfy ever-increasing public demand for waterfront property. One way is the construction of access canals that lead from open water to upland acreage (Barada and Partington, 1972). This method was recently used in Tampa Bay in northeast St. Petersburg, Fla., to connect a housing development with the estuary.

Shortly after draglines removed earth plugs between the excavated canal system and the bay, property owners gave this Laboratory permission to monitor the canals so that ecological conditions in the manmade waterways could be documented. This report contains ecological data recorded at canal and control stations during the first 13 months after the waterway system was completed. Conditions within the upland canal are compared with those recorded in bayfill canals of Boca Ciega Bay, Fla., and older upland canals.

DESCRIPTION OF AREA

The study area, known as Tanglewood Estates, is located at the southern end of Old Tampa Bay on a tract of land that was originally drained by a small tidal inlet of approximately 0.5 ha (Figures 1 and 2). During development, the inlet was dammed and pumped dry. Canals were dug to a depth of approximately 4 m below mean low water and stabilized by concrete seawalls (Figure 3). Bay water was introduced into the ditches in June 1970 creating a canal system of approximately 1.6 ha. Average tidal range in the canal system is about 1 m.

PROCEDURES

Hydrological (five stations) and biological (four stations) samples were collected monthly

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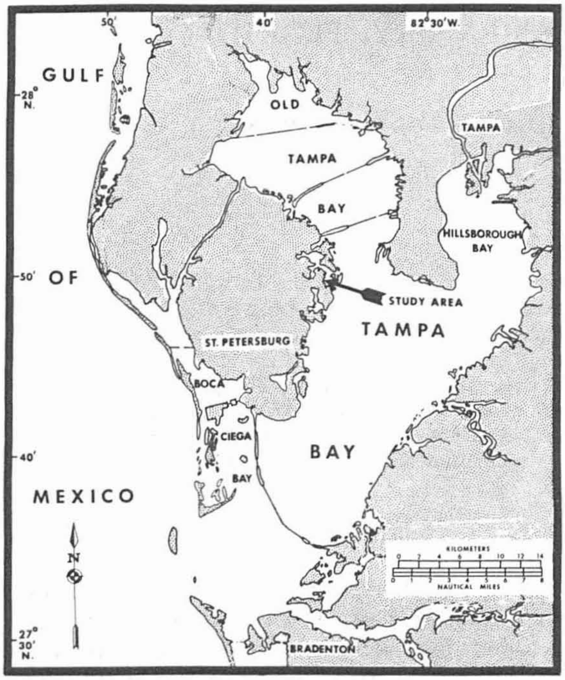

FIGURE 1.—Tampa Bay, Fla., showing location of study area.

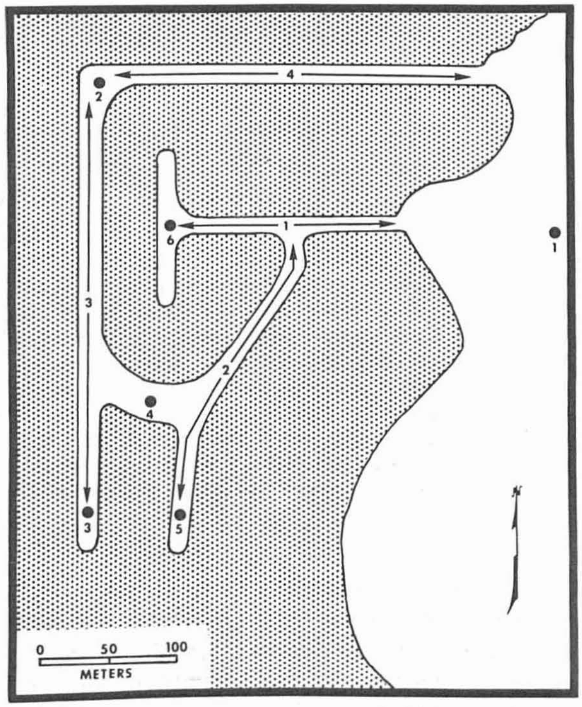

FIGURE 3.—Study area after alteration (hydrologic station •; trawl station ⟷).

within the canals between 0830 and 1130 hr from August 1970 through August 1971. Also, a hydrological control station, Station 1, was established in the bayou adjacent to the development site to monitor ambient water conditions in a natural area (Figure 3). Hydrological factors were recorded from surface and bottom water and included water temperature, dissolved oxygen, and salinity. Temperature was recorded to the nearest tenth of a degree with a handheld mercury thermometer; dissolved oxygen was determined by a modified Winkler method (Strickland and Parsons, 1968); and salinity was determined with a Model 10401 TS Goldberg refractometer[3].

Fish and invertebrates were collected with a 4.8-m otter trawl composed of a 2.5-cm stretched

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

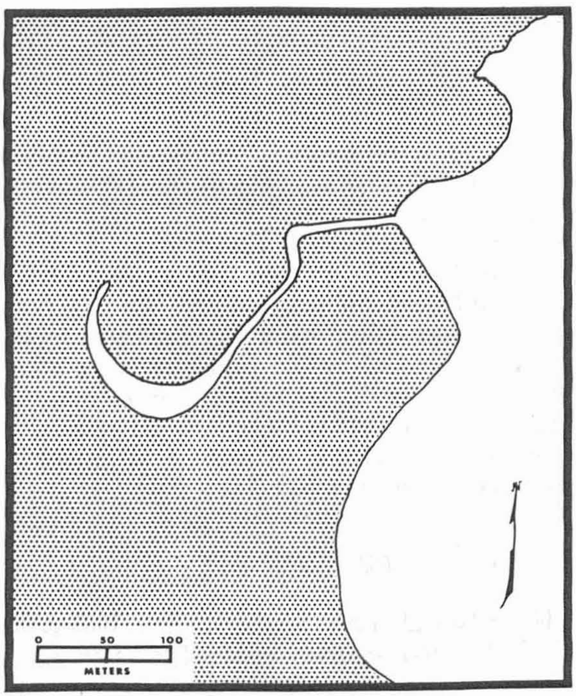

FIGURE 2.—Study area before alteration.

mesh body fitted with a 0.6-cm mesh inner liner in the cod end. No suitable control station for trawling was established in the adjacent bayou because of numerous snags and oyster beds. Specimens from the trawl were killed in a 10% Formalin-seawater solution and transferred to 50% isopropyl alcohol for preservation. All specimens were identified to species and enumerated.

RESULTS

TEMPERATURE

Only small differences were recorded between surface and bottom water temperature at canal stations or the control station in any sampling period (Table 1). With few exceptions, bottom temperatures were slightly lower than surface temperatures in all months except July and August 1971 when the situation was reversed. The greatest difference observed was at Station 4 in February when bottom temperature was 1.8°C lower than temperature at the surface.

SALINITY

Drought conditions prevailed throughout the Tampa Bay area during most of the study period, and, as a result, salinity rose almost steadily from 23.2‰ in August 1970 to greater than 30.0‰ by July 1971 (Table 1). During this period salinity at the control station was similar to that in the canals. Heavy rains in August 1971 reduced salinity values considerably. This was the only time during the study when stratification occurred at all stations. Bottom salinity at the control station was 9.0‰ higher than

TABLE 1.—Monthly hydrologic measurements of surface and bottom water, August 1970-August 1971.

Stn.	Depth	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Mean
							Temperature (°C)								
1	S	29.8	27.6	24.8	14.8	17.4	14.9	21.0	19.0	26.1	28.0	29.5	28.5	28.5	23.8
	B	--	27.5	24.7	14.7	16.7	14.7	20.8	19.0	26.4	27.8	29.5	29.0	29.4	23.4
2	S	29.5	27.4	24.8	14.8	17.2	15.2	20.8	19.2	25.8	27.8	29.0	29.0	28.4	23.8
	B	--	27.7	25.2	14.5	16.5	14.8	20.2	18.8	25.5	27.4	29.0	30.5	29.5	23.3
3	S	29.0	28.8	25.8	15.7	17.2	15.6	20.6	19.4	25.3	27.8	29.5	29.5	28.4	24.1
	B	--	28.5	24.7	15.5	17.0	15.6	19.7	18.4	25.1	27.2	29.4	30.1	30.0	23.4
4	S	29.5	28.7	25.5	15.2	17.3	16.1	20.6	18.7	25.5	28.0	29.4	29.1	28.5	24.0
	B	--	28.0	24.5	14.2	16.8	15.2	18.8	18.3	25.6	27.0	29.4	29.8	29.8	23.1
5	S	29.5	27.9	25.8	15.8	17.2	15.3	20.9	19.0	25.5	28.0	30.5	29.4	28.8	24.1
	B	--	27.8	24.9	15.3	17.0	15.2	20.7	19.1	25.5	27.0	30.0	30.3	29.8	23.6
6	S	29.5	28.1	25.2	15.5	17.7	16.0	21.0	19.5	25.9	28.2	30.0	29.1	28.8	24.2
	B	--	28.0	25.2	15.3	17.3	15.2	20.8	19.6	25.9	27.4	30.0	29.4	29.3	23.6
							Salinity (‰)								
1	S	24.72	25.67	25.67	27.61	29.00	29.06	26.72	29.78	30.06	29.94	31.39	30.17	13.28	27.16
	B	--	25.56	26.00	27.67	29.11	28.94	26.67	29.83	30.06	29.89	31.28	30.00	22.22	28.10
2	S	23.44	25.00	26.56	28.00	28.78	29.00	27.22	29.72	30.00	29.17	30.06	29.94	13.33	26.94
	B	--	25.28	26.56	27.94	28.72	29.06	27.94	29.67	29.89	29.33	30.72	30.22	27.89	28.60
3	S	23.22	25.11	26.11	27.94	29.00	29.06	27.39	29.44	29.89	29.17	30.61	29.61	13.61	26.94
	B	--	25.28	26.11	27.94	29.00	28.94	27.78	29.56	29.89	29.83	30.39	30.11	28.61	28.62
4	S	23.39	24.89	26.17	28.00	29.06	28.83	27.72	29.06	30.00	29.28	30.33	29.94	13.89	26.97
	B	--	24.56	26.44	27.89	29.06	29.06	27.67	30.06	30.11	29.72	30.83	29.00	28.00	28.62
5	S	23.39	25.11	26.39	28.06	28.94	29.00	27.61	29.44	29.89	29.61	30.72	29.28	13.89	27.03
	B	--	25.44	25.83	28.00	28.94	28.94	27.67	29.72	29.89	29.17	30.72	30.06	26.78	28.43
6	S	25.22	24.67	26.39	27.94	29.11	29.06	27.28	29.17	29.94	29.44	30.28	28.67	14.06	27.01
	B	--	24.56	26.28	27.94	28.89	28.83	27.50	29.83	29.89	29.83	30.44	29.00	25.72	28.23
							Dissolved oxygen (ml/liter)								
1	S	3.87	3.06	3.46	5.80	4.67	5.64	4.35	4.75	4.03	3.06	2.90	2.58	2.34	3.86
	B	--	3.62	3.38	5.64	4.83	5.23	4.35	4.67	4.11	2.98	3.06	2.66	2.18	3.89
2	S	4.19	3.87	4.43	5.72	4.43	5.07	4.67	4.91	3.22	4.27	3.14	2.18	3.63	4.13
	B	--	3.78	4.03	5.15	3.95	4.75	2.49	4.19	1.37	3.95	3.14	1.86	0.89	3.30
3	S	4.35	2.98	4.03	5.47	4.99	5.07	4.91	3.95	2.74	3.95	4.35	3.14	4.03	4.15
	B	--	2.66	2.42	5.40	4.51	4.35	1.13	3.10	1.62	2.98	3.46	0.00	0.82	2.70
4	S	4.35	2.26	4.27	5.64	4.75	5.31	4.67	3.78	2.66	4.59	3.62	3.30	4.67	4.14
	B	--	2.02	2.42	4.67	3.70	4.59	0.57	3.46	2.22	2.00	2.50	0.66	0.65	2.46
5	S	3.62	3.06	4.43	5.40	4.85	5.72	3.95	4.27	2.50	3.87	3.87	3.54	4.99	4.16
	B	--	2.90	4.35	5.23	4.75	4.59	2.66	3.14	2.34	2.98	3.81	0.08	0.57	3.12
6	S	4.19	2.90	4.51	5.64	5.15	5.23	4.75	4.67	3.30	3.22	3.71	2.98	4.43	4.12
	B	--	2.82	4.35	5.55	5.14	4.75	4.59	4.27	2.42	3.14	3.38	2.50	0.17	3.59

the surface. The stratification was even more evident at canal stations where the difference between surface and bottom values ranged between 11.6‰ (Station 6) and 15.0‰ (Station 3). In general, the most landward stations exhibited the greatest differences between surface and bottom salinities.

OXYGEN

Daytime concentrations of dissolved oxygen at the surface and bottom for each station are shown in Table 1. Only at the control station were surface and bottom values similar, varying linity at the control station was 9.0‰ higher than no more than 0.6 ml/liter at any one sampling time throughout the year. At this station the lowest observed concentration was 2.1 ml/liter (August 1971). Surface oxygen values within the canal system were comparable with those at the control station throughout the year. However, bottom oxygen dropped in the canals in February when less than 2.0 ml/liter was recorded at Stations 3 and 4. These values rose above 3.0 ml/liter in March, but in April and May dissolved oxygen near 2.0 ml/liter or less was recorded at several canal stations. In July less than 1.0 ml/liter was recorded at Stations 3, 4, and 5, and by August less than 1.0 ml/liter of oxygen was recorded at the bottom at all canal stations.

To determine the diel changes in oxygen concentration during the July sampling period, a 24-hr sampling program was conducted at each station. Results showed that surface and bottom values were similar only at the control station (Figure 4). Surface oxygen concentration in the canals corresponded with values recorded at the control station and never fell below 2.0 ml/liter. However, at all canal stations the bottom was nearly anoxic throughout the 24-hr sampling period.

FISHES AND MACROINVERTEBRATES

Thirty-six species and 10,497 individuals of vertebrates and invertebrates were collected within the canals during the year (Table 2). Of the 36 species, 32 were finfish (23 of sport or commercial value), 1 was the diamondback

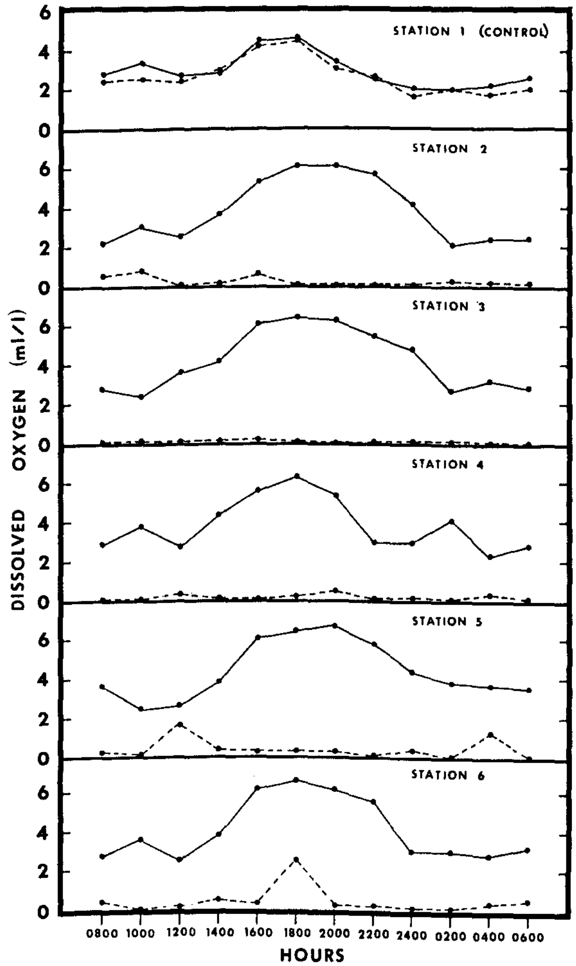

FIGURE 4.—Results of 24-hr oxygen survey in July 1971 (surface ·———·; bottom ·--------·).

terrapin, *Malaclemys terrapin*, and 3 were commercially important invertebrates (blue crab, *Callinectes sapidus;* pink shrimp, *Penaeus duorarum;* and brief squid, *Lolliguncula brevis*).

The four species of fish caught in greatest abundance represented 92% of the total number of specimens. They were the bay anchovy (*Anchoa mitchilli*), spotfin mojarra (*Eucinostomus argenteus*), spot (*Leiostomus xanthurus*), and silver jenny (*Eucinostomus gula*). The bay anchovy alone made up nearly 72% of the total.

The brief squid was by far the most abundant invertebrate (84% of all invertebrates collected)

TABLE 2.—Monthly occurrence and number of individuals of vertebrates and invertebrates collected with otter trawl at all stations from August 1970 through August 1971. No individual collected in July and August 1971.

Species	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total Number	Total Percent
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*		
Vertebrates:													
Anchoa mitchilli[1]	56	539	1,582	26	0	93	698	1,376	746	16	2,425	7,557	72.0
Eucinostomus argenteus[1,2]	0	120	135	241	220	153	16	25	6	0	5	921	8.8
Leiostomus xanthurus[1,2]	0	1	0	0	26	24	108	661	1	0	0	821	7.8
Eucinostomus gula[1,2]	0	0	18	82	164	99	1	8	0	0	0	372	3.5
Micropogon undulatus[1,2]	0	0	0	0	0	0	1	20	7	34	9	71	0.7
Cynoscion arenarius[1,2]	0	0	0	3	10	8	20	8	0	0	2	51	0.5
Menticirrhus americanus[1,2]	0	0	3	15	13	1	1	0	1	4	5	43	0.4
Pogonias cromis[1,2]	0	0	1	0	3	7	4	4	4	0	1	24	0.2
Archosargus probatocephalus[1,2]	0	0	0	2	10	4	2	1	1	2	1	23	0.2
Lagodon rhomboides[1,2]	0	0	1	4	6	3	0	6	1	0	0	21	0.2
Microgobius gulosus[2]	0	0	0	0	0	0	1	11	2	0	0	14	0.1
Cynoscion nebulosus[1,2]	0	3	4	4	0	0	1	0	0	0	2	14	0.1
Chaetodipterus faber[1]	0	0	4	0	1	2	0	1	1	0	4	13	0.1
Arius felis[1,2]	0	0	0	0	1	0	3	5	3	0	0	12	0.1
Malaclemys terrapin	0	0	0	2	0	0	0	1	5	4	0	12	0.1
Bairdiella chrysura[1,2]	0	0	1	0	2	5	1	0	0	0	1	10	0.1
Gobiosoma bosci[2]	0	0	0	0	0	0	0	7	1	1	0	9	0.1
Prionotus tribulus[2]	0	1	1	4	1	0	0	0	0	0	0	7	0.1
Orthopristis chrysoptera[1,2]	0	0	1	0	0	0	0	2	3	0	1	7	0.1
Sphoeroides nephelus[1]	0	0	0	3	1	1	0	0	0	0	0	5	0.1
Opisthonema oglinum[1]	0	0	0	0	0	0	0	0	0	0	4	4	0.0
Dasyatis sabina[2]	0	0	1	0	0	0	2	0	0	0	0	3	0.0
Mugil cephalus[1,2]	0	0	0	0	0	1	1	0	0	0	0	2	0.0
Chloroscombrus chrysurus[1]	0	0	0	0	0	0	0	0	0	2	0	2	0.0
Anchoa hepsetus[1]	0	0	0	0	0	0	0	0	0	0	2	2	0.0
Achirus lineatus[2]	0	0	0	0	0	0	0	0	0	0	2	2	0.0
Synodus foetens[1,2]	0	0	0	0	1	0	0	0	0	0	0	1	0.0
Opsanus beta[2]	0	0	0	0	0	0	0	1	0	0	0	1	0.0
Symphurus plagiusa[2]	0	0	0	0	0	1	0	0	0	0	0	1	0.0
Sciaenops ocellata[1,2]	0	0	0	0	1	0	0	0	0	0	0	1	0.0
Paralichthys albigutta[1,2]	0	0	0	1	0	0	0	0	0	0	0	1	0.0
Chasmodes saburrae[2]	0	0	0	0	0	1	0	0	0	0	0	1	0.0
Gymnura micrura[2]	0	0	0	0	0	1	0	0	0	0	0	1	0.0
Invertebrates:													
Callinectes sapidus[1,2]	0	8	2	2	1	5	3	9	12	4	1	47	0.5
Penaeus duorarum[1,2]	0	4	2	7	2	4	5	1	0	0	1	26	0.3
Lolliguncula brevis[1]	0	45	55	93	43	4	15	6	29	87	20	395	3.8
Total species	1	8	15	15	18	19	18	19	16	9	17	36	
Total individuals	56	721	1,811	489	506	417	883	2,153	821	154	2,485	10,497	100.0

[1] Of commercial or sport value.
[2] Demersal or bottom feeder.

and made up nearly 4% of the total number of animals collected during the year.

The first trawl sample was made in August 1970, 2 months after bay water was introduced in the canal system. At that time the only species of fish found in the canals was the bay anchovy, and 98% of the specimens were taken at Station 4 (Figure 3; Tables 3, 4, 5, 6). By September, the blue crab, pink shrimp, brief squid, and four additional species of finfish were caught within the canal system. Station 4 contained seven species of vertebrates and invertebrates while Stations 2 and 3 contained five species each. No specimens were yet found at Station 1. In October, 5 months after water was introduced, fishes and invertebrates were found in all canals, and a total of 15 species were collected. Station 4, with 11 species, still contained the greatest faunal diversity. Stations 1, 2, and 3 contained 10, 5, and 4 species, respectively.

Through the winter, spring, and early summer months (November through June) an average of 16 species per month was collected throughout the area. The number of species and individuals at each station declined in April and May corresponding to reduction in dissolved oxygen, but in June the number of species and individuals increased again at all stations.

TABLE 3.—Monthly occurrence and number of individuals of vertebrates and invertebrates collected with otter trawl at Station I from August 1970 through August 1971. No individual collected in August and September 1970 and in July and August 1971.

Species	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total	
										Number	Percent
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*		
Vertebrates:											
Anchoa mitchilli	118	16	0	1	77	31	0	9	412	664	58.9
Eucinostomus argenteus	49	1	6	51	13	9	5	0	4	138	12.3
Leiostomus xanthurus	0	0	2	3	41	50	0	0	0	96	8.5
Eucinostomus gula	10	3	41	39	0	0	0	0	0	93	8.3
Micropogon undulatus	0	0	0	0	0	1	0	21	0	22	2.0
Menticirrhus americanus	1	0	4	0	0	0	1	0	0	6	0.5
Archosargus probatocephalus	0	1	2	0	1	0	1	0	0	5	0.4
Malaclemys terrapin	0	2	0	0	0	1	0	2	0	5	0.4
Cynoscion arenarius	0	1	0	1	0	0	0	0	2	4	0.4
Lagodon rhomboides	0	0	0	2	0	1	1	0	0	4	0.4
Opisthonema oglinum	0	0	0	0	0	0	0	0	4	4	0.4
Microgobius gulosus	0	0	0	0	0	2	2	0	0	4	0.4
Chaetodipterus faber	1	0	0	0	0	0	1	0	1	3	0.3
Prionotus tribulus	1	2	0	0	0	0	0	0	0	3	0.3
Cynoscion nebulosus	0	2	0	0	0	0	0	0	0	2	0.2
Pogonias cromis	0	0	0	0	0	0	0	2	0	2	0.2
Orthopristis chrysoptera	1	0	0	0	0	0	0	0	1	2	0.2
Sphoeroides nephelus	0	2	0	0	0	0	0	0	0	2	0.2
Bairdiella chrysura	0	0	0	1	0	0	0	0	0	1	0.1
Chloroscombrus chrysurus	0	0	0	0	0	0	0	1	0	1	0.1
Gobiosoma bosci	0	0	0	0	0	1	0	0	0	1	0.1
Invertebrates:											
Lolliguncula brevis	5	3	6	1	4	0	0	16	5	40	3.6
Callinectes sapidus	1	0	0	2	3	1	7	3	1	18	1.6
Penaeus duorarum	2	1	0	1	2	0	0	0	0	6	0.5
Total species	10	10	6	9	8	9	8	7	8	24	
Total individuals	189	134	61	101	142	97	20	52	430	1,126	100.0

In the latter part of June, after our monthly sample, a severe outbreak of red tide occurred in a large part of Tampa Bay, including the study area. Massive fish kills were noted in the Bay through most of July (Karen Steidinger, Florida Department of Natural Resources Biological Laboratory, pers. comm.). Data are not available on the size of the kill, but an estimated 3,000 tons of various species were removed from beaches in the Bay area (Lloyd Dove, St. Petersburg Public Works Director, pers. comm.). No live specimens were collected in the study area during July or August. The absence of specimens during this period corresponded with low dissolved oxygen at the bottom.

DISCUSSION

At least 36 of the 265 species of finfish, shrimp, and crabs known to inhabit the Tampa Bay area (Springer and Woodburn, 1960; Dragovich and Kelly, 1964; Sykes and Finucane, 1966) utilized the study area throughout most of the year. It was not surprising to find bay anchovy as the dominant species as it is known to be dominant in bayfill canals of Boca Ciega Bay, Fla., (Taylor and Saloman, 1968) and in housing development canals in Texas (unpublished data[4]).

Although the majority of individual fishes taken in the study area was plankton feeders, most of the species (26) were demersal or bottom feeders based on knowledge of their life histories (Darnell, 1958; Springer and Woodburn, 1960; Odum, 1971). Taylor and Saloman (1968), using the same trawl size and procedures as in our study, reported that no demersal fishes were taken in bayfill canals of Boca Ciega Bay. However, examination of additional, unpublished data[5] from canals in Boca Ciega Bay showed that

[4] Unpublished data on file at Gulf Coastal Fisheries Center, National Marine Fisheries Service, NOAA, Fort Crockett, Building 302, Galveston, TX 77550.

[5] Unpublished data on file at Gulf Coastal Fisheries Center, National Marine Fisheries Service, NOAA, 75 33d Avenue, St. Petersburg, FL 33706.

TABLE 4.—Monthly occurrence and number of individuals of vertebrates and invertebrates collected with otter trawl at Station 2 from August 1970 through August 1971. No individual collected in August 1970 and in July and August 1971.

Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total	
											Number	Percent
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*		
Vertebrates:												
Anchoa mitchilli	23	800	8	0	21	384	1,083	480	2	1,392	4,193	86.0
Leiostomus xanthurus	0	0	0	5	1	0	4	0	0	0	353	7.2
Eucinostomus argenteus	13	46	0	29	40	3	5	1	0	0	137	2.8
Eucinostomus gula	0	5	1	22	15	1	0	0	0	0	44	0.9
Micropogon undulatus	0	0	0	0	0	0	4	0	8	1	13	0.3
Lagodon rhomboides	0	0	0	5	1	0	4	0	0	0	10	0.2
Menticirrhus americanus	0	0	0	3	0	0	0	0	4	2	9	0.2
Cynoscion arenarius	0	0	0	1	0	3	3	0	0	0	7	0.1
Gobiosoma bosci	0	0	0	0	0	0	4	1	1	0	6	0.1
Bairdiella chrysura	0	0	0	0	4	0	0	0	0	1	5	0.1
Arius felis	0	0	0	0	0	0	3	1	0	0	4	0.1
Malaclemys terrapin	0	0	0	0	0	0	0	3	1	0	4	0.1
Cynoscion nebulosus	2	0	0	0	0	0	0	0	0	1	3	0.1
Sphoeroides nephelus	0	0	1	1	1	0	0	0	0	0	3	0.1
Microgobius gulosus	0	0	0	0	0	0	3	0	0	0	3	0.1
Archosargus probatocephalus	0	0	0	2	0	0	0	0	0	0	2	0.0
Chaetodipterus faber	0	0	0	0	0	0	0	0	0	2	2	0.0
Pogonias cromis	0	0	0	0	1	0	0	0	0	1	2	0.0
Anchoa hepsetus	0	0	0	0	0	0	0	0	0	0	2	0.0
Gymnura micrura	0	0	0	0	1	0	0	0	0	0	1	0.0
Prionotus tribulus	0	0	1	0	0	0	0	0	0	0	1	0.0
Synodus foetens	0	0	0	1	0	0	0	0	0	0	1	0.0
Chasmodes saburrae	0	0	0	0	1	0	0	0	0	0	1	0.0
Opsanus beta	0	0	0	0	0	0	1	0	0	0	1	0.0
Dasyatis sabina	0	1	0	0	0	0	0	0	0	0	1	0.0
Invertebrates:												
Lolliguncula brevis	2	15	0	2	0	0	2	18	13	4	56	1.2
Callinectes sapidus	4	0	2	1	0	0	1	2	0	0	10	0.2
Penaeus duorarum	0	0	3	1	0	0	0	0	0	1	5	0.1
Total species	5	5	6	12	10	5	12	8	6	10	28	
Total individuals	44	867	16	92	92	426	1,399	507	29	1,407	4,879	100.0

at least 13 of 21 species of fishes collected by trawl may be considered bottom feeders. Based on these data, it appears that new upland canals provide a better habitat for fishes than do much older bayfill canals in the sense that the former support greater abundance of species and individuals.

Undoubtedly, the lack of fish in the canals of Tanglewood Estates during the last 2 months of the study was due in part to effects of the red tide. Decomposition of the dead fish increased oxygen demand on the system during this period, but decline in dissolved oxygen in April and May and corresponding decline in the number of species and individuals indicated the system was deteriorating prior to the red tide outbreak. Our continued study will determine to what degree the system is stressed by low summer oxygen in the absence of red tide.

Others working in the Tampa Bay system have reported low bottom oxygen in areas of poor water circulation and soft sediment. Dragovich, Kelly, and Finucane (1966) recorded less than 2 ml/liter in June and August from a dredged location in central Boca Ciega Bay. In dredged and undredged areas of Hillsborough Bay, reduced oxygen near the bottom is common during the summer. There, the lack of dissolved oxygen has been attributed to sludge deposited from sewage, as well as high water temperature and poor water circulation (Saloman, Finucane, and Kelly, 1964; U.S. Federal Water Pollution Control Administration, Southeast Region, 1969). A similar condition is shared by older upland canals throughout south Florida (Barada and Partington, 1972) and certain housing development canals in Texas (see footnote 4). Oxygen depletion in all of these areas is the result of poor

TABLE 5.—Monthly occurrence and number of individuals of vertebrates and invertebrates collected with otter trawl at Station 3 from August 1970 through August 1971. No individual collected in July and August 1971.

Species	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total	
												Number	Percent
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*		
Vertebrates:													
Anchoa mitchilli	1	337	39	1	0	19	29	43	266	2	506	1,243	53.8
Eucinostomus argenteus	0	26	11	145	144	41	0	11	0	0	0	378	16.4
Leiostomus xanthurus	0	0	0	0	0	7	14	310	0	0	0	331	14.3
Eucinostomus gula	0	0	0	36	84	19	0	8	0	0	0	147	6.4
Cynoscion arenarius	0	0	0	2	9	6	0	5	0	0	0	22	1.0
Micropogon undulatus	0	0	0	0	0	0	0	5	5	3	4	17	0.7
Menticirrhus americanus	0	0	0	7	6	1	0	0	0	0	0	14	0.6
Pogonias cromis	0	0	0	0	1	2	4	3	1	0	0	11	0.5
Archosargus probatocephalus	0	0	0	0	2	2	1	1	0	0	0	6	0.3
Chaetodipterus faber	0	0	1	0	1	2	0	1	0	0	1	6	0.3
Arius felis	0	0	0	0	0	0	1	1	2	0	0	4	0.2
Cynoscion nebulosus	0	0	0	2	0	0	1	0	0	0	0	3	0.1
Microgobius gulosus	0	0	0	0	0	0	0	3	0	0	0	3	0.1
Lagodon rhomboides	0	0	0	1	0	0	0	1	0	0	0	2	0.1
Mugil cephalus	0	0	0	0	0	1	1	0	0	0	0	2	0.1
Achirus lineatus	0	0	0	0	0	0	0	0	0	0	2	2	0.1
Gobiosoma bosci	0	0	0	0	0	0	0	2	0	0	0	2	0.1
Malaclemys terrapin	0	0	0	0	0	0	0	0	2	0	0	2	0.1
Bairdiella chrysura	0	0	0	0	0	1	0	0	0	0	0	1	0.0
Chloroscombrus chrysurus	0	0	0	0	0	0	0	0	0	1	0	1	0.0
Dasyatis sabina	0	0	0	0	0	0	1	0	0	0	0	1	0.0
Orthopristis chrysoptera	0	0	0	0	0	0	0	0	1	0	0	1	0.0
Prionotus tribulus	0	1	0	0	0	0	0	0	0	0	0	1	0.0
Symphurus plagiusa	0	0	0	0	0	1	0	0	0	0	0	1	0.0
Invertebrates:													
Lolliguncula brevis	0	15	4	65	2	2	1	4	0	1	4	98	4.2
Callinectes sapidus	0	2	0	0	0	0	0	5	0	1	0	8	0.4
Penaeus duorarum	0	0	0	1	1	0	1	1	0	0	0	4	0.2
Total species	1	5	4	9	9	13	10	16	6	5	5	27	
Total individuals	1	381	55	260	250	104	54	404	277	8	517	2,311	100.0

circulation, accumulation of soft, organically rich sediments, and storm-water runoff from residential and agricultural areas.

Developers in the Tampa Bay area could reduce these problems in future projects through better design of canal systems. This would involve: (1) elimination of dead-end canals and (2) limiting depths to the euphotic zone approximately 1.5 m (5 ft) below mean low water. A flow-through system without deadends would insure better tidal exchange and circulation. Also, by limiting depths to approximately 1.5 m below mean low water, the canals probably would not serve as silt traps as readily as deeper canals, and stratification of the water column would be eliminated. In addition, light penetration would occur throughout the water column thereby allowing oxygen production through photosynthesis by benthic algae and diatoms.

Elimination of dead-end canals and limiting depths to the photic zone will not necessarily insure adequate flushing, however. A major factor that must be taken into account is water exchange through tidal action. Tidal range in most of Florida is very small, varying from 0.3 m to about 1.0 m, and will provide adequate water exchange in canals only short distances from the shoreline. Our data show serious oxygen depletion in the deep, dead-end canals only 150 m inland of the shoreline (Station 6). A safe distance for shallower, flow-through canals can best be determined by an environmental engineer knowledgeable of the tidal range and circulation patterns adjacent to the upland to be developed.

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TABLE 6.—Monthly occurrence and number of individuals of vertebrates and invertebrates collected with otter trawl at Station 4 from August 1970 through August 1971. No individual collected in July and August 1971.

Species	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Total	
												Number	Percent
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*		
Vertebrates:													
Anchoa mitchilli	55	179	625	1	0	52	208	219	0	3	115	1,457	66.8
Eucinostomus argenteus	0	81	29	95	41	21	0	0	0	0	1	268	12.3
Eucinostomus gula	0	0	3	42	17	26	0	0	0	0	0	88	4.0
Leiostomus xanthurus	0	1	0	0	0	7	18	15	0	0	0	41	1.9
Micropogon undulatus	0	0	0	0	0	0	1	10	2	2	4	19	0.9
Cynoscion arenarius	0	0	0	0	0	1	17	0	0	0	0	18	0.8
Menticirrhus americanus	0	0	2	8	0	0	1	0	0	0	3	14	0.6
Archosargus probatocephalus	0	0	0	1	4	2	0	0	0	2	1	10	0.5
Pogonias cromis	0	0	1	0	2	4	0	1	1	0	0	8	0.4
Cynoscion nebulosus	0	1	4	0	0	0	0	0	0	0	1	6	0.3
Lagodon rhomboides	0	0	1	3	1	0	0	0	0	0	0	5	0.2
Arius felis	0	0	0	0	1	0	2	1	0	0	0	4	0.2
Microgobius gulosus	0	0	0	0	0	0	1	3	0	0	0	4	0.2
Orthopristis chrysoptera	0	0	0	0	0	0	0	2	2	0	0	4	0.2
Bairdiella chrysura	0	0	1	0	2	0	0	0	0	0	0	3	0.1
Chaetodipterus faber	0	0	2	0	0	0	0	0	0	0	0	2	0.1
Prionotus tribulus	0	0	0	1	1	0	0	0	0	0	0	2	0.1
Sciaenops ocellata	0	0	0	0	1	0	0	0	0	0	0	1	0.1
Paralichthys albigutta	0	0	0	1	0	0	0	0	0	0	0	1	0.1
Dasyatis sabina	0	0	0	0	0	0	1	0	0	0	0	1	0.1
Malaclemys terrapin	0	0	0	0	0	0	0	0	0	1	0	1	0.1
Invertebrates:													
Lolliguncula brevis	0	28	31	25	33	1	10	0	9	57	7	201	9.2
Callinectes sapidus	0	2	1	0	0	3	0	2	3	0	0	11	0.5
Penaeus duorarum	0	4	0	2	0	3	2	0	0	0	0	11	0.5
Total species	1	7	11	10	10	10	10	8	5	5	7	24	
Total individuals	55	296	700	179	103	120	263	251	17	64	132	2,180	100.0

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