Table IV. Gonadal development and the number of specimens represented by months from 1961 through 1964 for the Atlantic croaker, *Micropogon undulatus*, from Area 02.

Date	Total No.	Stage of Development Adolescent	Immature	Maturing	Mature	Ripe	Spent
1-62	0	—	—	—	—	—	—
2-62	0	—	—	—	—	—	—
3-62	0	—	—	—	—	—	—
4-62	1	—	1	—	—	—	—
5-62	0	—	—	—	—	—	—
6-62	2	—	2	—	—	—	—
7-62	1	—	1	—	—	—	—
8-62	8	—	7	1	—	—	—
9-62	0	—	—	—	—	—	—
10-62	1	—	—	—	—	—	1
11-62	0	—	—	—	—	—	—
12-62	0	—	—	—	—	—	—
1-63	0	—	—	—	—	—	—
2-63	0	—	—	—	—	—	—
3-63	1	—	1	—	—	—	—
4-63	9	—	9	—	—	—	—
6-63	8	—	7	1	—	—	—
7-63	34	—	34	—	—	—	—
8-63	0	—	—	—	—	—	—
10-63	3	—	—	—	—	3	—
12-63	0	—	—	—	—	—	—
1-64	0	—	—	—	—	—	—
2-64	0	—	—	—	—	—	—
3-64	0	—	—	—	—	—	—
4-64	21	—	21	—	—	—	—
5-64	12	—	7	5	—	—	—
6-64	25	—	11	—	—	14	—

A THREE-YEAR STUDY ON THE EFFECTS OF LIME APPLICATIONS ON THE STANDING CROP OF BENTHIC ORGANISMS IN GEORGIA FARM PONDS

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ABSTRACT

Six Georgia farm ponds, three on sandy soils and three on clay soils, were observed during a 32-month study period to determine the quantitative production of benthic organisms in relation to applications of agricultural lime. Three of the ponds were treated with lime at the rate of one ton per acre. The remaining three ponds were maintained as controls. Water total hardness in the experimental ponds increased significantly during the first year after treatment and began to drop during the third year, although it remained at a level higher than that observed before treatment. The bottom soil calcium oxide content began to increase during the third year after treatment. The quantity of benthos in the experimental ponds began to increase after treatment and remained at a higher level during the entire study period while that of the control ponds remained relatively constant or decreased.

INTRODUCTION

Past research in soft-water farm ponds in Georgia has demonstrated that lime applications in conjunction with normal fertilization are necessary for optimum phytoplankton production.

Swingle and Smith (1947) demonstrated that phytoplankton production is limited by the availability of nitrogen, phosphorus, and potassium. However, Zeller and Montgomery (1957) found that still another element, calcium, may be a limiting factor in aquatic productivity in soft waters.

When fertilizer is applied in the absence of calcium ions, the nitrogen, phosphorus and potassium become bound by the colloidial complex, and therefore, are rendered unavailable. Calcium ions furnished to the aquatic habitat by agricultural lime have a greater affinity for the colloidial material than do the elements N., P, and K.; therefore, these elements are replaced on the complex in the presence of calcium ions and are made available.

Thomaston and Zeller (1961) concluded that phytoplankton production is increased by the addition of lime. Bowling (1963) conducted an investigation to determine if this increase in phytoklankton production brought about a subsequent increase in benthic production.

The purpose of this paper is to integrate the results from the original 20-month study by Bowling with the results from an additional 12-month study period from May, 1962, to May, 1963. The results from the additional 12-month study serve to substantiate the hypothesis that lime additions result in a higher standing crop of benthos.

DESCRIPTION OF THE STUDY PONDS

To allow for contrasting results, six study ponds were selected on two drastically different soil types. Three of the ponds were located in the Sand Hills Soil Province near Howard, Georgia; and the remaining three ponds were located in the lower Piedmont clay soil types near Macon, Georgia.

The ponds in the sandy soil area generally exhibited a much lower calcium content than did those ponds in the clay soil area. These ponds as a whole, failed to produce desirable plankton blooms even after infrequent fertilization treatments. The ponds in the clay soil region had received better management and were generally regarded as being more productive than those in the sandy soil region. The fertilization program in both the experimental and the control ponds were left entirely to the individual owners, and no accurate record pertaining to the dates and frequency of fertilization are available.

The ponds in each area were as nearly similar as possible with regard to size, depth, stocking, fertilization, and fishing pressure.

METHODS AND PROCEDURES

All methods and procedures were essentially the same during the entire 32-month study period.

Each of the six farm ponds were analyzed at approximately one-month intervals for chemical elements and physical properties of the water, chemical elements in the bottom soils, and occurrence of benthic organisms. Five sampling stations were located in each pond, and all soil and benthic samples were taken only at these permanently located stations. Water depth at the sampling stations ranged from approximately one to six feet.

Water Analyses

The following water analyses were conducted each month during the 32-month study period:

Total Hardness: Ethylenediaminetetraacetic acid (EDTA) titration method.

pH: Taylor slide comparator.

Turbidity: Secchi disc method.

Temperature: Mercury type themometer (surface water only).

Chemical Soil Analyses

From each of the five sampling stations, bottom soil was collected with an Ekman dredge, placed in specially prepared soil sample bags, and analyzed for pH, calcium, phosphorous, potassium, and soluble salts by the University of Georgia Soil Testing Laboratory.

Benthic Organism Analyses

Benthic samples were taken from each of the five sampling stations. These samples were mixed and screened through a ten-mesh and a thirty-mesh screen, fixed in ten per cent commercial formalin, and taken to the laboratory where the organisms were removed and measured volumetrically.

Lime Applications

One ton per acre of agricultural lime was applied to three of the ponds, one in the sandy soil area and two in the clay soil area. The lime was broadcast around the edges of these ponds and wind action distributed it throughout the water. Clarke's pond in the clay soil area was treated in late March, 1961; and Peed's and Jordan's ponds in the clay soil area were treated in late April, 1961. Two ponds in the sandy soil region and one pond in the clay soil region were maintained as controls.

RESULTS

After a study period of 32 months, there appear to be some very definite trends as the result of lime application. These trends appear to be most significant in the results of water total hardness, calcium oxide content of the bottom soil, and volume of benthic organisms present. The results presented here will include only these observations with a minor emphasis on chemical nutrients of the bottom soil, temperature, pH, and Secchi disc readings.

Control Ponds

Brown's Pond (Sandy Soil Area)

This pond was very unproductive and failed to produce a plankton bloom after attempts at fertilization. The water total hardness rarely exceeded 10 parts per million; and, in most cases, was much below this. Bottom soil calcium reached its highest peak during the first eight months of the study from October, 1960, through April, 1961, and the period from June, 1962, through January, 1963 (Figure 1). All other bottom soil nutrients remained at low concentrations throughout the 32-month study period.

The standing crop of benthos remained low throughout the study. During the first seven months, the volume of the organisms far exceeded the volume of any other period during the study (Figure 1-A).

The total volume of benthic organisms present in samples taken in October, November, December, January, February, and March, 1960—1961, was 62.8 milliliters per square meter; and for the same period in 1961—1962 and 1962-1963 there were 24.3 and 15.5 milliliters per square meter, respectively (Table 1).

Park's Pond (Sandy Soil Area)

Although located only two or three miles from Brown's pond, this pond responded much better to fertilizer applications. The bottom soil was mantled by about a six-inch layer of partially decomposed organic matter, and it was open to cattle and hogs which added to the fertility.

The total hardness of the water exceeded 10 parts per million several times during the period of study and remained near this figure at other times. The calcium oxide content of the bottom soil was generally higher during the colder months and reached a very high peak

Table I

Results of Soil Water and Benthic Analyses for Three Six-Month Periods October-March, 1960-61, October-March, 1961 -62*, October-March, 1962-63.

Pond	Period**	Soil Analysis Ca (ppm)	Water Analysis Total Hardness (ppm)	Benthos ml/sq. meter
SANDY SOIL				
Brown	1	643	7	62.8
	2	137	7	24.3
	3	457	6	15.5
Parks	1	629	8	132.7
	2	257	11	99.9
	3	812	9	103.7
Clarke***	1	848	8	59.5
	2	569	18	91.3
	3	721	11	39.6
CLAY SOIL				
Sanders	1	855	22	149.0
	2	382	16	205.8
	3	77	16	66.3
Jordan***	1	345	12	54.3
	2	563	19	260.1
	3	597	19	61.3
Peed***	1	399	12	62.9
	2	253	21	84.3
	3	708	19	53.4

* No samples taken in November, 1961—See footnote—Table 2.

** 1 Before, 2—One year after treatment, 3—Two years after treatment.

*** Experimental ponds.

from June, 1962, through January, 1963 (Figure 2). Other soil nutrients remained relatively constant throughout the study period.

The volume of benthic organisms was much higher than that recorded in Brown's pond, reaching its peak during the winter months of the first year (Figure 2-A).

Sanders' Pond (Clay Soil Area)

Sanders' pond is an exceptionally high quality Georgia farm pond which responded very well to fertilization. The water total hardness remained above 10 parts per million throughout the study, and often exceeded 20 parts per million. Calcium oxide content of the bottom soil exhibited three peaks during the study period, one in December of 1960, one in September of 1961, and a still higher peak in December of 1962, with the latter peak extending over a period of eight months (Figure 3).

The volume of benthos remained exceptionally high during the first two years of the study and dropped off considerably during the third year (Figure 3-A).

The volume of benthos remained higher in Sanders' pond than in any other pond in the study. The total volume was 149.0 milliliters per square meter during the first six months of the study, and for comparable six-month periods in 1961-1962 and 1962-1963 was 205.8 and 66.3 milliliters per square meter, respectively (Table 1).

Experimental Ponds

Clarke's Pond (Sandy Soil Area)

Clark's pond, like Peed's, was utilized extensively by cattle; and a high content of partially decomposed organic material was found in the bottom soil. In most instances, the water total hardness ranged around 10 or 20 parts per million. The content of calcium oxide in the bottom soil exhibited three peaks as was found in Sanders' pond. The peaks were noted in Clarke's pond in the winter months of 1960-1961, the summer of 1961, and again in the summer of 1962 (Figure 4).

There was a great increase in the volume of benthos after the applications of agricultural lime in late March, 1961. The increase became evident in August, 1961, and remained at a high level until July, 1962. The volume of benthos present during the third year fell below that of the period before lime was applied (Figure 4-A).

During the six-month period before treatment, there was a total of 59.5 milliliters per square meter of organisms present. For the same six-month period one year later, the total was 91.3 milliliters per square mter, an increase of 31.8 milliliters per square meter. During the comparable six-month period the third year of the study, the volume dropped to 39.6 milliliters per square meter (Table 1).

The total volume of organisms sampled for the three six-month periods, one before and two after lime application, was 6.9, 10.6, 10.6, and 4.6 milliliters, respectively (Table 2).

Jordan's Pond (Clay Soil Area)

Jordan's pond maintained a near optimum total hardness, dropping into the ten parts per million range only during the first few months of the study. Three relatively prominent peaks also occurred here in the calcium oxide content of the bottom soil. The first in the winter months prior to liming, the second and higher peak during the winter of 1961, and the third and still higher peak during the winter months of 1962 (Figure 5).

The volume of benthos remained relatively high throughout the study, reaching its highest level during the winter following lime application and dropping considerably the second winter after liming (Figure 5-A).

Here, again, the total volume of benthos per square meter increased the winter after liming. During the six-month period before liming, the volume was recorded at 54.3 milliliters per square meter, after which it increased to 260.1 milliliters during the comparable six-month period the next year. During the third year of the study, the volume of organisms dropped to 61.3 milliliters per square meter (Table 1).

The sample volume of bottom organisms from Jordan's pond was 6.3 milliliters during the six-month period before treatment, 23.7 milliliters during the comparable six-month period one year later, and 7.1 milliliters during the comparable six-month period two years after treatment (Table 2).

Peed's Pond (Clay Soil Area)

The total hardness of the water in Peed's pond increased to the 20 ppm range after liming, dropped to the 10 ppm range during the summer of 1962, reached the 20 ppm level in the fall of 1962 where it remained throughout the rest of the study.

The calcium oxide level of the bottom soil exhibited only two peaks, one of low level during the initial months of the study and one of a much higher level 18 months after lime application (Figure 6).

The volume of benthos remained relatively high during the entire study; however, it increased considerably for an entire year after lime was added in late March, 1961 (Figure 6-A).

The volume of benthos increased the year after lime application although not as much as in the two previous experimental ponds, nor did the volume drop as drastically during the second year after treatment. Before lime was applied, a total of 62.9 milliliters per square meter were present. During the next two comparable six-month periods 84.3 and 53.4 milliliters per square meter were recorded (Table 1).

The sample volume of benthos taken during the three six-month periods was 7.3, 9.8, and 6.2 milliliters (Table 2).

DISCUSSION

Not all factors incorporated into this study could be correlated with the standing crop of benthic organisms. Because pH is largely dependent upon the time of day at which it is taken, these values indicated no definite trends. Secchi disc readings were unreliable because of the extremely muddy conditions which often existed. Temperatures were recorded at the surface. In the bottom soil samples pH, phosphorus, and soluble salts fluctuated from time to time, but no definite trends were noted.

The most significant trend was found in the experimental ponds in the relationship between total hardness of the water and calcium oxide content of the bottom soil. Based on a six-month average, one period prior to lime application and two comparable six-month periods after application, it was observed that the water total hardness increased considerably in the experimental ponds one year after lime application (Figure 7). Two years after lime application the total hardness began to drop, with the exception of Jordan's pond. Total hardness in Clark's pond dropped much more than it did in the other experimental ponds. Clark's pond was the only experimental pond in the sandy soil area, and it is thought that the high porosity of this sandy soil allowed much of the calcium to be leached out before it became available.

An inverse relationship is exhibited by the calcium oxide content of the bottom soil and the total hardness of the water (Figure 8). Calcium in the bottom soil one year after treatment had decreased considerably, with the exception of Jordan's pond. During the same period,

Table 2

Volume of Benthos in Milliliters Present During Six-Month Periods Before Treatment of Experimental Ponds with Lime (Oct. 1960-Mar. 1961) and Two Comparable Six-Month Periods After Treatment (Oct. 1961-Mar. 1962 and Oct. 1962-Mar. 1963).

	Control Ponds			Experimental Ponds		
Month	Brown	Parks	Sanders	Clarke	Jordan	Peed
Oct. '60	0.1	2.4	2.0	1.3	0.5	3.0
Nov. '60	1.8	1.0	2.3	0.9	0.9	1.0
Dec. '60	1.3	3.3	4.5	1.2	1.6	1.1
Jan. '61	2.5	6.0	7.0	1.4	2.3	1.0
Feb. '61	1.2	2.4	0.7	1.6	0.6	1.1
Mar. '61	0.4	0.3	0.8	0.5	0.4	0.1
Total	7.3	15.4	17.3	6.9	6.3	7.3
Oct. '61	0.3	1.3	0.4	2.0	6.3	1.0
Nov.* '61	0.4	1.7	1.0	2.2	6.5	1.0
Dec. '61	0.5	2.1	4.5	2.4	6.7	3.0
Jan. '62	0.5	4.0	8.2	2.0	3.9	1.3
Feb. '62	0.9	1.0	3.8	1.1	4.3	1.3
Mar. '62	0.2	1.5	6.0	0.9	2.5	2.2
Total	2.8	9.9	23.9	10.6	30.2	9.8
Oct. '62	0.1	1.1	1.0	0.2	1.9	0.2
Nov. '62	0.1	1.1	0.5	1.5	3.2	0.7
Dec. '62	0.4	1.6	2.3	1.0	0.6	0.7
Jan. '63	0.5	4.7	2.1	0.6	0.6	3.1
Feb. '63	0.4	2.0	1.3	1.0	0.3	0.6
Mar. '63	0.3	1.5	0.5	0.3	0.5	0.9
Total	1.8	12.0	7.7	4.6	7.1	6.2

* No samples were taken in Nov., 1961, but to make the results more meaningful, arbitrary volumes falling between the values recorded for October and December of the same year were used.

the calcium content of the water was on the increase (Figure 7). Two years after lime application, the calcium content of the bottom soil in all three ponds had increased considerably while calcium in the water had again fallen to a lower level. An explanation for this phenomenon *might* be that the relatively high concentration of calcium in the water one year after liming began to precipitate out and leach into the bottom soils the second year after liming.

Peed's pond exhibited an exceptionally high total hardness during the last year of this study (Figure 6). The watershed of this pond comprised approximately 200 to 250 acres of pastureland. On consulting the owner, it was found that the pasture was responsible for the high total hardness content during the latter months of the study.

A very definite change in the composition of aquatic organisms was noted in Peed's pond during the 32-month study period. During the first 16 to 18 months of the study, the dominant organisms found in the bottom samples were *Chaoborus* and Oligochaeta. During the last 15 months, the organisms *Tendipes* and *Pentaneura,* along with *Chaoborus,* became the dominant groups.

On comparing the volume of benthos in all six ponds throughout the 32-month study period (Figures 1-A, 2-A, 3-A, 4-A, 5-A, and 6-A), the 32-month study period begining in October, 1960 (Figures 1-A, 2-A, 3-A, 4-A, 5-A, and 6-A), it is observed that in addition to a second year increase in the standing crop of benthos in the limed ponds there were also increases in two of the control ponds. Sanders' pond, which was a control pond, had a higher volume of benthos than any of the other ponds. This might be attributed to Sander' pond being a poor choice as a control by virtue of the fact that it far exceeds the average Georgia farm pond. In this pond, the total hardness remained very near the optimum throughout the study period and did not require the addition of lime nearly as much as the other two control ponds. A strict fertilization program was followed in this pond, and the banks were kept clear of vegetative growth. No shallow areas around the shoreline of the pond provided a suitable habitat for growth of aquatic vegetation. During summer months, a heavy bloom of filamentous algae often developed. When wind action deposited this algae along the edge of the pond, the owner would have it raked out onto the bank. No other pond in the study received such a high degree of management.

The other control pond which produced a large amount of benthic organisms was Park's pond in the sandy soil area. The greatest volume of benthos present during any single month of the 32-month study always occurred in January (Figure 2-A). The greatest production occurred during the first year of the study, dropped considerably during the second year, and again increased during the third year. The pond owner conducted a very conscientious fertilization program during the last year of the study. He often consulted the investigator and fertilized the pond whenever he was advised to do so. A heavy plankton bloom was evident during the entire summer of 1962.

Even though located on a relatively sterile, sandy soil, Park's pond produced a good crop of benthic organisms, probably as the combined result of organic detritus supplied by cattle and hogs and the application of inorganic fertilizer.

All three experimental ponds exhibited an increase in benthic production about one year after the addition of lime (Figure 4-A, 5-A, and 6-A. Two years after lime application, the standing crop of benthic organisms in these ponds dropped considerably.

Although the total volume of benthos present in the three control ponds, with the exception of Brown's pond, was as high or higher, in one instance, than in the experimental ponds, there was a decrease in the volume present rather than an increase as found in the experimental ponds. The one control pond which did exhibit an increase in the volume of benthos during the second year of the study was Sanders' pond. The probable reasons for this have been given previously.

Benthos was found to be in its greatest abundance primarily during the winter months. Aquatic earthworms in the order Oligochaeta, an entirely aquatic group exhibiting no terrestrial existence, were found to be present in all the study ponds. Although relied upon extensively by forage fish as food, these organisms exhibited no seasonal abundance and, therefore, were included in the monthly samples in relatively constant numbers. It is possible, however, that this group is relied on as food by forage fishes to a greater degree during summer months when other organisms have emerged as adults and the competition among fishes for food is more intense.

Benthos present in the samples taken from the experimental ponds during the months of their highest occurrence (October-March) indicated a pronounced increase in volume during the first year after treatment with lime (Figure 9). Jordan's pond had the greatest increase, with Clarke's and Peed's ponds having a somewhat lesser increase one year after lime application.

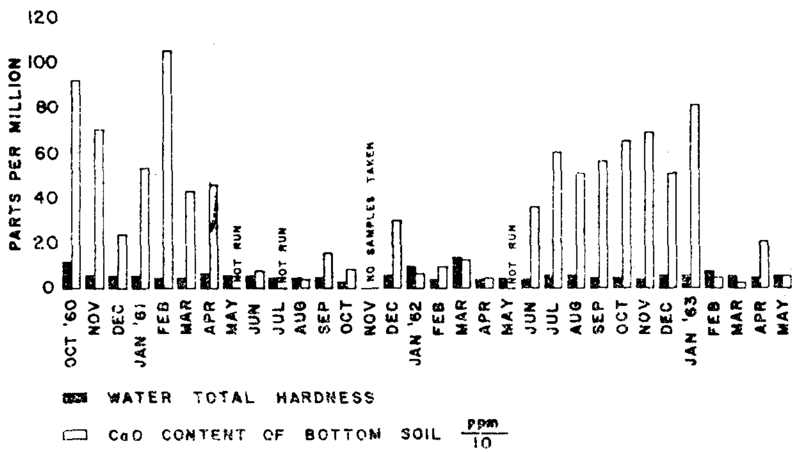
The control ponds, on the other hand, indicated a decline rather than an increase in benthos produced during the period of time when the experimental ponds were indicating an increase (Figure 10). The one exception to this, as mentioned previously, was Sanders' pond. The total volumes of benthos collected from both the experimental and the control ponds during the three six-month periods are presented in Table 2.

It is generally agreed that the months of maximum benthos occurrence are December, January, and February (Eggleton, 1930, Howell, 1941, Bowling, 1963). The total volume of organisms present for each of the months December, January, and February in the years 1960-61, 1961-62, and 1962-63 again illustrate that one year after treatment the experimental ponds had an increase in the volume of organisms present in the samples (Figure 11). There was a decrease during the second year after treatment in all three experimental ponds. The control ponds, with the exception of Sanders, showed a continuous decrease in the volume of benthos for these months during the three-year study.

Although this study lends itself well to partially answering some of the questions concerning benthic production in relation to lime content, many questions remain unanswered. It would be desirable to conduct a study in which all ponds were located in the same soil type and geographic location before trying to draw conclusions from a study involving two very different soil types and areas. Several newly constructed ponds having a low calcium content within the same area, half treated with lime and half maintained as controls, would perhaps furnish more and better information concerning the calcium requirements for ponds in such localities. It would be most desirable to conduct such a study before fish were introduced into the ponds.

FIGURE I.

BROWN (CONTROL)

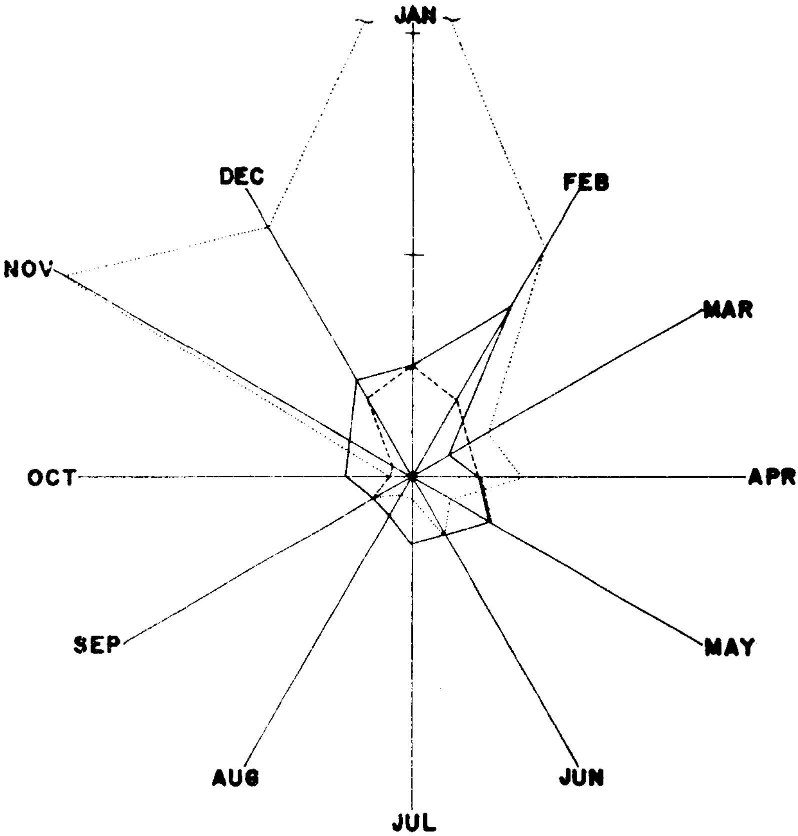


CONCLUSIONS

Although this study provides no definite recommendations concerning the quantity of lime necessary to bring about optimum production of benthic organisms, very definite increases were observed in ponds treated with agricultural lime at the rate of one ton per acre.

The calcium content of the water shows a significant increase soon after lime is applied to the pond; however, the maximum calcium content in the bottom soil does not occur until the second year after treatment. It appears that a major portion of the calcium precipitates out and becomes available only after a long period of time.

FIGURE I-A.



BROWN (CONTROL)

FIRST YEAR ·············

SECOND YEAR ————

THIRD YEAR --------

Horizontal marks on the January Axis represent 1.0 cubic centimeter of benthos.

Nutrients in porous, sandy soils appear to leach out more rapidly than in clay soils, and it is probable that much of the calcium leaches out of sandy soil ponds before it becomes available.

The addition of calcium carbonate at the rate of one ton per acre to ponds having a low hardness increases the quantity of benthos in such ponds. The increase becomes evident during the entire first year after application but does not continue into the second year after treatment.

The greatest abundance of benthos occurs during the fall and winter months, at which time the organisms are in the larval and pupal stages.

There appears to be an inverse relationship between the calcium content of the water and the calcium content of the bottom soil.

LITERATURE CITED

Bowling, M. L. 1963.
The Effecs of Lime Applications on the Standing Crop of Benthic Organisms in Georgia Farm Ponds.
M. S. Thesis. Univ. Ga.

Eggleton, F. E. 1930.
A limnological Study of the Profundal Bottom Fauna of Certain Fresh Water Lakes.
Ph. D. Thesis Univ. Mich., Ann Arbor.

Howell, H. H. 1941.
Bottom Organisms in Fertilized and Unfertilized Fish Ponds.
M. S. Thesis Ala. Polytechnic Institute.

Swingle, H. A., and E. V. Smith. 1947.
Management of Farm Ponds.
Agr. Exp. Sta. Bull. 254. Auburn, Ala.

Thomaston, W. W. and H. D. Zeller. 1961.
Results of a Six-Year Investigation of Soil and Water Analysis and Lime Treatments in Georgia Farm Ponds.
Proc. S. E. Assn. Game and Fish Commission. 15:236-244.

Zeller, H. D. and A. B. Montgomery. 1957.
Preliminary Investigation of Chemical Soil and Water Relationships and Lime Treatment of Soft Water in Georgia Farm Ponds.
Proc. S. E. Assn. Game and Fish Commission. 11:71-75.

APPENDIX

FIGURE 2.

PARKS (CONTROL)

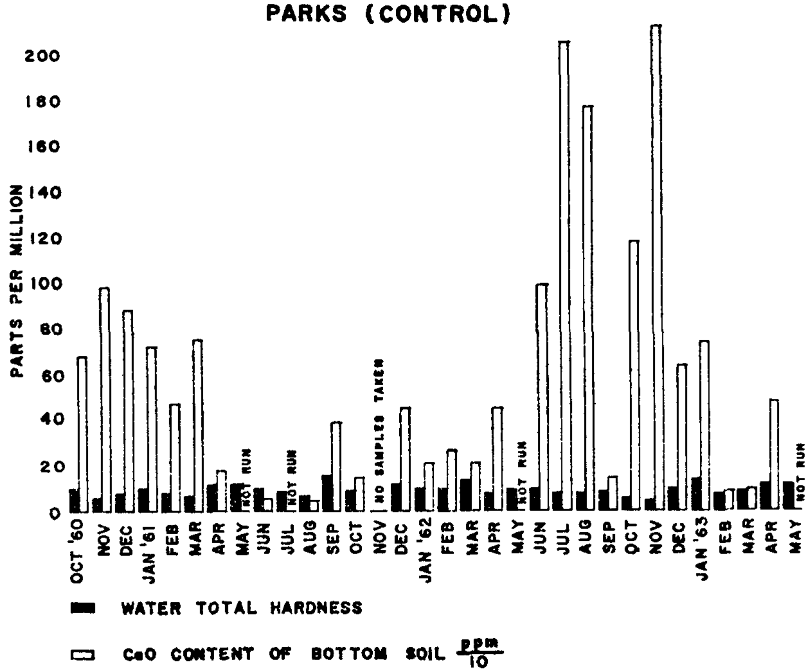
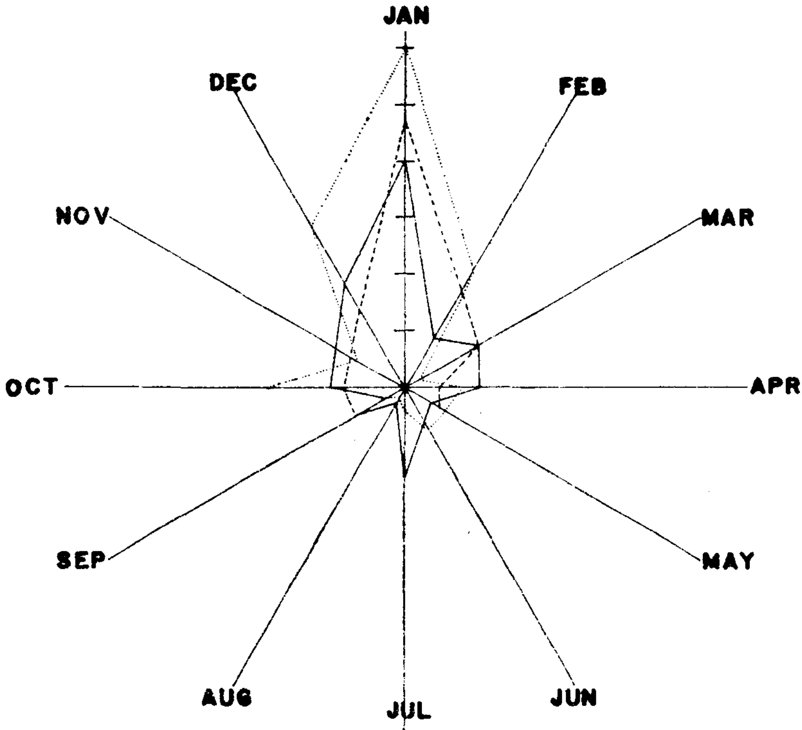


FIGURE 2-A.



PARKS (CONTROL)

FIRST YEAR ....
SECOND YEAR ————
THIRD YEAR --------

Horizontal marks on the January Axis represent 1.0 cubic centimeter of banthos.

FIGURE 3.

SANDERS (CONTROL)

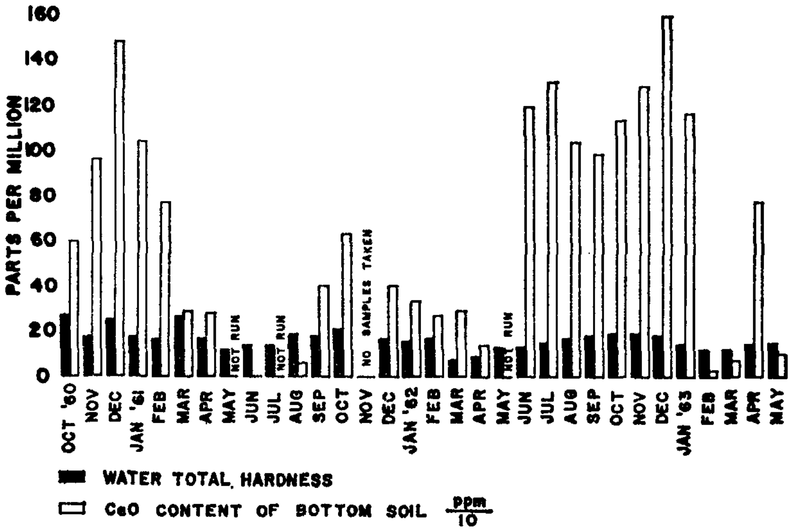
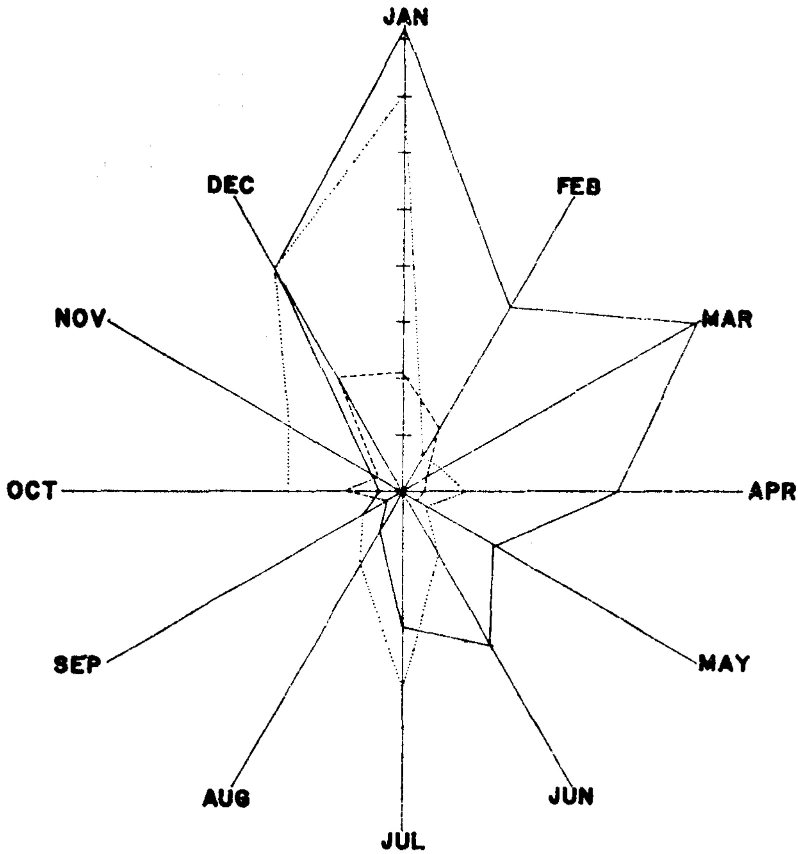


FIGURE 3-A.



SANDERS (CONTROL)

FIRST YEAR ....

SECOND YEAR ———

THIRD YEAR ------

Horizontal marks on the January Axis represent 1.0 cubic centimeter of banthos.

FIGURE 4.

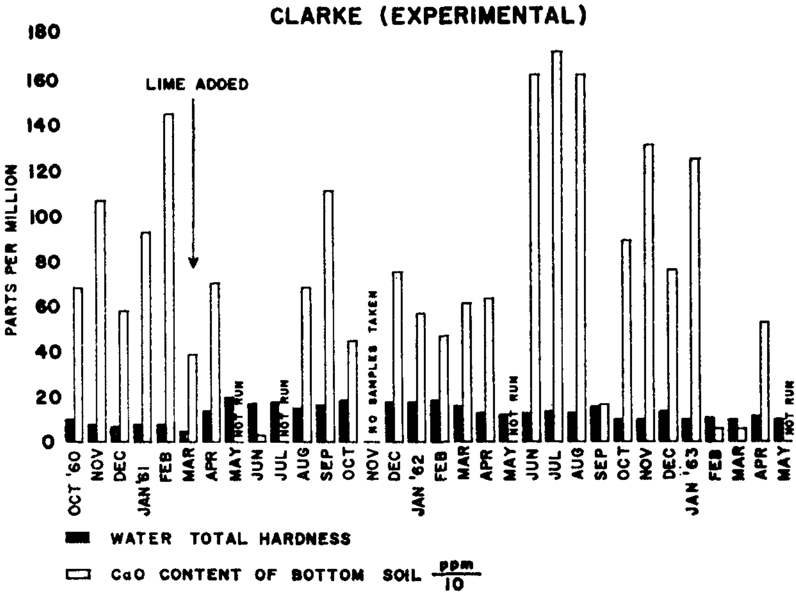
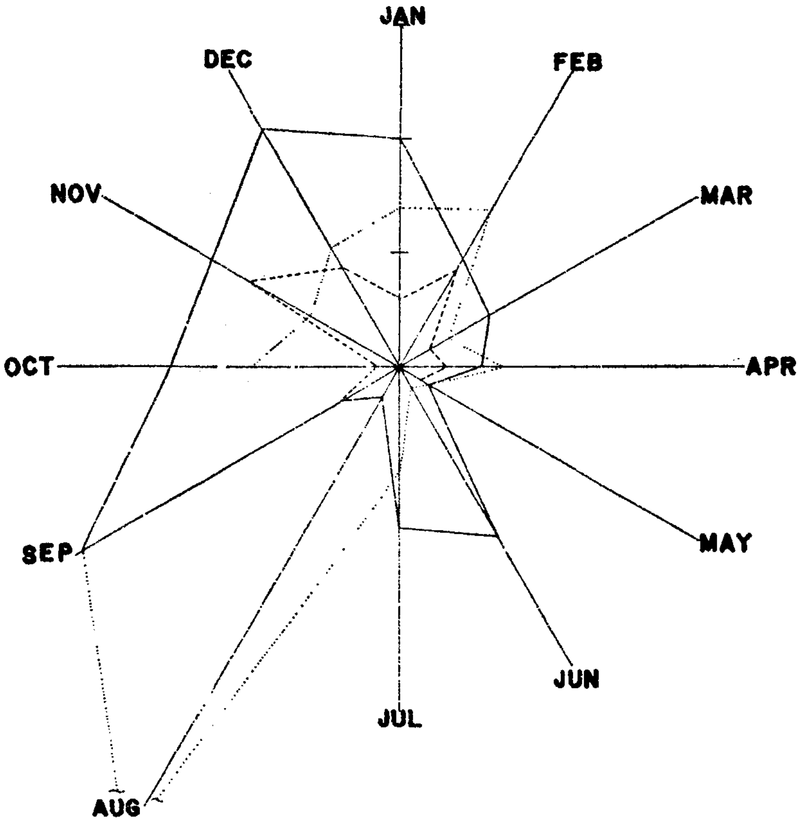

CLARKE (EXPERIMENTAL)
PARTS PER MILLION
180
160
140
120
100
80
60
40
20
0
LIME ADDED
NOT RUN
NO SAMPLES TAKEN
OCT '60
NOV
DEC
JAN '61
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN '62
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN '63
FEB
MAR
APR
MAY
WATER TOTAL HARDNESS
CaO CONTENT OF BOTTOM SOIL ppm/10

FIGURE 4-A.



CLARKE (EXPERIMENTAL)

FIRST YEAR ·· ·· ····
SECOND YEAR ———
THIRD YEAR - - - - - -

Horizontal marks on the January Axis represent 1.0 cubic centimeter of banthos.

FIGURE 5.
JORDAN (EXPERIMENTAL)

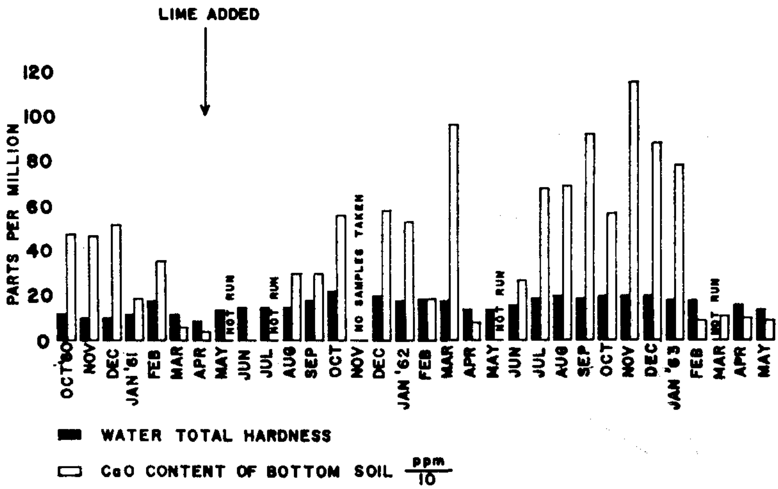
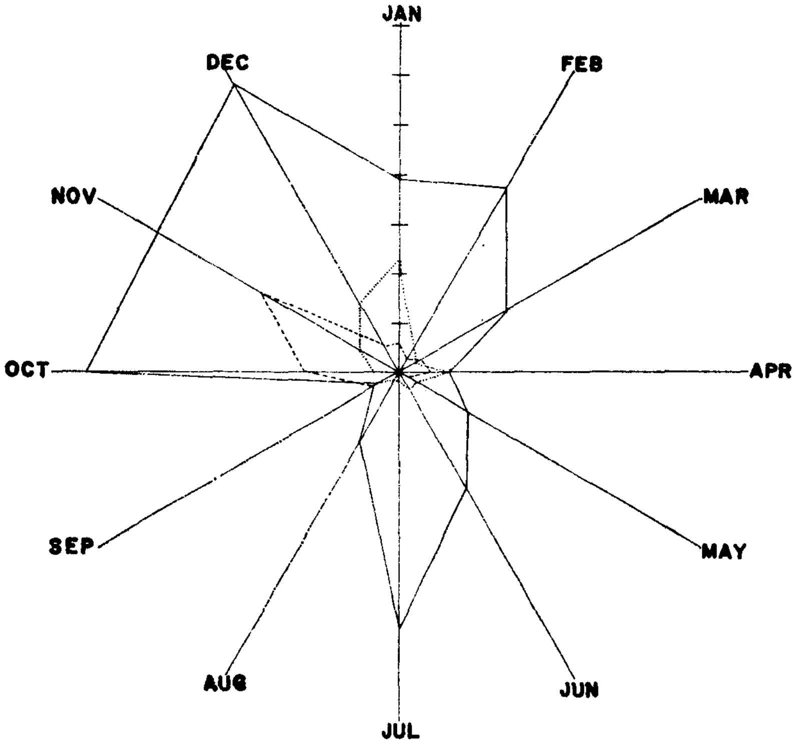


FIGURE 5-A.



JORDAN (EXPERIMENTAL)

FIRST YEAR ....
SECOND YEAR ————
THIRD YEAR ---------

0.5 INCHES ON MONTHLY AXES REPRESENTS 1.0 CUBIC CENTIMETERS OF BENTHOS.

Horizontal marks on the January Axis represent 1.0 cubic centimeter of banthos.

FIGURE 6.

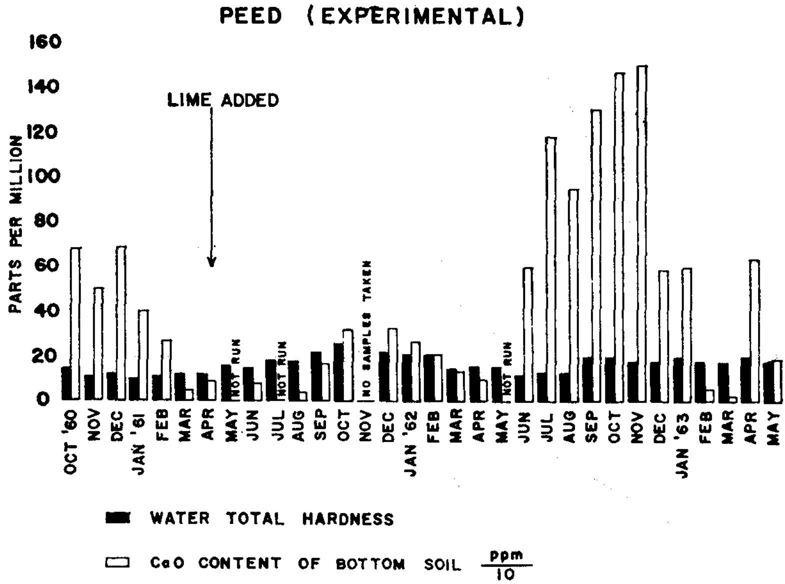
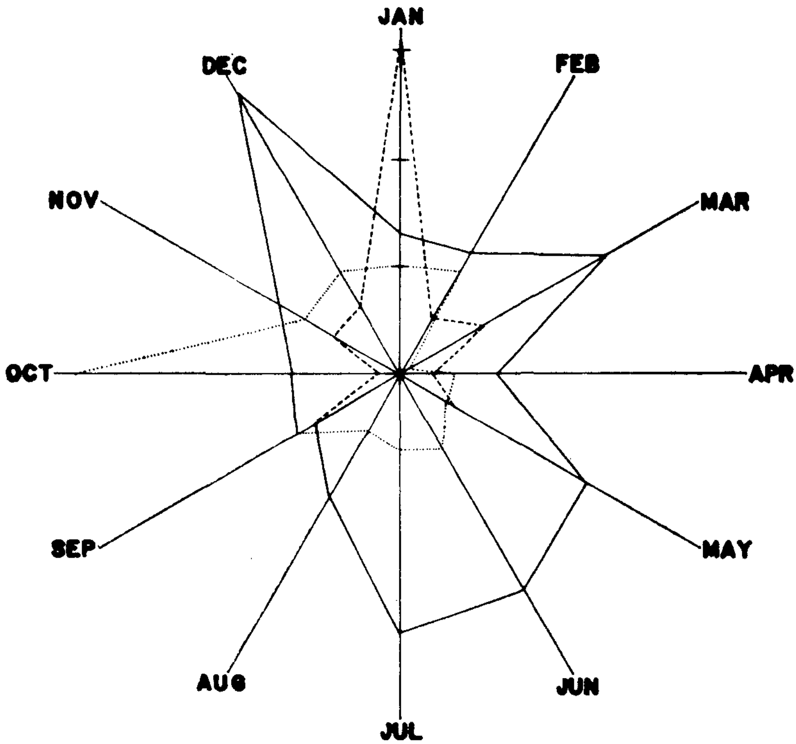

PEED (EXPERIMENTAL)
160
140
120
100
80
60
40
20
0
PARTS PER MILLION
LIME ADDED
NOT RUN
NOT RUN
NO SAMPLES TAKEN
NOT RUN
OCT '60
NOV
DEC
JAN '61
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN '62
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN '63
FEB
MAR
APR
MAY
WATER TOTAL HARDNESS
CaO CONTENT OF BOTTOM SOIL ppm/10

FIGURE 6-A.



PEED (EXPERIMENTAL)

FIRST YEAR ··········
SECOND YEAR ———
THIRD YEAR ------

Horizontal marks on the January Axis represent 1.0 cubic centimeter of banthos.

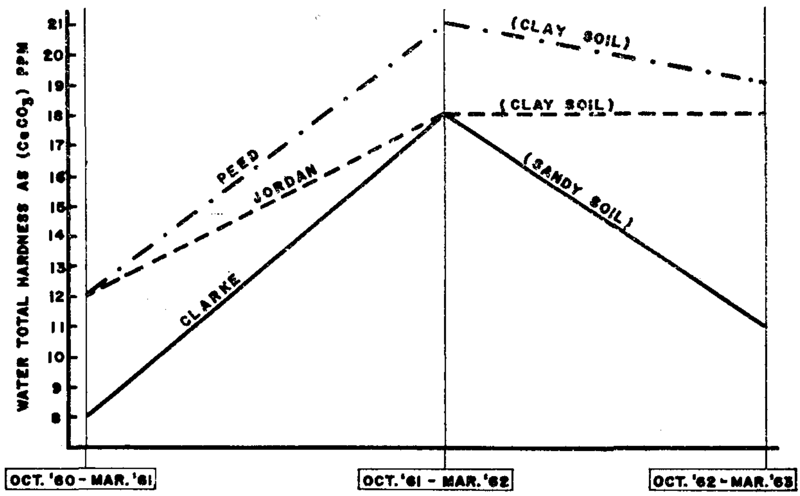


FIGURE 7.— Average total hardness of water in experimental ponds during three six-month periods.

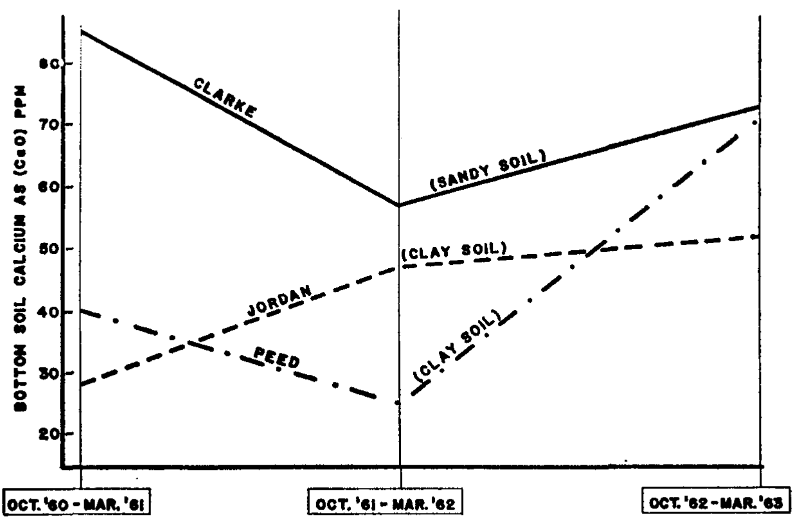


FIGURE 8.— Average CaO content of bottom soil in experimental ponds during three six-month periods.

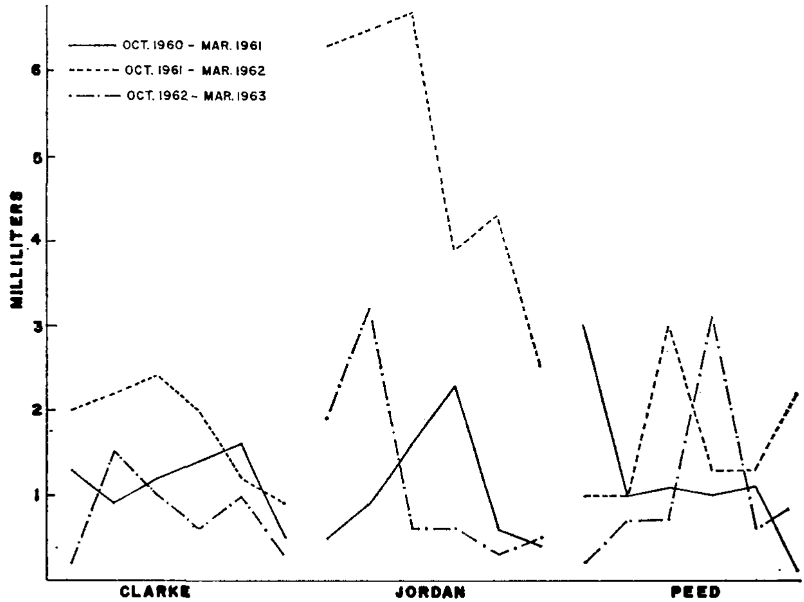


FIGURE 9.— Volume of benthos sampled from experimental ponds during months of their highest occurance.

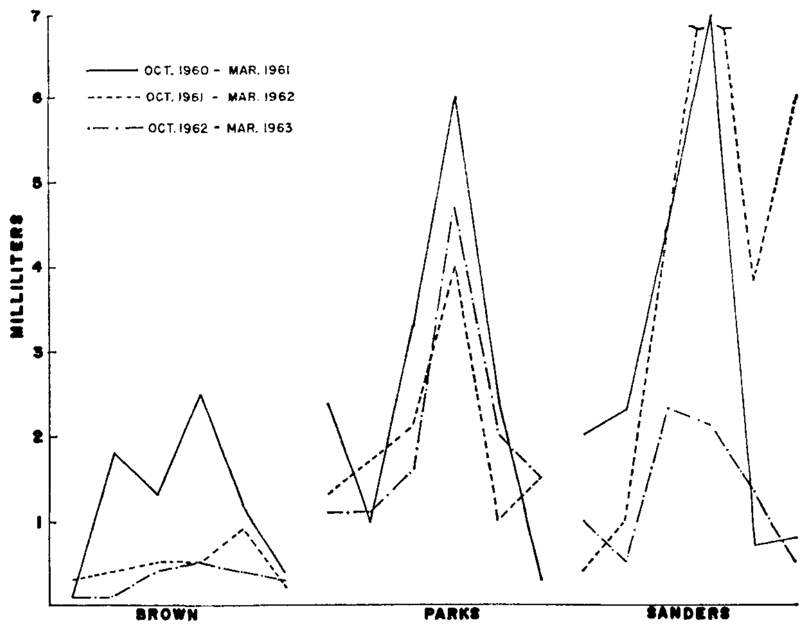


FIGURE 10.— Volume of benthos sampled from control ponds during months of their highest occurance.

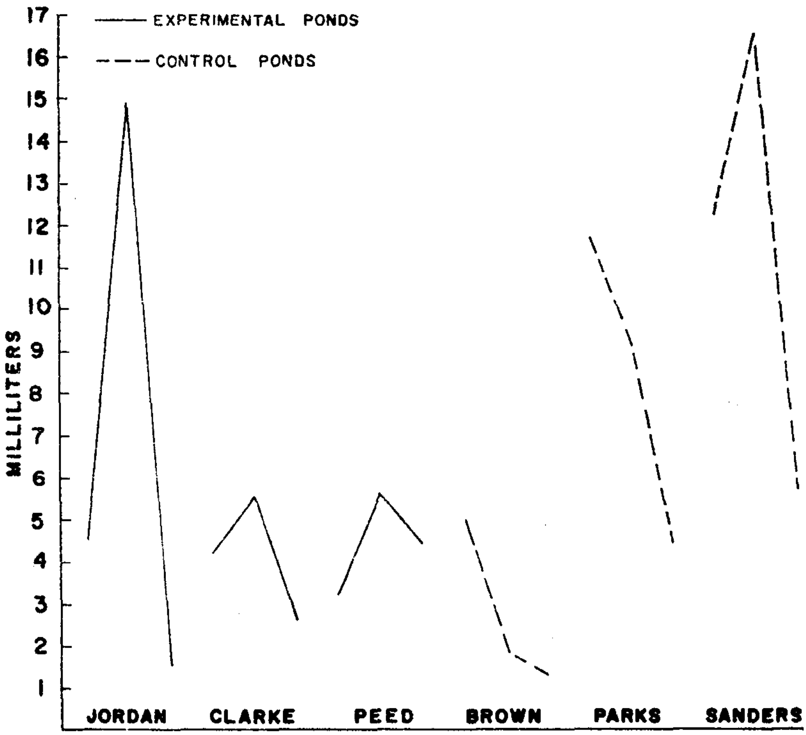


FIGURE 11.— Total volume of benthos sampled during the months December, January, and February of 1960-61, 1961-62, and 1962-63.