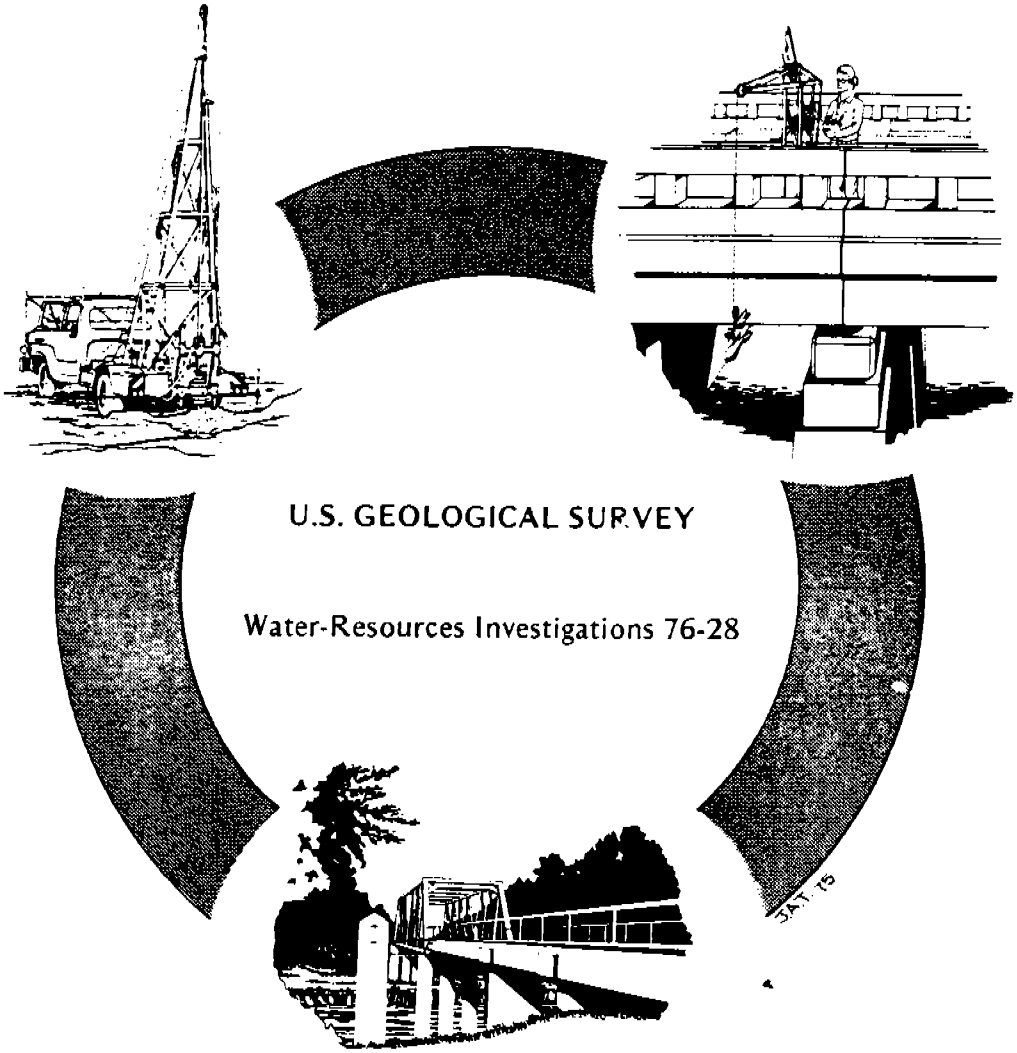
ANALYSIS OF SELECTED BENTHIC COMMUNITIES IN THE FLORIDA EVERGLADES WITH REFERENCE TO THEIR PHYSICAL AND CHEMICAL ENVIRONMENT



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 76-28

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS
JACKSONVILLE DISTRICT

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By Bradley G. Waller

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UNITED STATES DEPARTMENT OF THE INTERIOR

Thomas S. Kleppe, Secretary

GEOLOGICAL SURVEY

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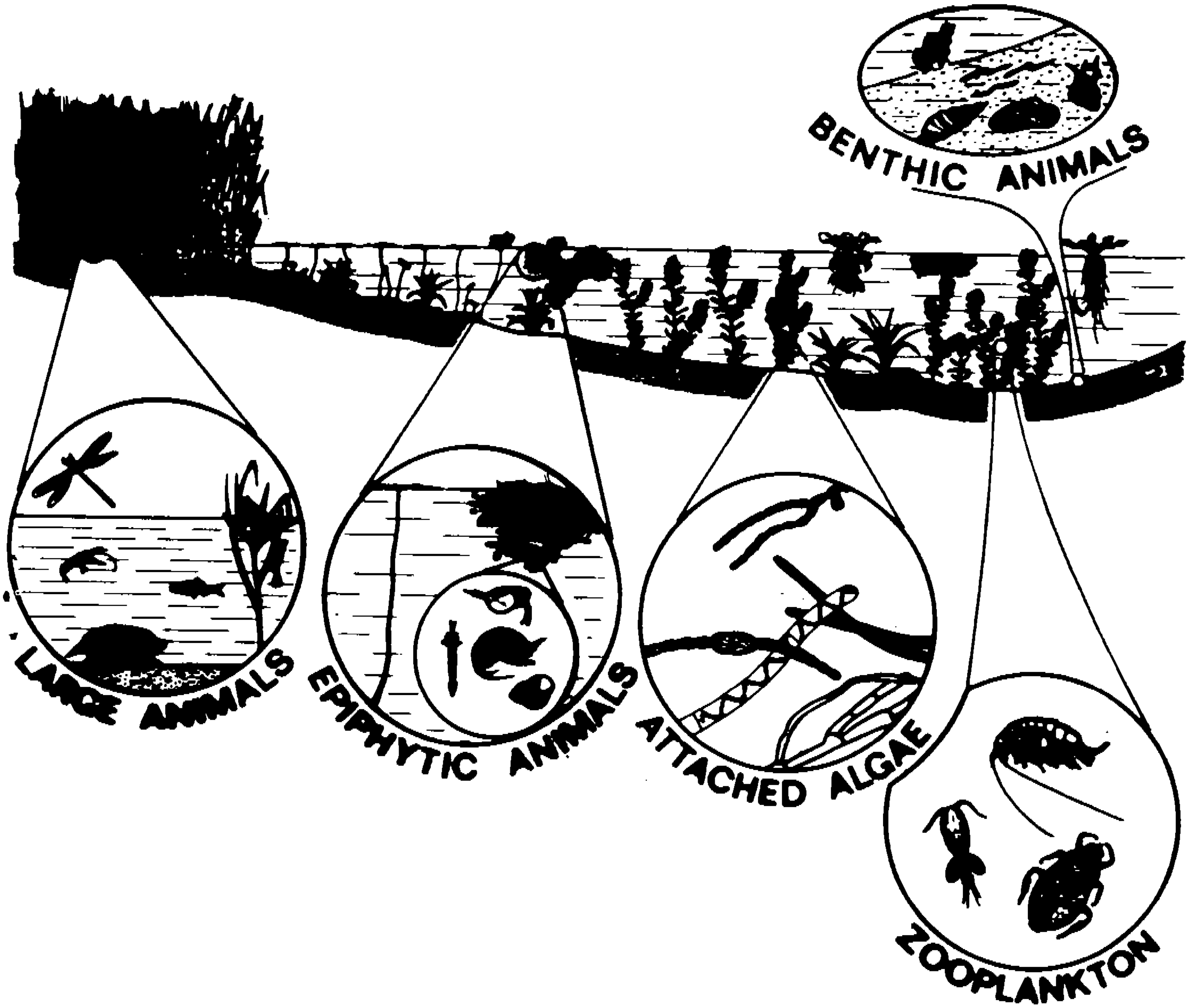

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ANALYSIS OF SELECTED BENTHIC COMMUNITIES IN THE FLORIDA EVERGLADES WITH REFERENCE TO THEIR PHYSICAL AND CHEMICAL ENVIRONMENT

By

Bradley G. Waller

ABSTRACT

Species diversity and numbers of benthic macroinvertebrates were determined at 12 sites, both canals and marshes, in the Everglades of south Florida. The values calculated are used to indicate long-term trends in water quality and variations between study areas.

Species diversity at all sites was generally in a range indicative of degraded water quality. The number of organisms per square metre of bottom surface was highly variable ranging from 43 to 8,200 organisms.

Chemical analysis of water and bottom material indicated no gross contamination from sewage or agricultural runoff in any of the canals where benthic organisms were collected. Other physical factors such as depth, velocity of flow, substrate type, and water-level fluctuation were responsible for the low species diversities and variable numbers of organisms, rather than contamination from urban or agricultural areas.

INTRODUCTION

The Everglades (fig. 1) extends from Lake Okeechobee southward through Everglades National Park (Leach and others, 1972). Historically, water moved as sheet flow over the shallow marsh during the wet season. During the drier months water levels declined, southward flow ceased, and the water ponded in the deeper sloughs and alligator holes. Since the early 1900's, canals have been constructed throughout the area (fig. 1) and have altered the historic flow patterns (Parker and others, 1955). These canals also created new niches that

For use of those readers who may prefer to use metric units rather than English units, the conversion factors for the terms used in this report are listed below.

Multiply English unit	By	To obtain metric unit
feet (ft)	0.3048	metres (m)
inches (in)	25.4	millimetres (mm)
miles (mi)	1.609	kilometres (km)
square miles (mi^2)	2.590	square kilometres (km^2)

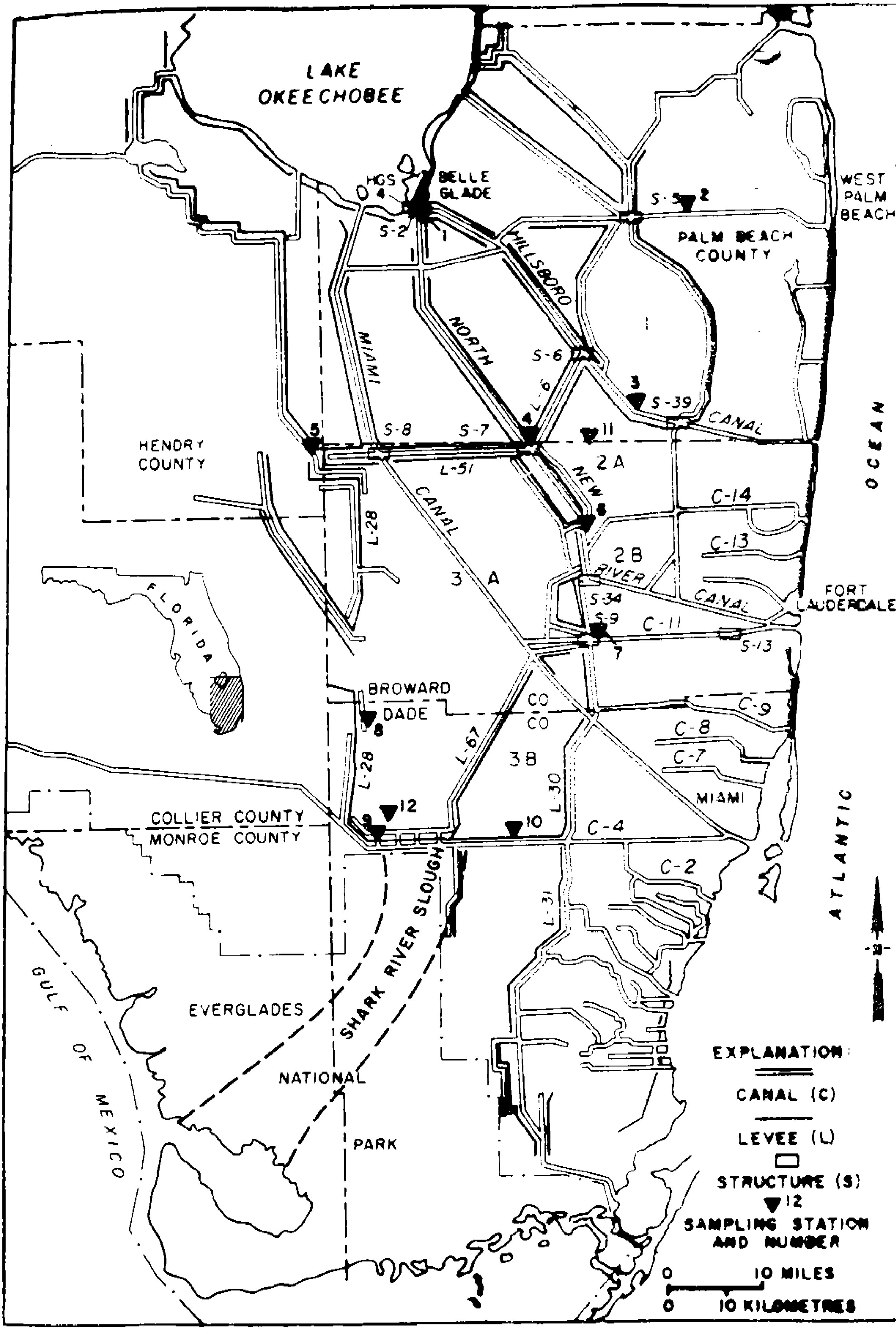


Figure 1.--Location of benthic sampling stations.

did not dry up when water levels were low and thus could support aquatic organisms all year. The canals also facilitated rapid movement of water throughout the area and gave plants and animals better channels for distribution.

Ecologically the area is eutrophic, characterized by highly organic peat and muck soils which cover most of the area. The soils overlie limestone (Parker and others, 1955). The major canals constructed within this area are cut into the limestone (fig. 2) and, depending on the age of the canal, have soft bottom material consisting of redeposited organic debris and finely divided limestone.

The chemical and physical characteristics of the environment control the ability of benthic (bottom-dwelling) organisms to survive at any given locality. Thus the benthic organisms that colonize an area may be used as an indicator of past and present water-quality conditions. Because of this property, a survey of benthic organisms in the Everglades was undertaken by the U. S. Geological Survey in cooperation with the U. S. Army Corps of Engineers to determine if the benthic organisms found at selected stations (fig. 1) indicate any long term water-quality changes.

The benthic organism survey was conducted in conjunction with a comprehensive sampling program at 25 stations within and adjacent to the Everglades. Chemical analyses of water and sediment were made on samples collected during the period July 1972 - June 1974. At 12 selected stations (table 1) long-term trends in water quality were evaluated using benthic organisms as an indicator.

Few previous surveys of benthic organisms have been undertaken in south Florida. Russo (1974) did a comprehensive study on a polluted urban canal in Broward County. In 1971, the Environmental Protection Agency (EPA) surveyed the benthic organisms in and around the Dade County Training and Transition Airport. Open marsh areas in the Shark River slough (fig. 1) were sampled quantitatively in the late 1960's (Kolipinski and Higer, 1969). Canals in the upper St. John's River basin were sampled for benthic organisms in the late 1960's (Goolsby and McPherson, 1971).

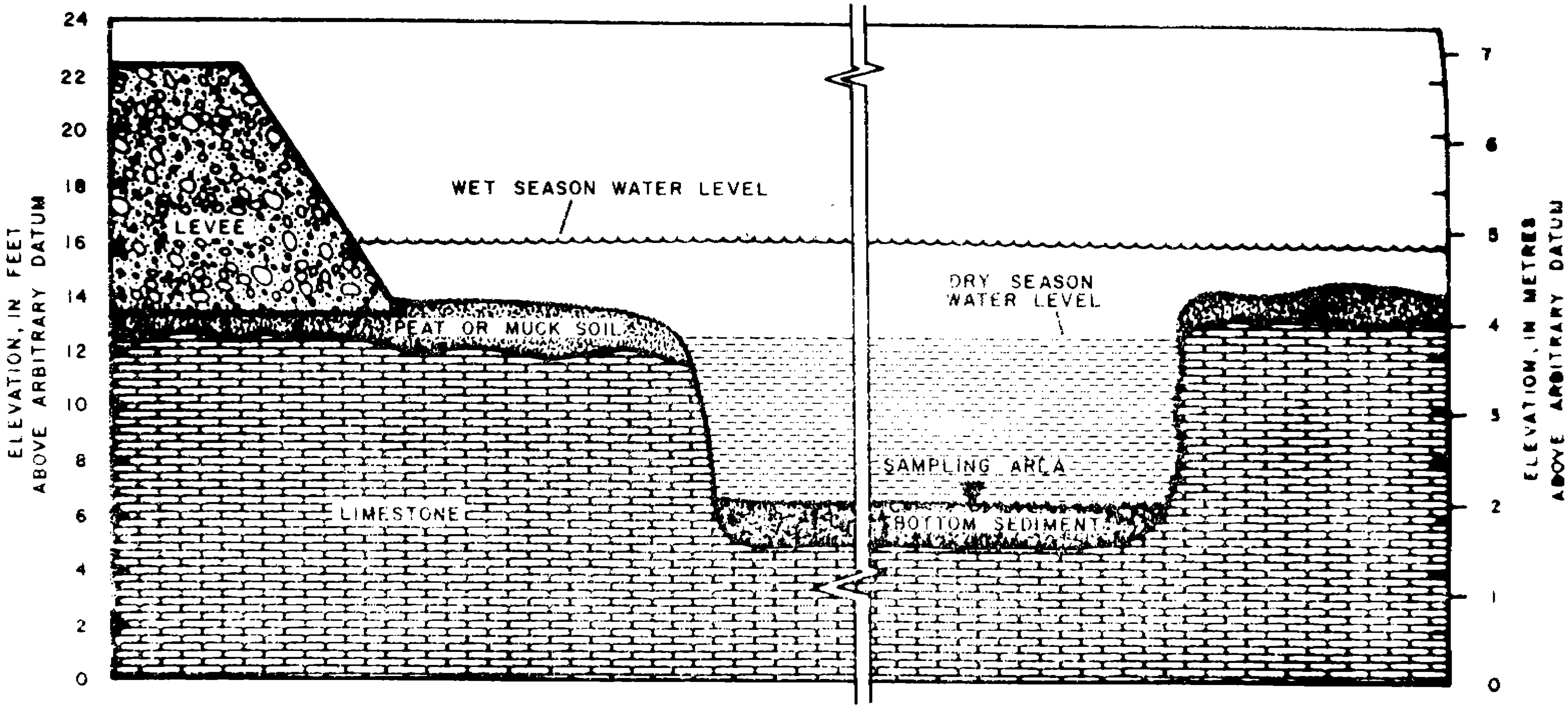


Figure 2. --Schematic cross section of a canal in the Everglades.

Table 1. Station names and numbers
(Locations shown on fig. 1)

Station number	Station name	Latitude-Longitude or downstream order number
1	North New River canal below HGS-4	02283500
2	West Palm Beach canal 1 mile east of S-SAE	26°41'00" 80°21'00"
3	Hillsboro canal above S-10C	26°24'00" 80°23'00"
4	North New River canal above S-7	26°20'00" 80°32'05"
5	L-3 canal 7 miles west of S-8	26°19'45" 80°53'00"
6	North New River canal above S-11c	02284501
7	South New River canal at S-9	0228540
8	L-28 East canal	25°56'00" 80°48'45"
9	Tamiami canal above S-12A	25°45'42" 80°49'30"
10	Tamiami canal outlets L-30 to L-67A	02289060
11	Everglades station 2-17	02284642
12	Everglades station 3-28	02289043

Purpose and Scope

The purpose of this investigation is to document the types of aquatic benthic organisms found within the Everglades and to determine the extent to which the chemical and physical character of surface water and bottom materials affect their distribution and community structure. During their lifespan in an environment, which is often in the order of months, benthic organisms integrate chemical and physical variables throughout their development. Because they integrate these variables over time, the organisms are used as indicators of past changes in water quality. Areas grossly contaminated with organic material are detected using both chemical and biological indicators. The benthic community may respond to changes in the chemistry of the overlying water or the bottom materials. The numbers of organisms and species often change in response to chemical changes in the environment.

The scope of this investigation included the collection of benthic organisms from October 1972 to April 1974. Two samplings were completed during the dry season (April 1973-74) and two during the wet season (October 1972-73). Of the 12 stations sampled, 10 were canals (stations 1-10) and 2, stations 11 and 12, were in the open marsh. Comparison of species diversities calculated from similar investigations done in south Florida in recent years is made.

Data Collection

Samples of bottom material were collected with a 6-in (150-mm) square Ekman dredge (Welch, 1948). Canals were sampled near the center (fig. 2) and the marsh stations were sampled in an open slough area (fig. 3). A sampling technique is utilized for collection of benthic organisms, in which samples are collected at random along a transect either down the canal or across an open slough. This sampling technique will probably produce the best results as far as species diversity for the number of samples collected. Ten samples were collected at each station giving a total of 0.225 m^2 (square metres) of bottom surface collected. At all stations except station 5, six samples were collected during the wet season (October) and four during the dry season (April). At station 5, three samples were collected in October and seven in April. The bottom material was preserved with a 5 percent formalin solution. Samples were sieved separately through a U. S. Standard No. 30 sieve (American Public Health Association, 1971) to exclude

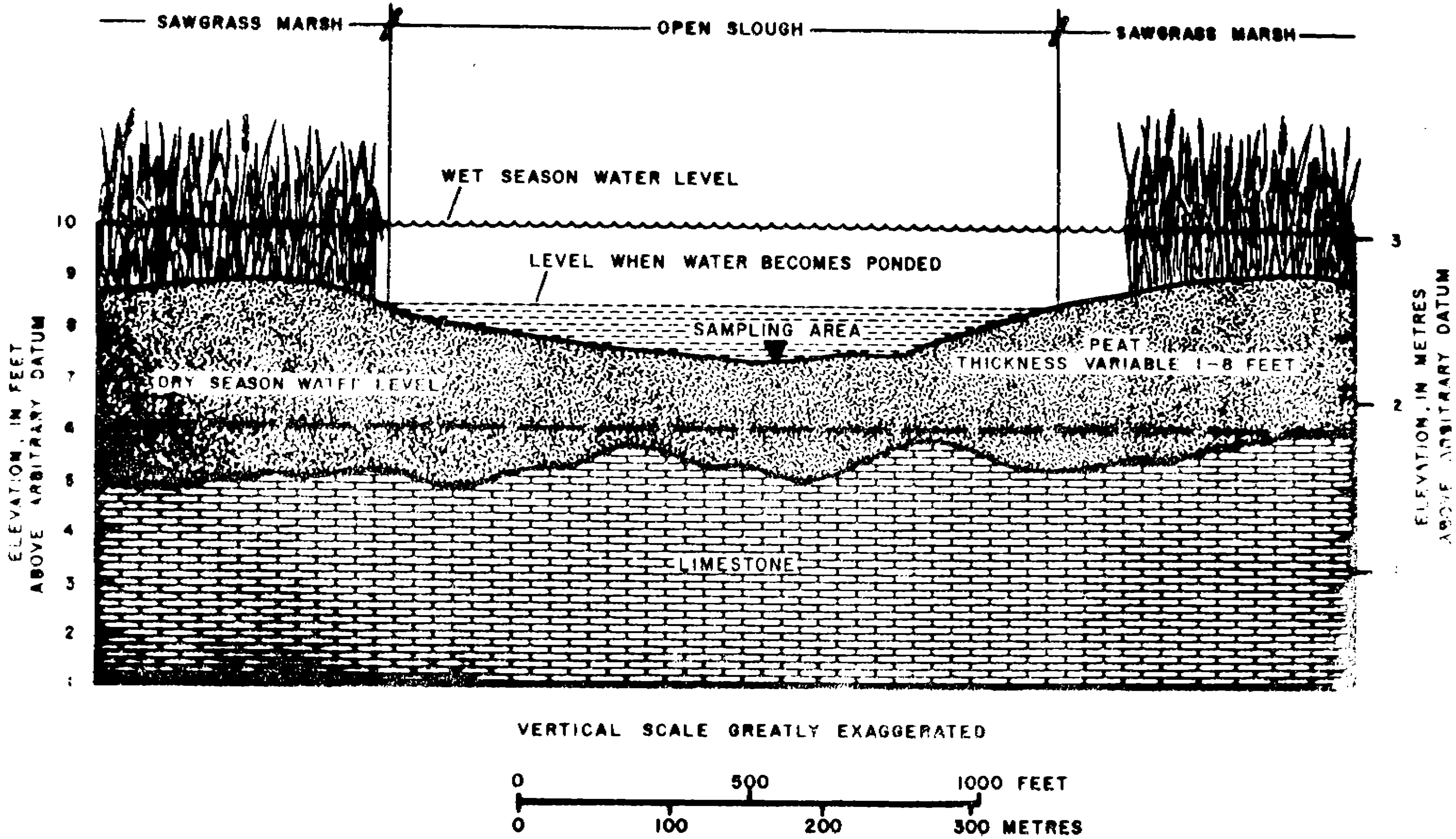


Figure 3.--Schematic cross section of an open slough area in the Everglades.

all organisms not considered macro-benthic and then represerved in a 70 percent solution of ethyl alcohol. Benthic organisms were then sorted from the detritis, counted and identified.

Bottom material samples for chemical analyses were collected with an Ekman dredge or scooped into the sample container along with the benthic samples. These were sent to the U. S. Geological Survey laboratories in Harrisburg, Pa. and Salt Lake City, Utah for determination of nitrogen species, phosphorus, carbon and organic content.

Water samples were collected monthly from July 1972 to June 1974. Samples were collected 1 foot (0.3 m) below the surface with a Kemmerer water sampler. Water samples were analyzed for nitrogen and phosphorus compounds, organic carbon and turbidity at the U. S. Geological Survey laboratory in Ocala, Florida. Biochemical oxygen demand (BOD) was determined at the U. S. Geological Survey office in Miami, Fla.

The stations sampled varied in their physical characteristics (table 2). Each station afforded the benthic community a different type of substrate, depth of overlying water and variable flow velocities.

CHEMICAL AND PHYSICAL CHARACTERISTICS

The composition of a benthic community is dependent on many abiotic factors. The two most important media that affect the organisms directly are the substrate (canal bottom) on which they live and the overlying water. Sewage discharged into the canals and excessive agricultural runoff pose a threat to the benthic communities. The chemical parameters that may indicate organic contamination from these two sources are nitrogen, phosphorus and carbon compounds. The dissolved oxygen (DO) concentration, BOD, and the turbidity of surface water may also indicate organic contamination entering a body of water. Chemical analyses of samples of water and bottom material collected at any given time may or may not indicate contamination from agricultural runoff or sewage. However, exposure to contaminants will affect the benthic community, even though the contaminants are not detected during the monthly water sampling.

Table 2. --Summary of selected physical characteristics of each station

Station	Approx. width (Feet)	Approx. depth (Feet)	Flow	Bottom material
1	200	18	controlled	Fine textured, organic
2	100	6-8	controlled	Organic detritus, sand
3	250	15	controlled	Fine textured, organic, peat detritus
4	200	18	controlled	Fine textured, organic
5	120	8	noncontrolled	Plant detritus, clay
6	200	20	controlled	Fine textured, organic, peat detritus
7	100	12	controlled	Sand, plant detritus
8	100	12	noncontrolled	Fine textured, organic
9	150	12	controlled	Fine textured, organic
10	150	12	noncontrolled	Plant detritus, peat
11	open marsh	0-3	noncontrolled	Peat, algal mat
12	open marsh	0-2	noncontrolled	Peat, algal mat

Surface Water

Nitrogen, phosphorus, and carbon compounds were analyzed in surface water samples collected monthly at the 12 benthic sampling stations. Concentrations of these compounds varied both monthly and seasonally but were highest generally during the summer wet season. Average concentrations of these constituents (table 3) indicated that no gross organic contamination was present during the study. Increases in nitrate (NO_3) and ammonia (NH_4) did occur when agricultural runoff entered the canals between Lake Okeechobee and the three conservation areas during the beginning of the wet season. For comparison, in Plantation Canal (in Ft. Lauderdale), contaminated with sewage effluent, phosphorus was as high as 13.5 mg/l (milligrams per litre) and ammonia (NH_4-N) exceeded 10 mg/l in many of the samples analyzed (Russo, 1974).

Total organic carbon (TOC) values reflect the organic nature of the muck soil in the Everglades. Average values ranged from 21 mg/l at station 9 to 63 mg/l at station 11. Although relatively high when compared with most urban areas in south Florida, it must be realized that the organic carbon is derived mainly from runoff that has had contact with the organic soils of the area. Average TOC values at the marsh stations 11 and 12, minimally affected by agricultural runoff, are in the same range as those average values determined at the canal stations (1-10) (table 3). In the canals TOC increases during the wet season because organic materials are flushed into them. In the marshes, TOC increases during the dry season when the water is ponded and most carbon compounds are concentrated by evapotranspiration.

DO levels fluctuated widely at all the sampling stations (Waller and Earle, 1975). The time of day, number of phytoplankton cells and other aquatic plants and the amount of flow are the major controls on the DO level. During the warmer months the canals were stratified with respect to DO and at most of the stations the DO at the bottom of the canals was less than 2.0 mg/l, indicative of anaerobic conditions. During the cooler months the DO remained generally above 2.0 mg/l and no stratification occurred.

BOD was measured quarterly. The BOD fluctuated very little from season to season and for the most part was low. The BOD data indicate that very little oxygen demanding material is entering these canals or marshes. The highest average levels were noted in the agricultural areas (stations 1, 2 and 5) where runoff carries fertilizers flushed from the cropland.

Table 3.--Average concentrations of monthly samples of nitrogen and phosphorus species, organic carbon, BOD, and turbidity in surface water, July 1972 - June 1974. (Concentrations in milligrams per litre except where noted.)

Station	Turbidity JTU*	BOD	TOC	NH_4-N	NO_3-N	NO_2-N	Org-N	Ortho P	Total P
1	9	2.3	40	0.33	0.55	0.08	2.0	0.08	0.08
2	7	2.6	32	.24	.64	.07	1.4	.07	.10
3	4	1.5	40	.10	.11	.02	2.0	.03	.04
4	4	1.7	44	.19	.37	.05	1.8	.02	.04
5	4	2.4	25	.08	.04	.01	1.5	.06	.09
6	3	1.7	44	.15	.10	.02	1.9	.02	.03
7	4	1.2	29	.44	.06	.01	1.4	.01	.02
8	5	2.1	23	.11	.05	.01	1.7	.01	.02
9	5	1.5	21	.11	.05	.01	1.7	.01	.02
10	9	1.3	22	.59	.03	.01	1.1	.01	.01
11	4	1.3	63	.20	.02	.01	2.6	.01	.02
12	4	1.9	24	.08	.00	.00	1.8	.01	.02

* Jackson turbidity units

Turbidity levels fluctuated monthly due to the changes in the amount of runoff and phytoplankton cells present. Generally the water in the canals remained turbid enough throughout the year and, in combination with the color of the water, prevented light from penetrating to the bottom of the water body. The lack of light penetration limited the productive (euphotic) zone of the canals and prevented growth of submersed or emergent aquatic vegetation in the sampling areas of the canals.

Bottom Material

The bottom material in the canals is an accumulation of organic debris and fine limestone particles that have settled out during periods of little or no flow. It generally has a high (greater than 20 percent) organic content (table 4) which should be expected because of the peat and muck soils that are present throughout the area. These soils break down when they are dry and can be oxidized readily. Rainfall flushes some organic particles out of the soils and they can enter the canals as runoff.

The deposition rate of the bottom material depends on velocity of flow in the canal, the duration of the flow, and the amount of organic material entering the canal with the surface runoff.

At marsh stations 11 and 12 the bottom material is peat, derived chiefly from sawgrass (*Cladium jamacensis*) and other aquatic plants. At the two stations, the organic content (table 3) is higher than at the other stations. The deposition of the peat has occurred slowly. The sampling surface is composed of decaying vegetation and a periphyton mat.

To rate the organic content of the various bottom materials an organic sediment index (OSI) is used (Ballinger and McKee, 1971). This index is calculated by multiplying the percent dry weight of organic carbon times the percent dry weight of organic nitrogen. The OSI values of most canal sediments greatly exceed 10, indicating the presence of a large quantity of organic material. The highest OSI's calculated were at stations 10-12 and these were an order of magnitude greater than those calculated for sediments located near sewage discharges (Russo, 1974). These values indicate the highly organic nature of the sediments in the Everglades, and that they cannot be compared in terms of OSI's with

Table 4. --Average concentrations of nitrogen, phosphorus, carbon, COD and organic content in bottom material

Station	Total Carbon g/kg	Organic Carbon g/kg	*NKJD mg/kg	$NO_3 + NO_2$ mg/kg	P mg/kg	Organic content (percent)	COD g/kg
1	181	98	11,000	1.1	91	28	510
2	42	24	5,800	0.3	68	8	190
3	206	163	17,000	1.1	88	43	570
4	153	90	10,000	.6	87	24	345
5	74	49	8,300	.8	1450	14	465
6	139	94	5,500	2.0	180	28	250
7	29	6.5	4,400		640	3.1	35
8	133	82	15,000	1.5	110	22	350
9	157	92	15,000	1.4	90	17	260
10	264	226	20,000	2.9	53	50	900
11	310	282	23,000	1.9	69	68	615
12	367	366	46,000	3.7	250	62	2700

* Kjeldahl nitrogen (organic nitrogen plus ammonia)

sediments, both contaminated and uncontaminated, found in other areas.

The bottom materials are enriched in nitrogen, phosphorus and organic carbon as compared with the overlying water. Kjeldahl nitrogen (organic and ammonia) concentrations in bottom material are 3 to 4 orders of magnitude higher than those in surface water. Total phosphorus and organic carbon concentrations in bottom material were 2 to 4 orders of magnitude higher than those in the overlying water. Most of the macronutrients in the bottom material are unavailable for use by plants or for release into the overlying water because they are not easily recycled. These nutrients can be assimilated by the detritus feeding benthic community.

The bottom sediments in canals remain fairly stationary once they are deposited, because low discharge occurs over most of the year (fig. 4). Only in the canals adjacent to pumping stations or control structures do the deep sections of the canals become scoured of the fine organic detritus. At stations 5, and 8 through 12 the flow velocity is low over the year. At other stations the velocity varies during the year.

BENTHIC ORGANISMS

Benthic organisms live on the bottom of lakes, reservoirs, and streams or, as in this study, in marshes and canals. They may be found in the littoral (shore) or in the profundal (deep) zone of a body of water. The littoral zone contains a wide variety of both vertebrate and invertebrate organisms that inhabit many varied niches and utilize every trophic level. The animals found in a profundal zone are generally less diversified than those found in a littoral zone of the same body of water. Profundal species consist primarily of segmented worms, immature insects, and certain mollusks. They have adapted to live in an environment that is often low in dissolved oxygen and is fairly stable in abiotic factors, such as temperature, flow, and substrate. Profundal species are generally low on the trophic level, feeding primarily on organic detritus, algae, bacteria, and microbenthos.

Benthic organisms adapt to their environment. They are, by definition, low in motility and are less able to avoid environmental stress than more motile organisms. In a lotic (flowing) body of water, they often attach to or borrow into the bottom. In a lentic (non-flowing) body

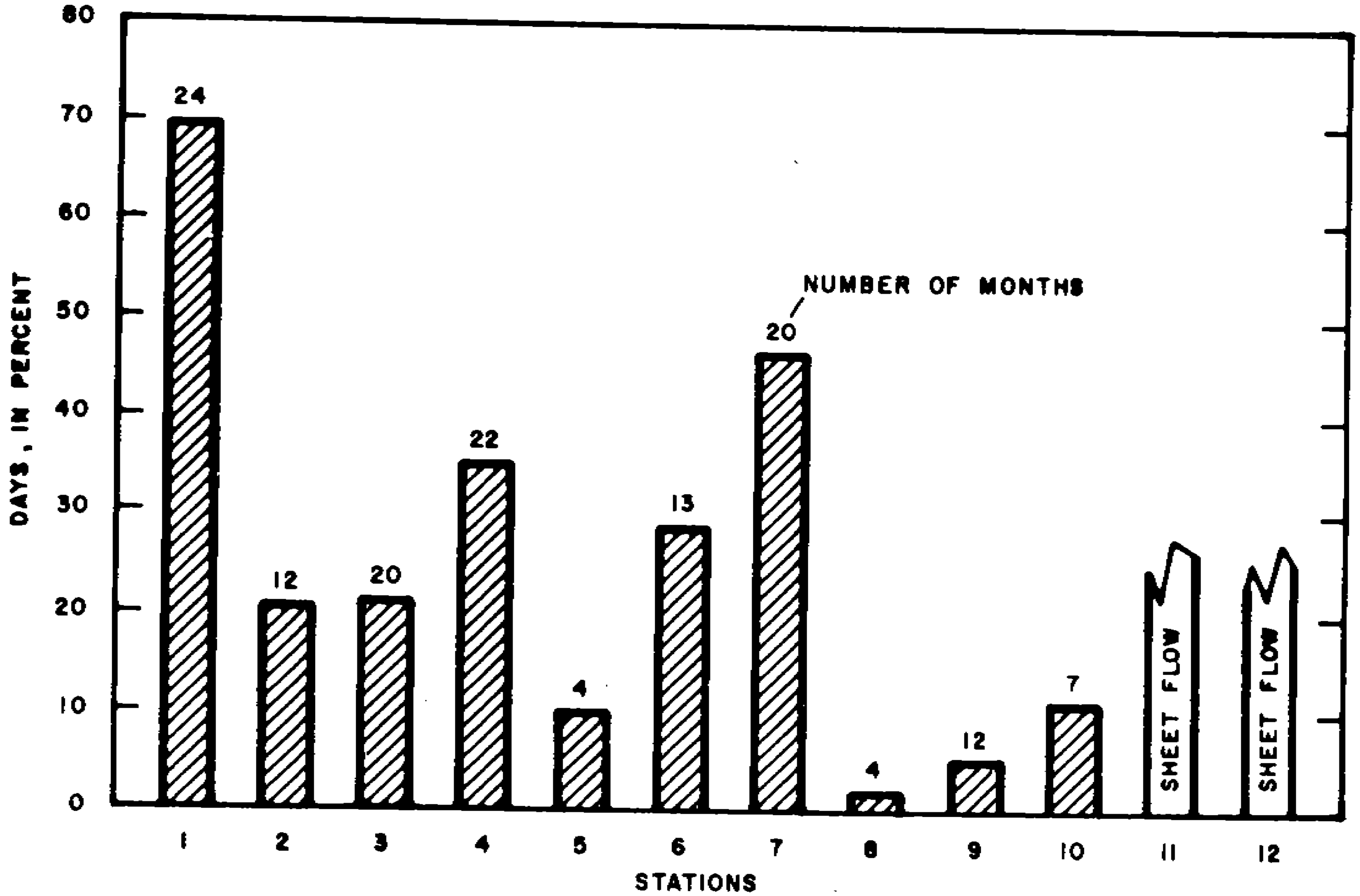


Figure 4.--Percentage of days where flow exceeded 100 cubic feet per second and number of months flow occurred at least one day from July 1972 to June 1974.

of water, many species are free living. On the basis of this factor of immobility, free-living species can also be used as an indicator of water quality in a given area. Because of this, they can often be used to evaluate water-quality changes. They can give the observer an idea of what the environmental factors, both physical and chemical, in water and bottom material, have been over recent months.

There are four major ways in which biological communities can be analyzed: (1) The diversity and population structure of the community. This analysis includes the relation between physical and chemical parameters in the environment and the community structure. (2) The adaptiveness of organisms to their specific environment. (3) The interrelation between the species comprising a community. These include prey-predator relations, trophic levels in the community and how the species interact (parasitic, commensal, mutual, saprophytic, and so forth), and (4) succession of one community into another. Of the four major ways cited above, this study considers only way number 1, the diversity and population structure in the analysis of the benthic community.

Quantitative Analyses

The number of organisms found at each station varied seasonally (table 5). Flow conditions at each station also varied seasonally. During the wetter months, June to November, flow is greater than during the remaining months. The greater flow displaces the organisms so that community populations have little time to develop. On the average, more animals were found during the April sampling and period of low flow, than during the October sampling, and period of higher flow, except at stations 1 and 2. At Station 1 there is flow during every month of the study (fig. 4) and at Station 2 water is discharged only during the dry season for aquifer recharge and irrigation.

A quantitative measure to determine the difference between biological communities can be derived from a species diversity index (Patten, 1962). This index is, in turn, derived from statistical analysis of the number of species in a sample and the total number of organisms found. Analyses of this index for a particular area can give an indication of community structure and environmental quality.

The species diversity index (table 6) is derived from the equation:

Table 5. --Calculated number of benthic organisms per square metre of bottom surface at each sampling station

Station	October 1972	April 1973	October 1973	April 1974	Total
1	472	229	815	559	2,075
2	1,745	472	400	129	2,746
3	472	1,173	114	1,204	2,963
4	529	1,258	586	2,494	4,867
5	1,330	300	--	1,591	3,221
6	500	243	86	4,644	5,473
7	443	2,488	43	43	3,017
8	129	8,180	1,072	2,494	11,875
9	229	586	57	215	1,087
10	315	3,146	1,158	6,106	10,725
11	114	1,573	1,859	2,365	5,911
12	129	157	4,690	215	5,191
Total	6407	19805	10880	22059	
Average	534	1650	989	1838	

Table 6.--Species diversity index after Patten, 1962

Station	October 1972	April 1973	October 1973	April 1974	Average
1	0.86	1.1	0.99	1.2	1.0
2	.21	.28	.90	.91	.58
3	.57	.45	.96	.30	.57
4	1.1	.89	2.4	.74	1.3
5	.88	1.3	---	.60	.93
6	.56	.70	.56	.43	.56
7	1.5	.19	.00	.00	.42
8	.00	.16	.23	.00	.10
9	.72	.27	.00	.00	.25
10	.32	.18	.46	.20	.29
11	.96	1.1	.41	1.2	.92
12	1.4	.83	.52	.62	.84

$$\text{Diversity index} = S-1/\ln N$$

Where S is the number of different species in the samples and N is the total number of animals present. (Patten, 1962)

In comparing the averages for all stations for each sampling period, no significant seasonal variation can be found. The lowest average species diversity was found at Station 8 (0.10) and the highest at Station 4 (1.3). Russo (1974) found that in an urban canal polluted with domestic sewage, the average species diversity ranged from 0.00 to 0.33. The average species diversities found within the Everglades were greater than 0.40 at 9 of the 12 stations.

Another species diversity index (table 7) developed by Wilhm (1970) is used for comparison with the first index calculated to see if the results are comparable. This diversity index has the advantage of being dimensionless and not dependent on the number of samples to derive a statistically valid index. It also expresses the relative importance of each species. The diversity index is derived by the equation:

$$-\bar{d} = \sum_{i=1}^{S} \frac{n_i}{n} \log_2 \frac{n_i}{n}$$

where n is the number of organisms, n_i is the number of individuals per taxon and S is the number of taxa.

Wilhm's diversity indices show a similar pattern as those found using the first index (Patten) although, on the average, they are higher for every station. Values ranged from 0.00 at Stations 7-9 to 2.1 at Station 4. Organically polluted bodies of water tend to have a diversity index, using this formula, of less than 1.0 (Wilhm, 1970). Over 50 percent of the benthic samples had indices below 1.0 and 5 stations (1, 4, 5, 11 and 12) had average indices greater than 1.0.

Although species diversity and numbers may evince possible degraded environmental quality (tables 6 and 7), other factors, such as flow, depth and water levels may be causing the low species diversity.

Table 7.--Species diversity index after Wilhm, 1970

Station	October 1972	April 1973	October 1973	April 1974	Average
1	1.6	1.9	1.1	1.8	1.6
2	.73	.20	1.5	.02	.84
3	.80	.19	1.1	.22	.58
4	1.5	1.2	2.1	1.3	1.5
5	1.3	1.9	---	1.0	1.4
6	.73	1.1	.65	.21	.67
7	2.0	.56	.00	.00	.64
8	.00	.36	.10	.00	.12
9	1.5	.99	.00	.00	.62
10	.94	.91	.80	.37	.76
11	1.1	1.4	.83	1.4	1.2
12	1.7	1.1	1.0	.97	1.2

Qualitative Analyses

To relate the distribution and variety of the biota to the chemical and physical characteristics of the body of water being studied, a Biotic Index was computed. This index, a numerical rating of the cleanliness of a body of water with respect to organic contamination, was devised by Beck (1969).

The hypothetical range of the Biotic Index may vary from zero to 40 when using only the dominant 20 species. Each benthic community receives its own numerical rating and by analyzing these ratings the investigator gains an idea of the relative health of the body of water being studied. A biotic index of 10 or more indicates a clean body of water; an index of 1 to 10 indicates a moderately contaminated body of water; and an index of less than 1 indicates a body of water grossly contaminated.

To determine a Biotic Index benthic organisms are first classified as to their tolerance of organic contamination (Beck, 1969). Class 1 includes species that tolerate no appreciable organic contamination and Class 2 includes those that can tolerate moderate organic contamination, but cannot exist under anaerobic conditions. The index is then calculated as follows:

$$\text{Biotic Index} = 2\,(n\ \text{Class 1}) + (n\ \text{Class 2})$$

where n equals the number of different species present.

The biotic indices in the Everglades ranged from 1 at Station 8 to 13 at Station 4. Indices varied seasonally and between stations (fig. 5). Based on the Biotic Index the waters of the Everglades vary between moderately contaminated to clean. Although the chemical analyses of the surface-water samples indicate no organic contamination present, the Biotic Index may reflect other factors such as hostile environments, including high temperatures, high flow, poor substrata. It should be noted that this index depends on a representative sample of the benthic communities at each station. Because of the limited number of samples (10) at each station caution was used when relying totally on these indices to indicate the health of a body of water.

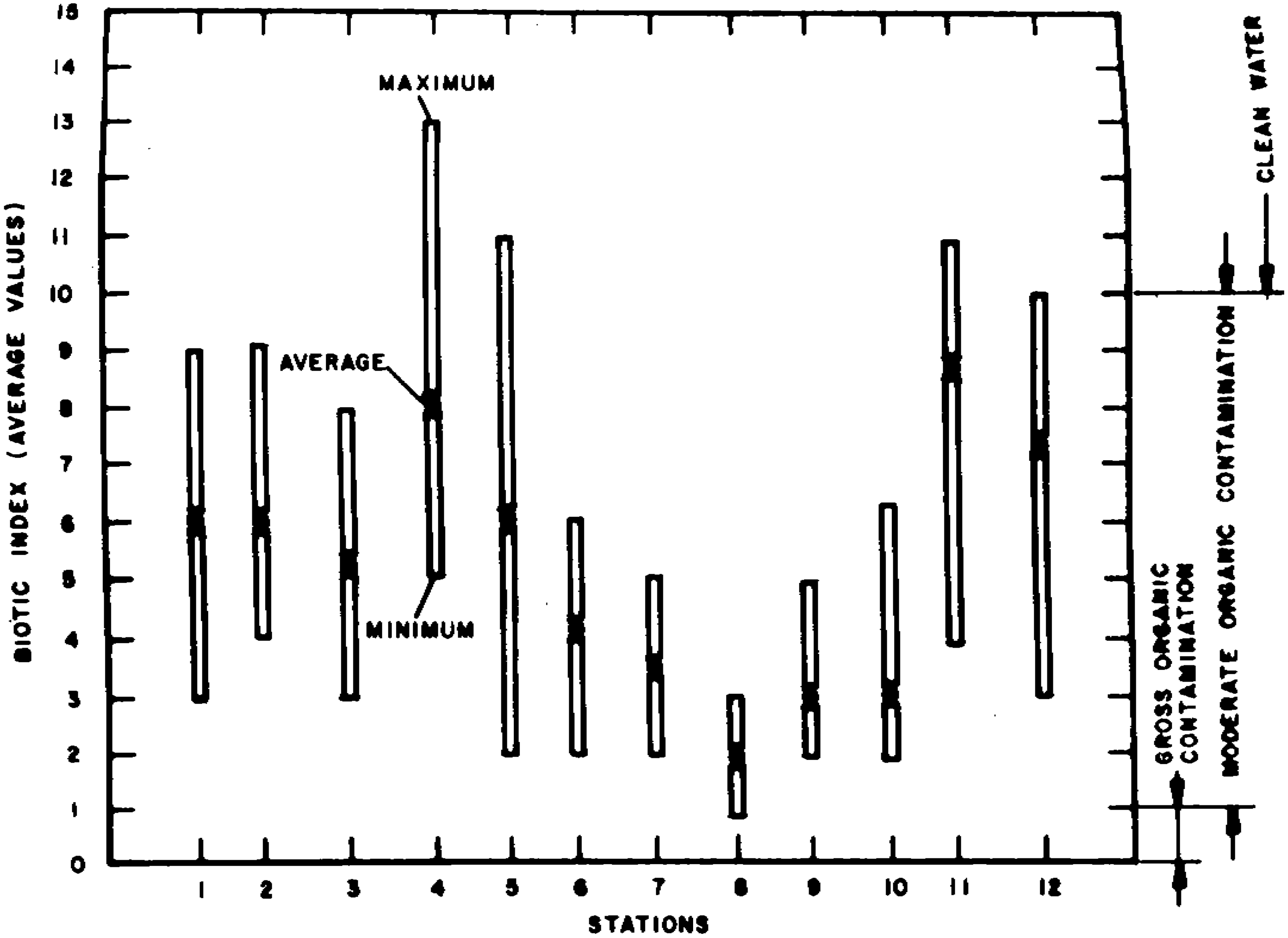


Figure 5.--Biotic Index of benthic organisms.

Both the quantitative and qualitative analysis of the benthic communities indicate some organic contamination. It should be remembered that these indices only indicate the relative health of a body of water and the values calculated depend on a representative sample.

DISTRIBUTION PATTERNS

Benthic organisms inhabit the particular ecological niche in which they are found because they have adapted to the environmental factors which are found in the benthic zone of a body of water. Many factors, both biotic and abiotic, determine the numbers, species composition, and distribution of the benthic population.

The Everglades includes niches that are both manmade and natural. Canals under low-flow conditions afford the benthic community a lake type environment for development. The marsh areas provide a large 1,340-mi^2 (3470 km^2) littoral zone for aquatic benthic organisms although seasonally the marshes are ponded or dry. All the sampling stations have water levels, depth of water and flow regulated artificially for water management purposes.

The chemical analyses of bottom material and water indicate that no gross organic contamination is present at the sampling stations. Considering that the area of investigation is eutrophic and highly organic, higher concentrations of organic compounds were found than were determined in a nearby polluted urban canal (Russo, 1974). DO levels fall below 2.0 mg/l in the bottom of canals during the warmer months when stratification occurs. This low DO level seems to have little effect on the profundal benthic community. When a canal is shallow or the water clear enough to allow a littoral zone to develop with increased light penetration, the benthic community changed with its habitat.

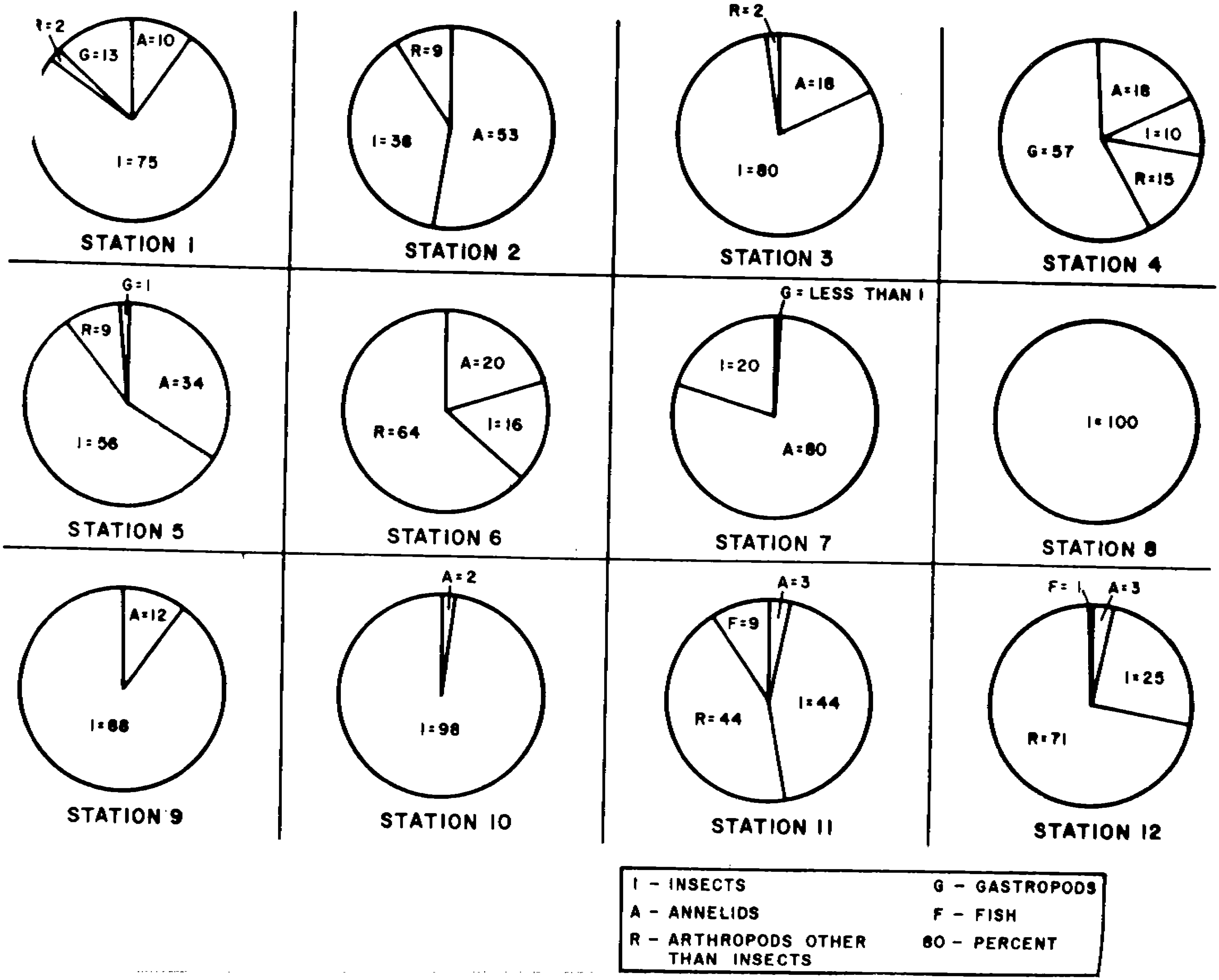
The benthic community in the open slough area is influenced greatly by the changing water levels. During the wetter months, when water covers most of the marsh, the organisms are dispersed throughout this large littoral zone. When water levels decline and ponding occurs, the organisms generally concentrate and their species composition changes. (Kolipinski and Higer, 1969).

Types of organisms varied among stations (fig. 6). Immature insects were the most prevalent and comprised 55 percent of all organisms collected. Annelids were the next most prevalent group (21 percent). They were found at all stations except 8 and were represented mostly by oligochaetes and some leeches (Hirundinea). Arthropods other than insects but including freshwater shrimp, a bottom associated organism, were collected at 8 of the stations (1-6, 11 and 12) and comprised 18 percent of all organisms collected. The marsh stations 11 and 12 had the largest percentage (44 and 71 percent, respectively). Gastropods were found at stations 1, 4, 5 and 7 and totaled 6 percent of all organisms collected. The greatest numbers of this group were found at stations 1 and 4 where the substrate is soft and flow occurs most of the year (fig. 4). Fish, although not benthic organisms, were collected at the marsh sampling stations 11 and 12 only when water was ponded and comprised less than one percent of all the organisms found.

The assortment of benthic organisms collected varied seasonally and from station to station in their distribution. Flow duration and velocity, water levels, depth and substrate appear to have a strong influence on the numbers and taxonomic composition of the benthic community.

Colonization of the profundal zone in the canals of South Florida by benthic organisms has occurred in the last 60 years. The man-made environment in which they live is controlled and changes from a generally lentic environment to a lotic one seasonally. The organisms have adapted to the hydrologic scheme, but their populations appear to vary more in response to physical factors than chemical factors.

Velocity and duration of flow have a definite influence on the numbers and development of a benthic community. They determine if the benthic community develops as a lentic (lake-type) or one that is characteristic of a flowing body of water. Qualitative analysis of organisms indicate that the benthic communities in the study area are lake types. Benthic organism studies in Lake Okeechobee (Beck and Hulbert, 1969) and Blue Cypress Lake (Goolsby and McPherson, 1971) show that similar types of organisms were collected in these two lakes as those collected in the Everglades. Flow patterns and duration are such that a lentic benthic community has developed in the canals of the Everglades. Flow frequently interrupts and inhibits community


=2
G=13
A=10
I=75
STATION 1
R=9
I=38
A=53
STATION 2
R=2
A=18
I=80
STATION 3
A=18
I=10
G=57
R=15
STATION 4
G=1
R=9
A=34
I=56
STATION 5
A=20
I=16
R=64
STATION 6
G = LESS THAN 1
I=20
A=80
STATION 7
I=100
STATION 8
A=12
I=88
STATION 9
A=2
I=98
STATION 10
A=3
F=9
I=44
R=44
STATION 11
F=1
A=3
I=25
R=71
STATION 12
I – INSECTS
A – ANNELIDS
R – ARTHROPODS OTHER THAN INSECTS
G – GASTROPODS
F – FISH
80 – PERCENT

development as is shown by the seasonal fluctuation in organisms collected (table 4), but the flow does not last long enough to establish a lotic benthic community.

CONCLUSIONS

The Everglades is a eutrophic area characterized by peat and muck soils, shallow marshes, and canals.

Chemical analysis of water and bottom material indicates no organic contamination at the sampling stations.

Long-term evaluation of environmental quality by analyses of benthic communities indicates that the organisms have not been affected by degraded water quality. A possible effect of organic contamination has been observed on the structure of the benthic organisms' population structure by using species diversity indices.

Flow velocity and duration, water levels, water depth, and substrate dictate the number and species composition of the benthic community to a greater extent than the chemical quality of the bottom material or overlying water.

SELECTED REFERENCES

American Public Health Association, 1971. Standard methods for examination of water and waste water. Amer. Public Health Assn., Amer. Water Works Assn., Water Poll. Control Fed., 13th ed., New York, N. Y. 845 p.

Ballinger, D. G., and McKee, G. D., 1971, Chemical characterization of bottom sediments: Jour. Water Poll. Control Fed., v. 43, no. 2, p. 216-227.

Beck, W. M., Jr., 1969, Stream monitoring biological parameters, in Florida's Environmental Engineering Conference on Water. Pollution Control; Florida Engineering and Industrial Experiment Station, Bull. Series No. 135, p. 60-63.

Beck, W. M., and Hulbert, J. L., 1969, Lake Okeechobee Survey; Bottom Faunas, Winter 1969. Florida State Board of Health. Mimeo 7 p.

Environmental Protection Agency, 1971, Big Cypress Swamp jetport monitoring program - annual summary and evaluation of data, Athens, Ga., p. 45-57.

Goolsby, D. A. and McPherson, B. F., 1971, Preliminary evaluation of chemical and biological characteristics of the upper St. Johns river basin, Florida: U. S. Geol. Survey open-file report 71001 p. 38-41.

Hutchinson, G. E., 1957, A Treatise on Limnology. v. I: New York, John Wiley and Sons, 1015 p.

__________, A Treatise on Limnology. v. II: New York, John Wiley and Sons, 1115 p.

Ingram, W. M., Mackenthun, H. M. and Bartsch, A. F., 1966, Biological field investigative data for water pollution surveys: U. S. Dept. of the Interior, Federal Water Pollution Control Adm. p. 18-46.

Kolipinski, Milton C. and Higer, Aaron L., 1969, Some aspects of the effects of the quantity and quality of water on the biological communities in Everglades National Park: U. S. Geol. Survey open-file report 69007. 97 p.

Leach, S. D., Klein, Howard and Hampton, E. R., 1972, Hydrologic effects of water control and management of southeastern Florida: Florida Geol. Survey Rept. of Inv. No. 60. 102 p.

McPherson, Benjamin F., 1970, Preliminary determinations of hydrobiological conditions in the vicinity of the proposed jetport and other airports in south Florida, July 1969: U. S. Geol. Survey open-file report 70004. 31 p.

Odum, E. P., 1971, Fundamentals of Ecology: Philadelphia, W. B. Saunders Co., 574 p.

Parker, G. G., Ferguson, G. E., Love, S. K., and others, 1955, Water resources of southeastern Florida, with special reference to the ground water and geology of the Miami area: U. S. Geol. Survey Water-Supply Paper 1255. 965 p.

Patten, B. C., 1962, Species diversity in net phytoplankton of Ravitan Bay: Jour. Mar. Res. v. 20. p. 57.

Pennak, R. W., 1953, Fresh-water invertebrates of the United States: New York, Ronald Press Co., p. 278-285.

Russo, T. N., 1974, Indicators of organic contamination in Plantation Canal, Broward County, Florida, 1971-72: Florida Geol. Survey Rept. of Inv. No. 70. 38 p.

Waller, B. G. and Earle, J. E., 1975, Chemical and Biological Quality of Water in a part of the Everglades, Southeastern Florida: U. S. Geol. Survey Water-Resources Investigation 56-75. 156 p.

Ward, H. B. and Whipple, G. C., 1918, Fresh-water biology: New York, John Wiley and Sons, 1111 p.

Welch, P. W., 1948, Limnological methods: New York, McGraw-Hill Book Co., p. 299-304.

Wilhm, J. L., 1970, Range of diversity index in benthic macro-invertebrate populations: Jour. Water Poll. Control Fed., v. 42 no. 5, part 2. p. R221-4.