EFFECTS OF PHOSPHATIC CLAY POLLUTION ON THE PEACE RIVER, FLORIDA

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ABSTRACT

Contamination of the Peace River with 1,500 acre feet of phosphate mine waste (montmorillonite clay) resulted in heavy mortality of stream fauna. The estimated kill of fishes exceeded 90% of the fish population in 76 miles of stream. Losses of macroinvertebrates were heavy or complete for all taxonomic groups, except oligochaetes and tendipedid larvae.

Excessive clay turbidity was determined as the cause of kill. Lethal concentrations of suspended particles was short term and within 9 days stream water quality returned to normal.

Recovery of stream fauna was monitored for a 15 month period. Data is presented concerning recovery rates for fish species, invertebrates, and degradation effects on stream habitat.

A monetary settlement was obtained from the responsible party in the amount of $200,000.00.

INTRODUCTION

South Florida's pebble rock phosphate industry is confined to the counties of Polk, Hillsborough, Manatee, and Hardee. Generally, strip mining is the method used to extract the ore which is slurried with water and separated by flotation. Waste by-products are sand and clay. Sand is used for land reclamation and dike construction while clays, referred to as slimes, are discharged into settling basins for permanent retention.

The clay-filled settling basins (slime pits) constitute the major problem in water pollution. Space becomes a critical factor in the deposition of these wastes and in some instances retention pits are overloaded resulting in breaks and contamination of public waters. Since tremendous water volume is required by the industry, most mining operations are located near major tributaries or streams.

On March 11, 1967, an earthen dike surrounding a 200 acre phosphate slime pit gave way releasing approximately 1,500 acre feet of slimes (clay) into the Peace River. The pit was located on the property of Mobil Chemical Company near the City of Fort Meade. Slimes entered the river about 5 miles above Fort Meade and coursed downstream to the Charlotte-DeSoto County line, a distance of 85 miles.

Components of slime, in this instance, were predominately montmorillonite clay, a nominal amount of phosphate, and water. Examination of particle size found the majority of particulate material to range from 3 to 10_u (P. R. Edwards, Personal Communication). No evidence of available toxic elements were detected.

METHODS

In order to include all habitats of the ecosystem, 11 sampling stations were established along the 85 miles of polluted stream. One station was maintained above the pollution zone for control. Supplemental information was collected between stations as required for accurate determinations. Also, for convenience of orientation, the contaminated portion of river was divided into 3 zones, upper, middle, and lower. These zones do not necessarily reflect ecological differences in the river. Figure 1 locates the sampling stations, river miles, and zones in relation to the geography of the Peace River.

Stream flow data was provided by the U. S. Geological Survey and Southwest Florida Water Management District. Computations were made for Station 6 only (Pioneer Park), representing the mid-point of the polluted zone, to provide relative information of water fluctuations.

Quarterly physico-chemical analyses of water were performed at the Fisheries Research Laboratory, Game and Fresh Water Fish Commission, by Standard Methods (12th Edition) and Atomic Absorption Spectrophotometry. Weekly measurements of dissolved oxygen, carbon dioxide, pH, and turbidities were conducted in the field by project personnel using the Hach DR Portable Laboratory.

The principal sampling gear employed for fish population studies was the block net—rotenone technique (2 ppm), although minnow seines, the electro-fishing device, and marked area rotenone samples (no block net) were used for supplemental data. Invertebrate collections were made with the Surber stream sampler or Ekman dredge as conditions

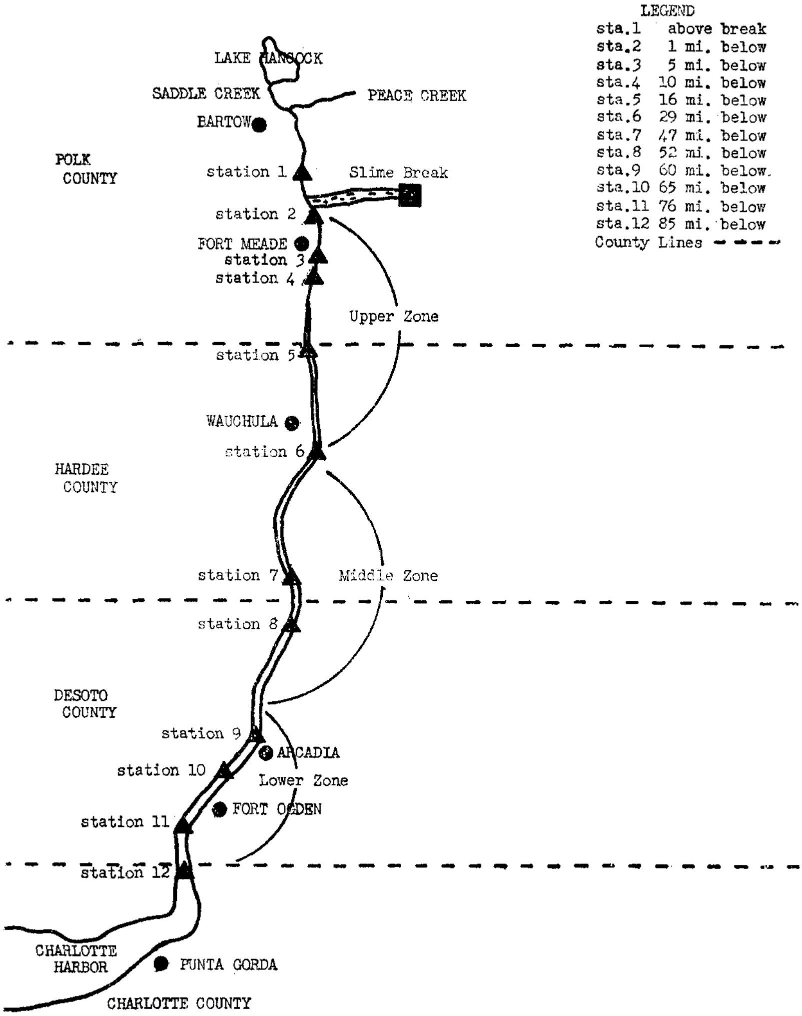

Figure 1 - Map of Peace River locating sampling stations and zones

required. Sampling frequency included the initial period of pollution and seasonably for a 15 month period following. A total of 97 fish population and 90 invertebrate samples were collected.

FINDINGS

Water quality

The detrimental effects of phosphate slime on aquatic life and habitat, in the Mobil incident, were mechanical or physical. The only toxic element detected was fluoride, and its availability was questionable. Therefore, the primary water quality constituents we were concerned with were suspended solids and turbidity.

Prior to the slime break of March 11, 1967, background water quality was satisfactory for the well being of aquatic life. Turbidities ranges from 74 Jackson Units (Station 1) to 32 J. U. (Station 11). When slimes entered the river, turbidities were recorded as high as 57,000 J. U. (Station 8) and suspended solids as high as 59,750 ppm (Station 4). Table 1 presents the recorded turbidities and suspended solids at various locations along the river before and during slime contamination. Nine days elapsed before stream water quality returned to normal and slimes settled to the bottom.

After slimes settled, water quality constituents remained normal until the June rains. High water caused additional slime movement and turbidities increased to a maximum of 125 J. U. Figure 2 shows maximum turbidities recorded at Stations 1 and 6, and corresponding flow at Station 6, for a 15 month period following the break. At no time were sufficient turbidities indicated to cause additional mortality to aquatic life, although turbidities were higher in the polluted zone during June, July, August, and October, 1967.

Fish Kill

During the week following the slime contamination, fish population and invertebrate sampling was initiated to determine the mortality to stream macro-fauna. Since monetary values could be assigned to fish loss, emphasis was given in this area. Observations of aquatic vegetation were noted during the course of the study.

Fish mortality was estimated by a random sample in a measured 100 yards of stream upstream from the polluted zone. This information was used to establish a standing crop per unit of area and species composition. Subsequent sampling (9 samples) using the same method throughout the polluted section provided a value of survival. A simple computation was then made by substracting the mean survival from the upstream standing crop to determine the extent of fish kill. To estimate species mortality the previously determined composition was applied to the total mortality. These data were expanded for the measured surface area of the river from topographical maps. Sampling results and mortality estimates are as follows.

FISH KILL ESTIMATES

Population above polluted area/100 yards stream—No. 786, Wt. 30.03 lbs.
Average population in polluted area/100 yards stream—No. 51, Wt. 2.06
Fish kill/100 yards stream–No. 735, Wt. 27.97 lbs.
Affected area of river—76 miles or 1,630.5 surface acres
Total kill—No. 983,430, Wt. 36,675 lbs.
Percent Mortality—91.3%

The marked area rotenone technique at 2 ppm + Noxfish was employed for the kill estimates because it was considered the least selective of available gear, especially for sport fish. High water and turbidity negated the use of electro-fishing or the more desirable block net—rotenone method.

Observations during the pollution incident supported sampling results. Dead fish were evident throughout the stream and in many instances fish were literally buried in slime deposits. Commonly, fish were in distress at the water's surface or had swam onto dry land attempting to escape. An examination of dead fish revealed opercular cavities and gills coated with slime particles. Cause of death was considered to be mechanical suffocation, resulting from stress and clogging of gill filaments. Conclusions presented on fish mortality were in substantial agreement with the biological staff of the responsible party (Mobil Chemcial Company—John F. Dequine, Personal Communication).

The extensive fish kill experienced in the Peace River, 91% of the total population in 76 miles of stream, is not completely supported by the literature on turbidity threshholds for fish. Wallen (1951) studied the effects of turbidity from montmorillonite clay on 16 species of fish. He reported that most fishes endured turbidities of 100,000 ppm, but finally died at 175,000 to 225,000 ppm turbidity. His average lethal turbidities for largemouth bass and channel catfish were 101,000 ppm and 85,000 ppm, respectively. He concluded that observable stress did not occur until turbidities of 20,000 ppm were reached. Conversely, Kemp (1949) considered turbidities of 3,000 ppm dangerous if maintained for 10 days. He attributed a large fish kill in the Potomac River during 1936 to a flood which produced turbidity levels of 6,000 ppm for 15 days. The EIFAC (1964) reported that many kinds of suspended solids can be present for short periods in concentration of at least several thousand ppm without killing fish, but may damage gills and affect their subsequent survival. In the Peace River, the highest recorded turbidity was 57,000 ppm and it was of short duration (2-3 days), but this concentration was sufficient to cause a heavy mortality of fishes.

Recovery of fishes

After the initial pollution, no additional mortality was detected and fish recovery was evident by June, 3 months after the break. During a series of seine samples, minnows endemic to the river were found abundantly and young-of-the-year largemouth bass, *Micropterus salmoides*, were recovered in all areas. Other centrachids were not collected and apparently had not reestablished by this time. Channel and white catfish, *Italurus punctatus* and *I. catus*, were common in the middle river zone, but were not found in the upper or lower river. The absence of adult sport fish and spawning activity suggested fish recovery at this point was due to re-invasion. This assumption was further supported by the abundance of fish and observed spawning in the tributaries.

Electro-fishing studies conducted in July, again recovered very few fish. In the upper, middle, and lower zones, only 17, 23, and 31 fish respectively, were collected. Each sample involved a 2 hour effort covering approximately one mile of stream. Young centrarchids, chiefly bass, plus young white and channel catfish comprised the bulk of the catch.

Block net sampling was initiated in August, 1967, and was used as the principal sampling tool thereafter. The summer results found little change in the standing crop weight from the time of the fish kill—both periods indicated about 6 pounds per acre (Figure 3). However, the numbers of sport fish had increased (Figure 4). Largemouth bass, bluegill, *Lepomis macrochirus*, and channel catfish, accounted for most of the increase.

By fall, accelerated recovery of the population was evident. The standing crop estimate had increased to 20 pounds per acre and two species, bluegill and redear sunfish, *Lepomis microlophus*, were peaking in density (numbers). Largemouth bass were now showing evidence of decline, signifying an early population increase, within 6 months, and now returning to a lower density equilibrium. Channel catfish and spotted sunfish, *Lepomis punctatus,* made their highest gains during this period (Figure 4). It should be noted that although sport fish had substantially increased, these were mostly sub-adult fish and a satisfactory "harvestable" population did not exist.

A continued increase in standing crop was recorded during the winter and spring (Figure 3). The estimated spring average of 87 pounds per acre compared favorably with estimates above the polluted area. The numbers of sport fish showed considerable shifting during this period. Channel catfish dropped from 136 per acre to 16, which was probably due to sampling prior to spawning and sampling error. Largemouth bass were showing a slight increase that was largely due to abundant reproduction—one sample recovered 60 bass fry. Bluegill and redear dropped slightly, whereas spotted sunfish continued to increase. Spotted sunfish were the most abundant sport fish by number 15 months after the kill—an average of 110 fish per acre (Figure 4). Harvestable size fish were now common.

Heavy rainfall, hurricanes, and continued high water prevented any additional sampling after the spring season of 1968. However, the 15 months of study conclusively demonstrated significant recovery of stream fishes by this time. Qualitatively, the population was good (Table 2). The species composition by number was 5% largemouth bass, 11% bluegill, 21% spotted sunfish, and redear and warmouth, *Chaenobryttus gulosus,* combined were 9%. Channel and white catfish were 6% and 7% respectively, while bullheads made up less than 3%. Forage fish, chiefly seminole killifish, *Fundulus seminolis,* lined sole, *Achirus lineatus,* black spot shiner. *Notropis maculatus,* comprised most of the remainder—37%. Coarse fish made up a minor 2%. Quanitatively, no peak in standing crop expansion was evident, but the spring 1968 average of 87 pounds per acre was a substantial gain (81 pounds) during the 15 month recovery period.

The occurrence of successful reproduction of sport fish in the river was noted for the first time 13 months after the fish kill. Active centrarchid nests were found commonly during March, April, and May, 1968. In general, reproduction was considered satisfactory throughout the river.

Growth of fishes during population recovery appeared normal. Age -O largemouth bass were monitored from June, 1967, through April, 1968, to serve as a growth index (Figure 5). The length frequency mean increased from 2.5 inches to 7.7 inches (TL) during the 10 month period. Average monthly increment was 0.52 inches, which is satisfactory for this area under natural conditions. Highest growth occurred during the summer, approximately 1 inch a month, when forage was abundant and competition from other species low.

By late spring and summer 1968, limited sport fishing had returned to the river. Channel and white catfish, bluegill, spotted sunfish, and largemouth bass were available in varying quantities. Occasional reports of successful fishermen were received, but for the most part people had the erroneous belief that a fishery did not exist. One marine species, the snook, *Centropomus undecimalis,* provided a substantial sport fishery in the lower river, although it was completely unexploited by local fishermen (Ware, personal experience).

Invertebrates

The absence of background information, plus low quality habitat in the control area, required sort of a "back door" approach to the measurement of invertebrate losses and recovery. Many researchers have defined the typical benthic organism response to various wastes (Hynes, 1966; Bartsch and Ingram, 1959; Gaufin and Tarzwell, 1956). However in this instance, benthos damage was immediate, so sampling had to be continued through sufficient time lapse until results were duplicated and comparable to an expected norm for stream production. Beck (1954) stated that an attempt to show pollution damage by a few pollution indicator organisms will fail, but it is the complex or association that is of greatest importance. Accordingly, Ingram et. al. (1966) reported that different types of benthic organisms respond in a variety of ways to adverse changes in their environments. He further added that an unpolluted stream will support many different kinds of organisms but relatively few individuals, whereas the converse most often exists in a polluted stream. In the Peace River, it was this loss of diversity of invertebrates that best demonstrated the effects of phosphate slime pollution.

Submerged vegetation (southern naiad and eelgrass) was chosen as the principal sampling area since this substratum was known to support the greatest variety of organisms, both periphyton and benthos (unpublished data). It was felt that a sampling scheme of all habitats could be too complex for a precise recovery index due to the diverseness of invertebrate production between micro-habitats. Other stream substrata were investigated, but the data was used primarily as a supplemental recovery measurement. Figure 6 shows the results over a 12 month period.

Invertebrate sampling at all stations following the dam break found oligochaetes to be the predominate benthos. Numbers ranged from 36 to 2,410 per square foot at various locations. Midges of the family Tendipedidae were the only other organisms considered to be abundant—ranging up to 288/ft.^{2}. Other invertebrates recovered included fingernail clams (Sphaeriidae) at two stations, beetles at 3 stations, an occasional Diptera larva, and two caddis larva at Station 11. For the most part, the healthy invertebrate population had been eliminated from 76 miles of stream (Figure 6).

By late Summer there was some evidence of recovery. Submerged vegetation showed an increase in fingernail clams, plus the presence of snails, dragonfly, and damselfly nymphs. Oligochaetes and tendipedid larva were still the dominant groups (Figure 6). Additional sampling in mats of water hyacinths found 620 organisms/ft.^{2} at Station 1 (above pollution), whereas only 68 organisms/ft.^{2} were found at Station 6 (below). However, mayfly nymphs, damselfly nymphs, and scuds, *Hyalella azteca,* were becoming increasingly common in the polluted area.

High water prevented any additional sampling until October, 7 months after contamination. By this time invertebrate recovery was well under way. The oligochaete population was considerably reduced (38/ft.^{2}) and substantial increases of the important "fish-food" organisms were evident during November (Figure 6). Caddis larva and mayflies showed population densities upwards of 300-500/ft.^{2} respectively. Scuds, clams, and beetles each ranged between 50 and 200/ft.^{2}, while snails, dragonflies, and damselflies showed moderate increases. Although these major gains were most apparent in submerged vegetation, water hyacinth sampling recovered 210 organisms/ft.^{2} and included for the first time a healthy population of the shrimp, *Palemonetes* (29/ft.^{2}).

Similar quanitative and qualitative estimates recorded during January, March, and April, 1968, indicated that the invertebrate population had recovered to the approximate stream norm by November, 1967, 8 months after the dam break (Figure 6). Supplemental samples taken from other substrata were in substantial agreement with these findings. However, there were still some areas of the stream bottom that were depressed in benthos production because of slime accumulations. For example, a slime deposit sample at Station 10 revealed 392 organisms/ft.^{2} of which 60% were oligochaetes and the remainder Diptera larva. An adjacent sample free of slime recovered 424 organisms/ft.^{2} and included 92 mayfly nymphs, 92 caddis larve, 36 damselflies, 24 beetles, 4 clams, and 176 Diptera. Of course, one sample does not reflect the entire river, but there was sufficient repetitive evidence to show that the presence of slimes serve as a qualitative detriment to invertebrate production.

Aquatic vegetation

No evidence of damage to rooted aquatic plants was attributed to slime pollution. In some instances, accumulations of several inches collected over the base and root systems of plants without apparent adverse effect.

CONCLUSIONS

1. Phosphate slime pollution eliminated over 90% of the fish population in 76 miles of the Peace River. The estimated kill of fishes was 983,430, weighing 36,675 pounds. Cause of death was mechanical suffocation, resulting from clogging gill filaments by excessive clay turbidity.

2. After the initial period of pollution (7-9 days), no additional mortality of aquatic life was detected.

3. Three months after the fish kill some evidence of fish population recovery was indicated. Young largemouth bass, channel and white catfish, and minnows endemic to the river were found commonly. Other centrarchids were not evident at this time. By September (7 months), accelerated recovery was in progress with all species of sport fish represented in varying quantities. The estimated standing crop had increased from 6 to 20 pounds per acre.

4. After 15 months the average standing crop of fishes was estimated at 87 pounds/acre and compared favorably with the unpolluted area of river. Harvestable size fish were common and fish population recovery was believed to be near completion. Successful reproduction of sport fish in the river was observed at 13 months after the kill. Growth and food habits were considered normal during the recovery period. Qualitatively, the "new" population was good and a limited sport fishery was available in the middle and lower river by May, 1968.

5. Invertebrate mortality was heavy or complete in 76 miles of river for all taxonomic groups, except for the Class Oligochaeta, Diptera family Tendipedidae, and in some areas clams of the family Sphaeriidae.

6. Invertebrate recovery was rapid and within 8 to 9 months had returned to the expected stream norm except where heavy slime deposition remained. Slimes were found to be a qualitative detriment to invertebrate production.

7. No damage to rooted aquatic vegetation was determined.

8. Physically, slimes filled the deeper portions of the stream bottom, especially the peripheral areas of pools, thereby reducing stream capacity for water storage and utilization by fishes. This condition (sedimentation) is known to be detrimental to a healthy, productive ecosystem.

POLLUTION DAMAGE SETTLEMENT

In compliance with Florida Law Chapter 61-1615, House Bill No. 1612, the Florida Game and Fresh Water Fish Commission sought to obtain a monetary settlement for damages incurred on the Peace River from Mobil Chemical Company. In part the law stated; "Whoever shall cause an unlawful discharge of pollution such as to destroy fish or fish food in the Peace River shall be liable for payment of all reasonable costs and expenses incurred by the Florida State Board of Health in tracing the sources of such pollution and the expenses of the Florida Game and Fresh Water Fish Commission in restoring the river as a suitable habitat for fish and food fish and in restocking the stream with fish." Subsequently during a 4½ month period, negotiations proceeded through six separate meetings involving Mobil's legal staff, Commission personnel, the Attorney General's office, and in at least two occasions, the Governor's office. In mid-August, 1967, an agreement was reached in which a $200,000.00 settlement was paid by Mobil—$25,000.00 to the State Board of Health and the balance to the Game and Fresh Water Fish Commission.

TABLE 1. Recorded turbidities and suspended solids before and after slime contamination, Peace River

Station	Turbidities (Jackson Units)			Suspended Solids (ppm)	
	March 11-16, 1967		March 19, 1967	March 11-16, 1967	
	Before	After	After	Before	After
1	74	.....	..	..	.....
2	..	8,000	..	..	16,450
3	..	38,000	18	..	37,530
4	..	23,000	50	..	35,400
5	..	50,000	40	..	59,750
6	30	37,500	28	..	26,400
7	..	18,750	..	..	20,260
8	..	57,000	..	..	.....
9	30	53,000	..	..	37,300
10	40	31,000	35	..	27,680
11	20	13,000	28	..	8,430
12	..	.....	..	..	.....

TABLE 2. Principal Species Composition One Year After Fish Kill, Peace River
Number of Samples 5 (5½ acres); Sample Method, Block net—Rotenone

Species	Size Range	Number	Weight	% Comp. Number	% Comp. Weight
Largemouth bass	1" - 21"	76	16.30	4.94	2.29
Bluegill	2" - 9"	170	17.75	11.05	2.50
Spotted sunfish	1" - 7"	321	18.10	20.87	2.55
Redear sunfish	3" - 9"	39	5.00	2.54	0.70
Warmouth	2" - 5"	88	2.00	5.72	0.28
Channel catfish	2" - 30"	95	595.00	6.18	83.70
White catfish	1" - 8"	113	5.75	7.35	0.81
Brown bullhead	3" - 5"	6	0.05	0.39	0.01
Yellow bullhead	2" - 12"	24	2.70	1.56	0.38
Snook	14" - 21"	10	15.60	0.65	2.19
Lake chubsucker	2" - 7"	6	0.50	0.39	0.10
American eel	12" - 23"	9	4.80	0.59	0.68
Longnose gar	13" - 39"	3	16.20	0.20	2.28
Florida spotted gar	8" - 21"	3	1.60	0.20	0.23
Seminole killifish	1" - 5"	326	8.15	21.20	1.15
Lined sole	1" - 4"	143	1.05	9.30	0.15
Notropis	1" - 3"	106	0.25	6.89	0.04
TOTAL		1538	710.80	100.02	100.04

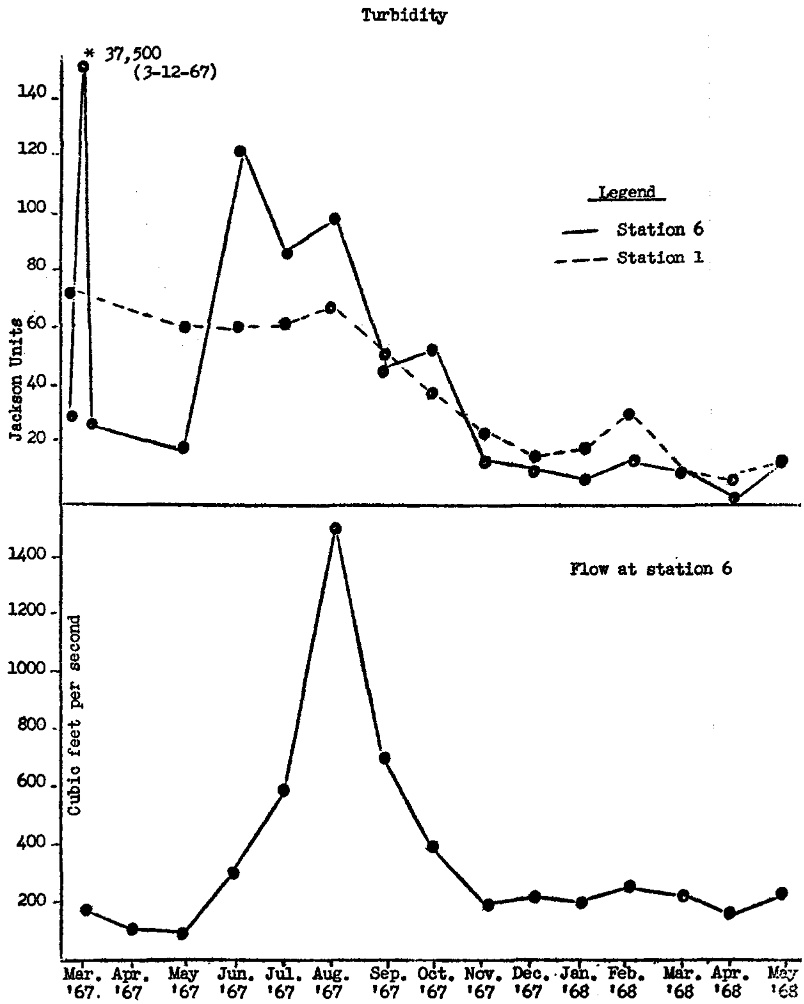

Figure 2. Maximum turbidities at stations 1 and 6 and mean flow at station 6, Peace River.

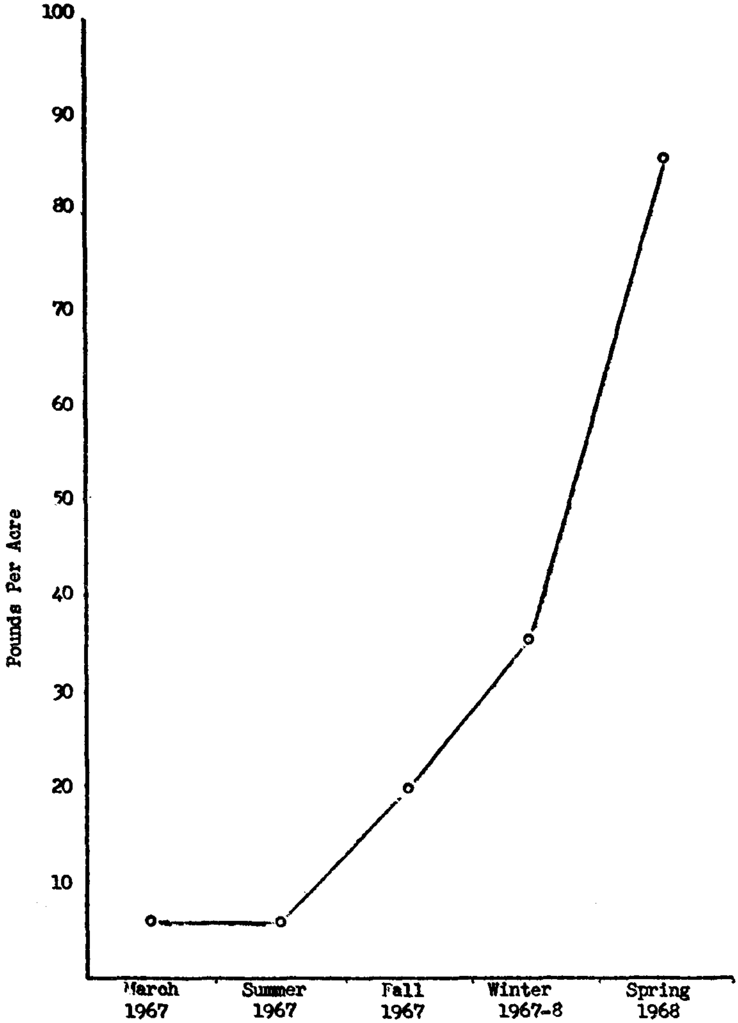

Figure 3. Average standing crop of fishes during stream recovery.
(Summary of 23 rotenone samples)

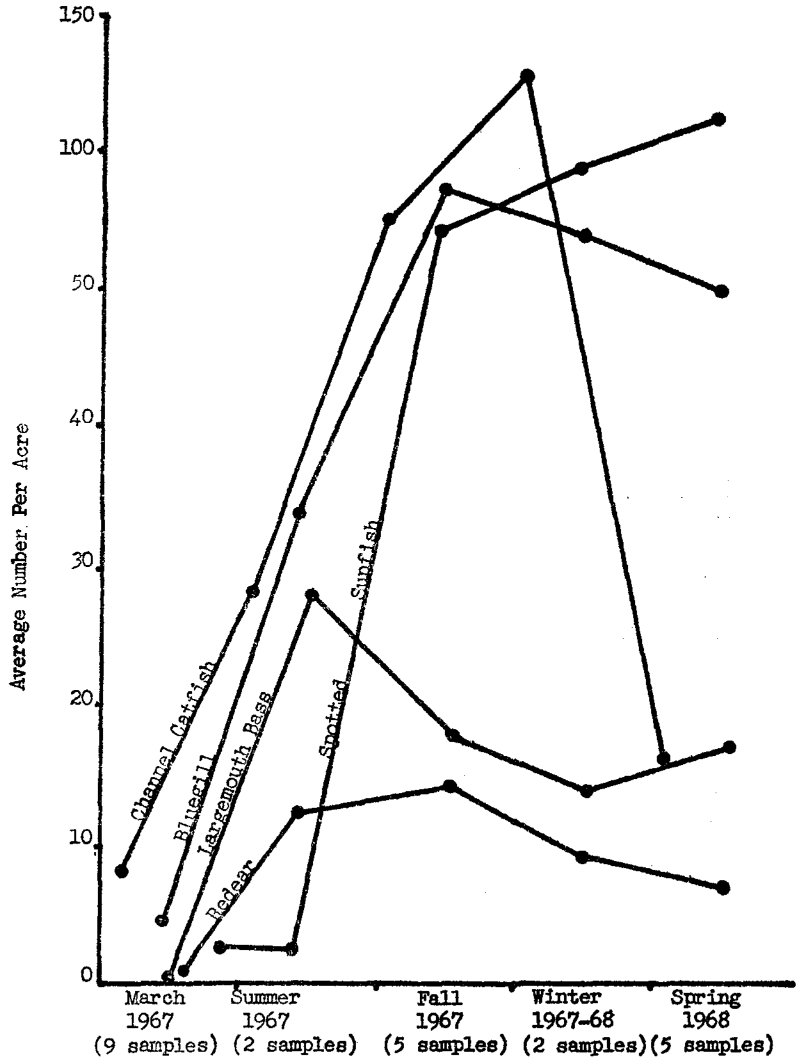

Figure 4. Recovery of principal sport fish, Peace River.

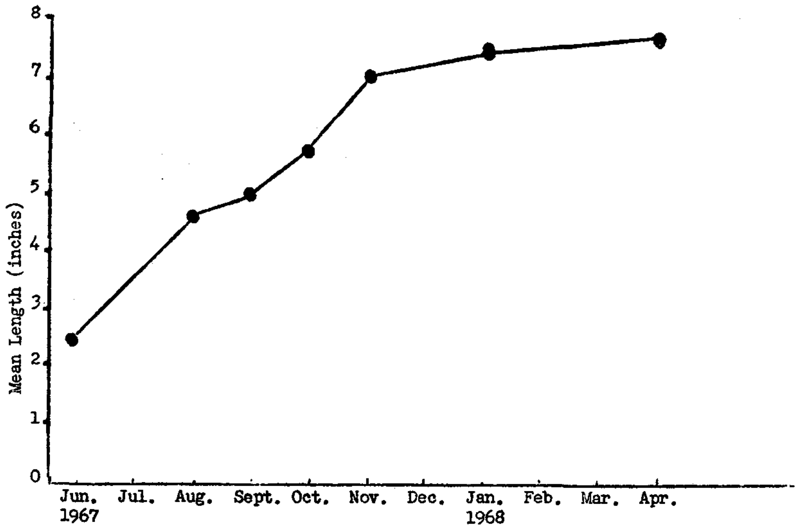

Figure 5. Growth increment of Age-0 Largemouth Bass, Peace River.

SPECIES COMPOSITION AND MONETARY VALUE OF FISH KILL

Species	Percent Comp. No.	Number Killed	Avg. Cost* Per Fish	Total Value
Lrgmth. bass	1.3	12,784	$1.68	$ 21,477.12
Panfish	57.8	568,422	0.54	306,947.88
Channel & White catfish	5.5	54,088	0.50	27,044.00
Brown & Yellow bullhead	3.3	32,453	0.66	21,418.98
Forage fish	32.1	315,681	0.02	6,313.62
	100.0	983,428		$383,201.60

* Stubbs, John M. 1966. "Monetary Values of Fish." Tenn. Game & Fish Commission.

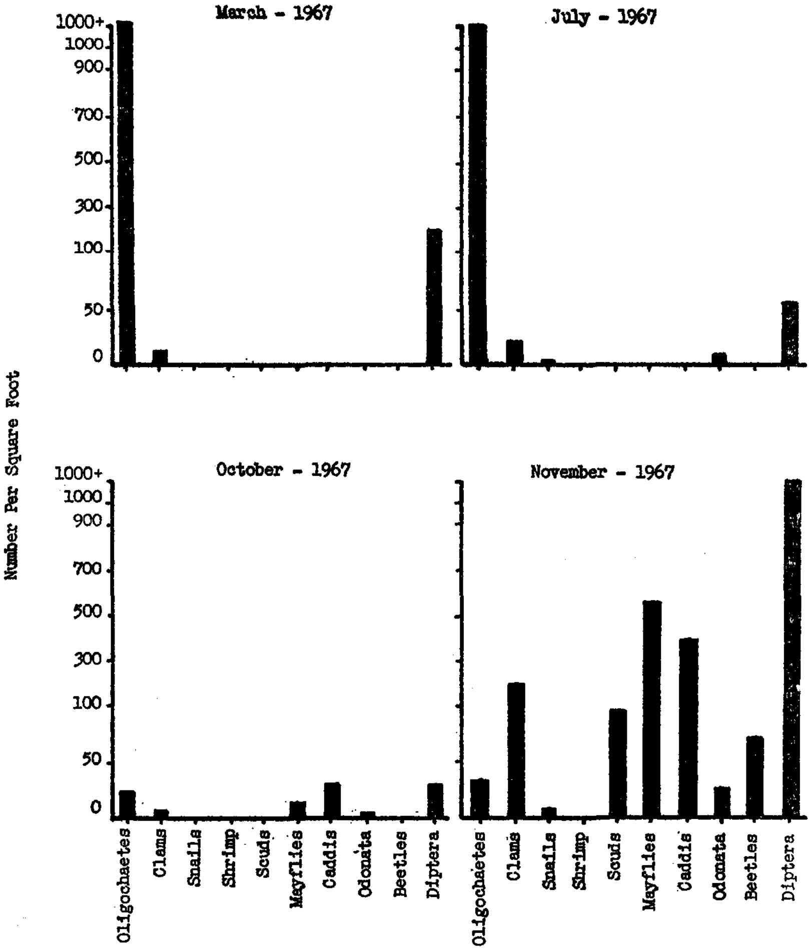

Figure 6. Invertebrate recovery, Peace River.
Substratum - Submerged vegetation

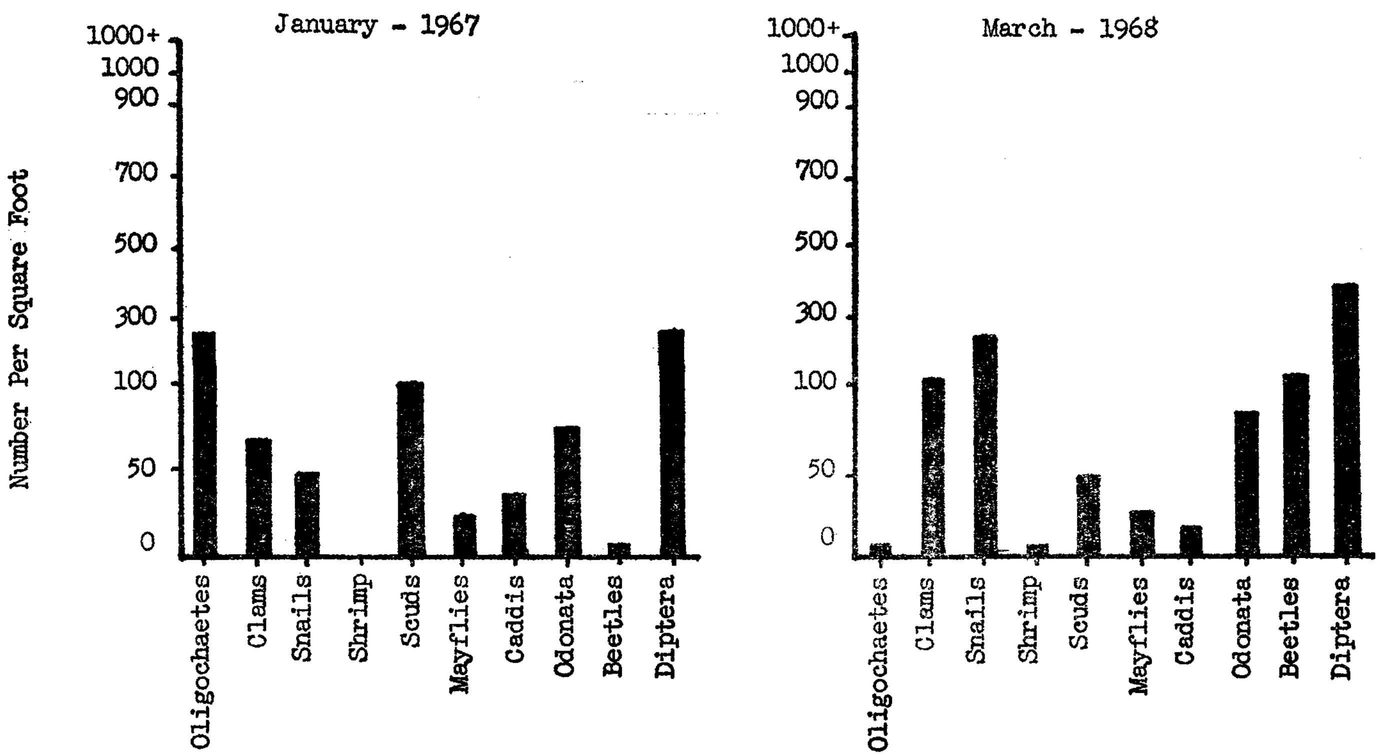

Figure 6. Continued

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EFFECT OF WATER HYACINTHS AND FERTILIZATION ON FISH-FOOD ORGANISMS AND PRODUCTION OF BLUEGILL AND REDEAR SUNFISH IN EXPERIMENTAL PONDS [1]

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ABSTRACT

Eighteen 0.1-acre ponds at the Auburn University Fisheries Research Unit, Auburn, Alabama, were used from April 5 through November 20, 1967. Both species of fishes were stocked together randomly at a rate of 4,000 fingerlings per acre. The experimental design consisted of three control ponds without fertilization or hyacinths; three control ponds without fertilization, but with hyacincths; three ponds with 0-8-0 (N,P,K) fertilization, but no hyacinths; three ponds with 0-8-0 fertilization, but with hyacinths; three ponds with 8-8-0 fertilization, but no hyacinths; and three ponds with 8-8-0 fertilization, but with hyacinths. The fertilizers were applied to stimulate the growth of hyacinths and fish-pond organisms.

Greater numbers and dry weights of fish-food organisms were associated with roots of water hyacinths in control ponds than in fertilized ponds. Snails and odonate numphs were dominant in control ponds but were not important in fertilized ponds. Dry weight of am-

[1] This research was supported in part by Rockefeller Foundation Grant RF 65061.

[2] This paper is based on a thesis submitted to the Graduate Faculty of Auburn Univ. in partial fulfillment of the requirements for the M.S. Degree.