be the best suited of the two for commercial production in coastal areas. It is already accepted as a commercial pond species and is also tolerant of many of the conditions experienced in coastal waters.

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CHANGES IN POND BOTTOM SOILS DURING THE INITIAL FIVE YEARS OF USE

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ABSTRACT

Bottom soil samples were taken after each draining during a five-year period from a series of 12 small earthen ponds ranging in size from 0.70 to 1.39 acres. Except in one pond, drainings occurred one or more times annually. The ponds were used to produce one or more crops of fingerling fish each year. Species cultured were largemouth bass, bluegill, channel catfish and redear sunfish. Chemical analyses for pH, calcium, phosphorus, potassium, carbon and nitrogen were done on each sample. All ponds except one were fertilized and supplemental feeding was done on a limited scale in some of the ponds.

The quality of the water supply was a significant influence for modification of the parameters included, with artificial enrichment also appearing to exert an important effect. Generally, the soils became more alkaline and richer in calcium. Phosphorus increased tenfold in one pond from beginning to end of the period and potassium showed a moderate rate of increase although the fertilizer mix did not contain this element. Carbon increased in all instances, and nitrogen was also higher at the end of the period. The carbon to nitrogen ratio was narrower at the end of the study period in 10 of the 12 ponds than at the beginning. The two deviants had a narrow C/N ratio at the start.

INTRODUCTION

The importance of the pond bottom soil in influencing the productive processes in the overlying aquatic habitat has long been recognized. Schaperclaus (1933) stated that the nature of the pond floor is of no less importance from the standpoint of biological productivity than the water of the pond. Mortimer and Hickling (1954) review the extensive European and Asiatic research in pond fertilization devoting a chapter of the review to pond muds, their chemistry and treatment. Various authors are quoted emphasizing the importance of the mud surface of the pond bottom as the "chemical laboratory" of the pond. In Israel, Hepher (1965) reported on work similar to ours for fertilized and unfertilized fishponds. Although less attention has been given to changes in pond bottom soils in warm-water fish culture in the United States, Meehean (1935) and Meehean and Marzulli (1943) did some preliminary work on carbon/nitrogen (C/N) ratios resulting from addition of cottonseed meal fertilizer or cottonseed meal and superphosphate to bass rearing ponds. Research in this direction was not continued far enough to answer questions they raised regarding fertilization and productivity. Later Snow and Jones (1961) employed results of bottom soil sample analyses as a basis for liming to produce neutral conditions in pond bottom soils.

From a review of work which had been done on the relationship between the pond bottom and fertilization practices adopted to increase fish production or to control unwanted aquatic plants, it seemed obvious that more knowledge was needed regarding the effect that present cultural practices have in modifying the character of pond bottom soils when continued over a period of time. Because of this, the following study was initiated in 1960 at the National Fish Hatchery, Marion, Alabama.

MATERIALS AND METHODS

Extensive renovation of a block of ponds on the Marion National Fish Hatchery in 1959-60 provided an opportunity to study pond bottom soil changes in "new" ponds as normal cultural practices were followed in succeeding years. The renovation work consisted of subdividing larger ponds into smaller units, regrading bottoms which were stripped of topsoil to a minimum depth of 0.3 foot; relocation of drain outlets and addition of a common water supply considerably different from the one previously employed.

The block of ponds (Figure 1) included 38 units having a combined surface area of 32.8 acres. The size of individual ponds varied from 0.5 to 1.44 acres. Shape of the ponds was rectangular with a length to width ratio varying from about 1.5:1 to 2:1. The dikes were constructed to a 2.5:1 slope with maximum depth at outlet being 5½ feet, minimum depth at shallow end of the pond being about 2½ feet. Figure 2 shows a typical view of the deep end of one of the ponds.

The water supply came from three wells located in the pond area of approximately the same chemical characteristics. Location of the wells is shown in Figure 1. Details regarding water quality and quantity are shown in Table 1.

Twelve ponds of the 38 were arbitrarily selected for study. These were located in three groups of four ponds each, on a diagonal line which extended from the highest to the lowest elevation of the pond area. Prior to initial filling and about five days after each draining, each pond was sampled by taking one-inch deep core samples from each of five sampling stations permanently marked in each pond. Two stations were in the deep end of the pond, two in the shallow end and one in the center. The five cores taken at each location were combined to give a composite sample for the pond. The cores were obtained with a sampler constructed according to the description of Walker (1955) which proved to be quite satisfactory for the purpose except when the surface layer was thin mud. This generally did not occur because of the five-day delay in sampling which normally followed draining.

After collection the samples were first air-dried and then oven-dried at a temperature of 100°C for processing. After drying they were ground in a hand-powered burr mill to a fineness which would pass through a U. S. Standard Number 40 seive. Mechanical analysis of the samples taken before initial flooding of the ponds provided basic information for classification to a sandy clay loam type except in one pond, Number S-38, which was classified at a loam. Table 2 shows the classification of the pre-flooding samples by the Soils Testing Laboratory, Auburn University. In addition to mechanical analysis, this laboratory also made determinations for calcium, phosphorus, potassium, pH, magnesium [1] and lime requirement.

Analyses by the Soils Testing Laboratory were those ordinarily provided farmers, gardeners and horticulturists on a fee basis. Analytical methods were of acceptable standards of accuracy for production control work and were performed in duplicate or triplicate depending upon the analysis in question.

Analyses performed in our laboratory were pH, organic carbon and nitrogen. pH was measured according to a method described by Woodruff (1947) employing a Beckman pH meter equipped with a glass electrode. Organic carbon and nitrogen determinations were made according to Maciolek's (1962) quantitative dichromate oxidation method. Carbon values in grams per kilogram were divided by nitrogen levels in g per kg to yield a carbon/nitrogen (C/N) ratio.

Production records were kept on each pond according to standard operating procedures for this hatchery. Routine entries were made of date of filling the pond; date, kind, and amount of fertilizer applied; date, kind, and amount of herbidical treatment; daily supplemental feeding record; species, size, number and weight of fish harvested; and date of draining the pond. In addition, ponds were usually inspected visually at weekly intervals during the growing season for a determination of need for fertilization, weed control, disease or other treatment and to record notes on response of the pond to past management techniques. At this time a Secchi disc reading was taken and the depth in inches where the disc could no longer be seen was noted.

Fingerling fish produced were weighed, usually to the nearest .02 pound, during processing. Numbers were estimated on the basis of sample counts of three or more weighed samples of each size fish produced in a given pond.

Eleven of the twelve ponds were fertilized with either organic or inorganic nitrogen source materials and with inorganic phosphorus supplied from either ordinary superphosphate or diammonium phophate. The twelfth, unfertilized, pond served as a warming pond for the water supply of a fish holding house. It was maintained in a fish-free condition and was not employed in the station production program except as a

[1] Analysis for magnesium was not begun until July 1, 1963. All samples submitted after that date were analyzed for magnesium content.

water supply. Intermittent drainings for vegetation control purposes made soil sampling possible. In normal use, water exchange in this pond ranged from 50-125 gallons per minute.

The requirements of the station production program dictated the use to which a pond was put and the time the crop was harvested. Production techniques were not necessarily standard but generally reflected procedures followed in the southern half of the United States where two or more crops of fingerling warm-water fishes are reared in each pond during the growing season, which averages 229 days according to the nearest weather station of the U. S. Weather Bureau.[2]

The study period covered five complete growing seasons for each pond beginning in November 1960 and terminating in April 1966 when the last pond devoted to the 1965 crop was drained. Ten instances occurred where poor communication between the investigators and production personnel resulted in the ponds being refilled without a soil sample being taken. Also, one pond was dry 182 days during the fall and winter after the last draining before being sampled because of an oversight following the retirement of the senior author. A total of 107 samples was taken from the 12 ponds, the number per pond ranging from six in the unfertilized pond, S-36, to eleven in two ponds. One pond was sampled ten times, five were sampled nine times and three were sampled eight times.

To compare the amount of variability between sampling stations within a given pond, one pond was arbitrarily selected and 25 one-ich cores were taken at stations in the deep end, the center and the shallow end. A composite sample from the stations normally used was taken at the same time. Analytical data for the indices studied are shown in Table 3.

These data show that considerable variation in the elements measured can occur from station to station within a pond and that combining samples from various locations achieves results similar to those where data from separate stations are averaged after analysis. The average value for three locations was in reasonably close agreement with the composite sample for all elements except calcium and phosphorus.

RESULTS AND DISCUSSION

Pronounced changes were noted in the parameters measured for the study. Our observations were inadequate to provide an explanation for some of the variations recorded, although the long-range pattern of change appeared to be influenced primarily by the water supply and artificial enrichment, as might be expected. Findings for the different elements are listed in Tables 4 and 5. Some of the trends are illustrated by Figures 3 to 9 and each element is discussed in more detail below.

Change in pH

The block of four ponds on the highest elevation was in soil containing slightly more sand and had, on the average, a pH more nearly neutral. At the end of the five-year period all were virtually neutral as were three of the remaining eight ponds. All ponds were more alkaline at the end than at the beginning except one which showed a pH of 4.8, 0.2 lower than at the first. Without the influence of the water supply, pH would be expected to become more acid because of the use of ammonium nitrate as a source of inorganic nitrogen, addition of organic fertilizers and supplemental feeding in several instances. In S-18 where no appreciable change occurred, no supplemental food and only a moderate amount of organic nitrogen was applied. However, this pond reecived the highest rate of inorganic nitrogen addition of any pond in the series, and this may have been the deciding factor in keeping the

[2] Climate and Man. 1941 Yearbook of Agriculture, U. S. Department of Agriculture, U. S. Government Printing Office, Washington, D. C. 1248 pp.

pH acid. Even with a water supply such as that in use for these ponds it appears that liming for achieving a neutral pH would be necessary if fertilizers or other additions were as acidic as those applied here.

Calcium

Calcium levels increased dramatically in all of the samples taken (Table 4). The beginning level was the lowest in each instance, although all but one of the final samples were lower in this element than were samples taken at some other draining. An increase of more than twenty fold took place in the unfertilized pond. This was probably due to a heavy growth of *Chara sp.* and *Najas flexilis* which was present most of the time, and to a high rate of water exchange. Withdrawal by the plants of free and half-bound CO_2 brought about precipitation of calcium in the supply water causing an accumulation of this element. While more moderate levels were present in the other units, the calcium content ranged from two to about seven times greater in the final samples (Figure 4) than at the outset.

Magnesium determinations were made on samples taken after July, 1963. Levels of this element followed a pattern similar to calcium, which is expected since calcium and magnesium behave in a similar fashion in the presence of aquatic plants.

Phosphorus

Substantial additions of inorganic phosphorus source materials in the form of superphosphate and diammonium phosphate (Table 6) were made each year to all of the study ponds except one which was inadvertently fertilized one time. Since phosphorus levels were quite low initially, amounts at the end of the period were several times what they were at the beginning. However, final samples from three of the 11 fertilized ponds were low enough in phosphorus to fall into the "low" category established by the Soils Testing Laboratory for field crop soils.

Figure 5 illustrates the beginning and ending levels of phosphorus in the samples from the study ponds. Of interest was the decline in phosphorus in the unfertilized pond. One sample showed a zero level and the final sample contained only 0.5 ppm, only about 10 percent of the amount present at the beginning.

Since our analysis measured the phosphorus available for plant use, accumulations of from two to ten times the amount present at the start indicates that the artificial enrichment added was sufficient for the fish crop plus extra amounts which accumulated. In view of the extensive research on this element in European carp culture reviewed by Mortimer and Hickling (1954), these results could be expected.

Potassium

The water supply for the ponds contained about twice the amount of potassium which Swingle and Smith (1939) found to be optimum for growth of phytoplankton. Because of this the fertilizer mix used omitted potassium. Changes in levels of potassium in samples taken over the five-year period (Table 4) showed an increase in all instances. The increase was slight in pond S-20 but was more than twofold in some ponds. The contrast between beginning and final amounts of this element is shown graphically in Figure 6.

Nitrogen

Both inorganic and organic nitrogen were applied to 11 of the 12 study ponds. In addition, eight of the ponds received moderate amounts of supplemental feed for one or more crops of fish. On the basis of the amount of total nitrogen, Ponds S-17, 1, 20, 14 and 35 received more than 500 pounds N_2 per acre. Three of these five ponds also had the highest level of organic nitrogen in the final samples taken, although the unfertilized pond also was in the top five ponds based on nitrogen content of the final sample.

A logical explanation for the increased amount of N_2 in the unfertilized pond is not available although N_2 addition from the atmosphere in rainfall totals 5-10 pounds per acre per year in humid climates according to Lyon and Buckman (1943). Concentration of available nutrients by the rooted aquatics in this pond appeared to have enriched the bottom soil in organic nitrogen to a marked degree. As shown in Figure 7 and Table 5 an increase of about 600 percent occurred and one of the intermediate samples showed an amount more than 1,000 percent greater than the beginning level.

Samples from all of the study ponds showed increased organic nitrogen levels, the increase being from two- to ten-fold. A continuation of this trend over an extended period of time could render the addition of nitrogenous fertilizers unnecessary as has been recommended by European carp culturists (Mortimer and Hickling) and by Swingle et. al. (1965) for farm pond fertilization. With the increased use of supplemental feeding for rearing warm-water fishes, especially channel catfish, the buildup of organic nitrogen in the bottom mud layer could be a matter requiring corrective actions such as pond rotation, fallowing, flushing, plowing, or supplemental aeration.

Organic carbon

Another interesting parameter indicative of the degree of richness present in the pond bottom mud is organic carbon. This component has not been studied for pond bottom muds to the extent it has for terrestrial environments although Hepher (1965) found a higher accumulation of organic matter in a fertilized pond than in one which was unfertilized. He quotes Stangenberg[3] as having found a higher organic matter and nitrogen content in the eutrophic zone of a lake than in other areas, although he was unable to establish a correlation between these parameters and fish production in several fish ponds studied. In our study we also were unable to demonstrate a significant correlation between the final carbon levels and the total pounds of fish produced per acre from the ponds. In view of the number of variables affecting fish production, however, it would be surprising if such a relationship could be demonstrated. Table 5 shows the beginning and final levels of organic carbon in the samples along with the range of values for the period.

Carbon/Nitrogen (C/N) ratio

Thompson (1957), reviewed the relationship between carbon and nitrogen in field crop soils. Meehean and Marzulli (1943) reported that a positive correlation was measured between fish production (largemouth bass fingerlings) and the C/N ratio. They found that fertilization with organic nitrogen in the form of cottonseed meal and phosphate as colloidal phosphate caused an increase in the C/N of the pond bottom.

Our findings show a decrease in the C/N ratio in 10 of the 12 study ponds. The two ponds not showing a decrease in C/N ratios had a narrow ratio initially, the result of a comparatively high level of nitrogen in the pre-flood sample. Whether the decrease in C/N ratio was the result of artificial enrichment or other influences is not indicated as only one pond of the 12 was unfertilized rendering insufficient control to conclusively support a statement regarding this.

Eight of the 12 ponds appeared to have C/N ratios in the range where mineralization of organic matter would make nitrogen available to plants other than the putrefying bacteria, i.e. less than 17. The other four showed values for the final samples which were substantially below the upper point (33/1) where N_2 needs of decay bacteria were met by that contained in the matter being mineralized. The extent of this change is illustrated by Figure 8, showing beginning and ending C/N ratios.

[3] Stangenberg, M. 1949. Nitrogen and carbon in the bottom deposits of lakes and the soil under carp ponds. Verh. Int. Limnol. 10:422-437.

Initial samples from the ponds had a range of C/N ratios from 90 to 14. The final samples showed a range of 23 to 13. As shown in Table 5, ratios went as low as 7-8 after some drainings. Obviously nitrogen was not being lost in the productive processes at a rate exceeding the additions and even though carbon was accumulating, nitrogen was accumulating at a faster rate until a relatively narrow C/N ratio was achieved. After this, the sample values appeared to be fairly stable from draining to draining.

Pond flora

Management of ponds at Marion devoted to culture of largemouth bass fingerlings is aimed at producing zooplankton for the fish reared to a size of 1-2 inches and midge larvae for those reared to a size of three inches. Bluegill, channel catfish and redear sunfish rearing ponds are managed to induce a bloom of phytoplankton which is maintained by adding additional doses of fertilizer along with appropriate weed control measures when the bloom fades. The phytoplankton organisms feed midge larvae and other invertebrates which are in turn consumed by the fish crop. The weekly Secchi disc readings and notes regarding the dominant form of plant present can be used to approximate conditions regarding vegetative development. Comparing records for the ponds for the first three drainings with those for the last three drainings, it appeared that two ponds were supporting better crops of phytoplankton at the end, five ponds were the same and five were more dominated by the weed forms infesting the Marion pond system at the end than at the beginning.

Admittedly, influences other than changes in the pond bottom character were involved in these developments but it appears that as pond bottoms become progressively more fertile, weed algae such as *Hydrodictyon reticulatum*, *Pithophora oedogonia* and overabundant growths of *Anabaena sp.* become more troublesome.

Other criteria of change

Fish production would be a logical parameter to include in a study of this kind. However, due to the diverse use to which it was deemed necessary to put the test ponds from season to season, it is doubtful that an attempt to correlate fish production with the changes in bottom soil composition would be worthwhile. Such an effort should be made in the future in conjunction with the next planned sampling date which is scheduled for the 1971 production season. Total weight production of fish per acre in the study ponds is shown in Table 6. The higher weights were the result of supplementally feeding channel catfish during one or two growing seasons. There was no indication from the analytical data obtained that the moderate rate of supplemental feeding applied had any drastic influence on the parameters studied. Of six ponds where feeding was done (one for two seasons) pH was more alkaline in five instances; more acid than the two previous measurements twice; phosphates were up once and lower six times; carbon was higher in five instances and lower in two; nitrogen was lower twice and higher five times; the C/N ratio was the same in two cases, higher twice and lower three times. Though far from conclusive, the limited data suggest that supplemental feeding of catfish tends to enrich the pond bottom as would be expected.

These data emphasize the variability of earthen ponds, even those adjacent to one another. The findings also show how important water supply can be in shaping the productive capability of the pond environment. While management techniques can provide lacking elements, the presence of near optimum levels in the water supply can save time and money as long as the fish cultural operation exists.

From our data, it does not appear necessary or desirable to analyze samples of bottom soil too often under production conditions. Preflooding data and later sampling at three- to five-year intervals could be most helpful in charting long-range trends and indicating the need for changes in management before productivity becomes greatly affected by an adverse development.

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TABLE 1. Water analysis data of three wells supplying 12 ponds included in bottom soils study.

Component	Well Number 4	9	11
Volume, GPM	100.00	150.00	240.00
pH	7.60	7.60	7.30
Free CO_2[4]	3.30	3.60	12.00
Alkalinity (as $CaCO_3$)	112.00	112.00	115.00
Total hardness (as $CaCO_3$)	106.00	108.00	115.00
Iron	0.05	0.26	0.00
Copper	0.02	0.01	0.00
Zinc	0.05	0.05	0.00
Manganese	0.10	0.10	0.00
Calcium	34.00	34.00	34.00
Magnesium	10.00	5.60	16.00
Sodium	3.20	3.70	1.90
Potassium	4.00	4.00	0.00
Sulphates	2.80	3.20	0.00
Bicarbonate (as HCO_3^-)	136.00	136.00	129.00

TABLE 2. Mechanical analysis of preflooding composite samples of 12 selected ponds in study group.[5]

Pond Number	Percent Sand	Percent Silt	Percent Clay	Textural Classification
S-1	58	14	28	Sandy clay loam
S-2	66	10	24	Sandy clay loam
S-3	66	10	24	Sandy clay loam
S-4	54	12	34	Sandy clay loam
Average of Group 1	61	11.5	27.5	Sandy clay loam
S-17	48	18	34	Sandy clay loam
S-18	62	16	22	Sandy clay loam
S-19	60	14	26	Sandy clay loam
S-20	58	15	27	Sandy clay loam
Average of Group 2	57	15.8	27.2	Sandy clay loam
S-35	46	26	28	Sandy clay loam
S-36	50	24	26	Sandy clay loam
S-37	50	20	30	Sandy clay loam
S-38	44	30	26	Loam
Average of Group 3	47.5	25.0	27.5	Sandy clay loam

The above determinations were made on samples which had been ground to pass through a U. S. Standard Screen Number 40 (420 micron openings).

[4] Amounts shown are ppm for all of the following components.
[5] Performed by Soil Testing Laboratory, Auburn University, Auburn, Alabama.

TABLE 3. Comparison between single location and composite bottom soil samples from Pond S-17.

Element	77	77A	77B	77C	77D	Average B C & D
	Sample Number					
Calcium, ppm	3,080	3,528	2,720	4.032	2,784	3,179
Magnesium, ppm	275	210	250	290	210	250
Phosphorus, ppm	4	2	10.5	0.0	6.5	5.7
Potassium, ppm	148	154	138	172	143	151
Organic carbon, g/kg	15.4	17.0	12.4	22.5	12.2	15.7
Organic nitrogen, g/kg	1.270	1.515	0.859	1.793	1.139	1.264
C/N ratio	12	11.5	14.4	12.6	10.7	12.6
pH	6.9	6.9	6.9	7.0	6.7	6.9

Sample No. 77 taken in customary way on 1/5/65, 25 one-inch cores from five locations.

Sample No. 77A composite of 25 cores from same locations were sample 11 was taken. This sample taken on 1/14/65.

Sample No. 77B taken from center of deep end of pond on 1/14/65.

Sample No. 77C taken from center of pond mid-way from deep to shallow end on 1/14/65.

Sample No. 77D taken from center of pond in shallow end on 1/14/65.

TABLE 4. Changes in inorganic content of bottom soil sample as new ponds aged and were used for warm-water fish culture.

Pond No.	pH			Calcium (Ca) (ppm)			Phosphorus (P) (ppm)			Potassium (K) (ppm)		
	At Start	At End	Range	At Start	At End	Range	At Start	At End	Range	At Start	At End	Range
S-1	5.7	7.0	5.7-7.6	1,200	3,115	1,200-3,115	1.9	9.0	1.9-19.5	98	151	98-166
S-2	7.0	7.6	7.0-7.7	1,120	3,880	1,200-4,800	3.3	12.5	2.4-14.5	94	145	75-145
S-3	6.6	7.0	6.6-7.5	1,280	2,580	1,280-2,832	3.7	32.0	3.7-73.0	118	135	118-160
S-4	4.8	6.4	4.8-7.6	384	2,560	384-2,600	4.4	16.0	3.0-16.0	53	123	53-139
S-17	4.9	5.9	4.9-6.7	387	2,760	387-3,080	8.7	17.5	4.0-17.5	53	116	53-148
S-18	5.0	4.8	4.8-6.4	260	1,320	260-2,660	4.4	6.0	3.7-19.0	52	90	52-123
S-19	5.1	6.2	5.1-7.5	644	2,400	644-3,744	4.8	28.0	0.0-28.0	83	126	83-160
S-20	5.4	6.2	5.4-7.4	670	1,880	670-4,032	5.4	14.0	1.0-14.0	104	108	104-200
S-35	5.3	7.0	5.3-7.8	576	3,840	576-4,104	4.6	10.0	3.7-12.5	58	123	58-144
S-36	5.1	7.3	5.1-7.7	386	8,400	386-8,400	4.6	0.5	0.0- 4.6	41	99	41-108
S-37	5.2	6.6	5.2-7.3	336	1,440	336-2,712	1.7	17.0	1.7-22.0	36	71	36-197
S-38	5.6	7.1	5.6-7.6	568	2,382	568-2,784	4.6	32.0	2.0-32.0	50	94	37-116

TABLE 5. Changes in organic content of bottom soil samples from new ponds during aging and use.

Pond No.	Carbon (gms/kg)			Nitrogen (N_2 gms/kg)			C/N Ratio		
	Pre-Flood	At End	Range	Pre-Flood	At End	Range	Pre-Flood	At End	Range
S-1	2.07	8.00	2.07-17.25	0.084	0.341	0.070-0.770	25	23	13-53
S-2	1.31	4.42	1.31-13.94	0.023	0.243	0.023-1.750	57	18	8.57
S-3	3.45	6.30	3.45-13.60	0.082	0.294	0.082-1.030	42	21	11-42
S-4	2.76	8.30	2.76-14.10	0.173	0.644	0.173-1.195	16	13	12-17
S-17	4.14	11.32	4.14-15.40	0.245	0.775	0.077-1.270	17	15	12-71
S-18	4.83	5.31	4.21- 8.14	0.120	0.350	0.105-1.000	40	15	8-40
S-19	3.45	5.59	3.45-19.80	0.091	0.364	0.091-1.768	38	15	7-38
S-20	2.08	4.14	2.08-19.11	0.023	0.280	0.023-1.400	90	15	12-90
S-35	3.93	11.80	3.93-18.63	0.289	0.761	0.289-2.216	14	16	8-16
S-36	2.69	6.35	2.69- 8.21	0.058	0.364	0.058-0.614	46	17	10-46
S.37	2.76	3.93	2.76-15.00	0.061	0.266	0.061-1.470	45	15	10-45
S-38	3.45	5.11	3.45- 8.80	0.240	0.322	0.080-0.770	14	16	10-72

TABLE 6. Artificial enrichment and fish production data for 12 study periods

Pond No.	Total lbs. per acre added: Inorganic N_2	Organic N_2	P_2O_5	Supplemental feed	Total lbs. per acre fish removed
S-1	310	183	430	895 (54) [6]	1,957
S-2	249	71	325	611 (37)	1,373
S-3	317	94	450	209 (13)	1,276
S-4	275	74	353	0	1,553
S-17	210	146	365	2,423 (145)	3,811
S-18	426	88	579	0	1,003
S-19	320	65	364	2,531 (152)	2,387
S-20	327	66	420	2,224 (133)	2,891
S-35	338	103	546	2,819 (169)	3,333
S-36	8	0	8	0	0
S-37	252	79	360	719 (43)	2,272
S-38	282	132	418	0	888

[6] Figure in parenthesis is approximate amount of nitrogen present in feed assuming a protein content of 35 percent for all kinds fed.

FIGURE 1. Area view of ponds involved in bottom soil study with those sampled indicated by number.

FIGURE 2. Typical view of a dry pond in the test series showing the deep end.

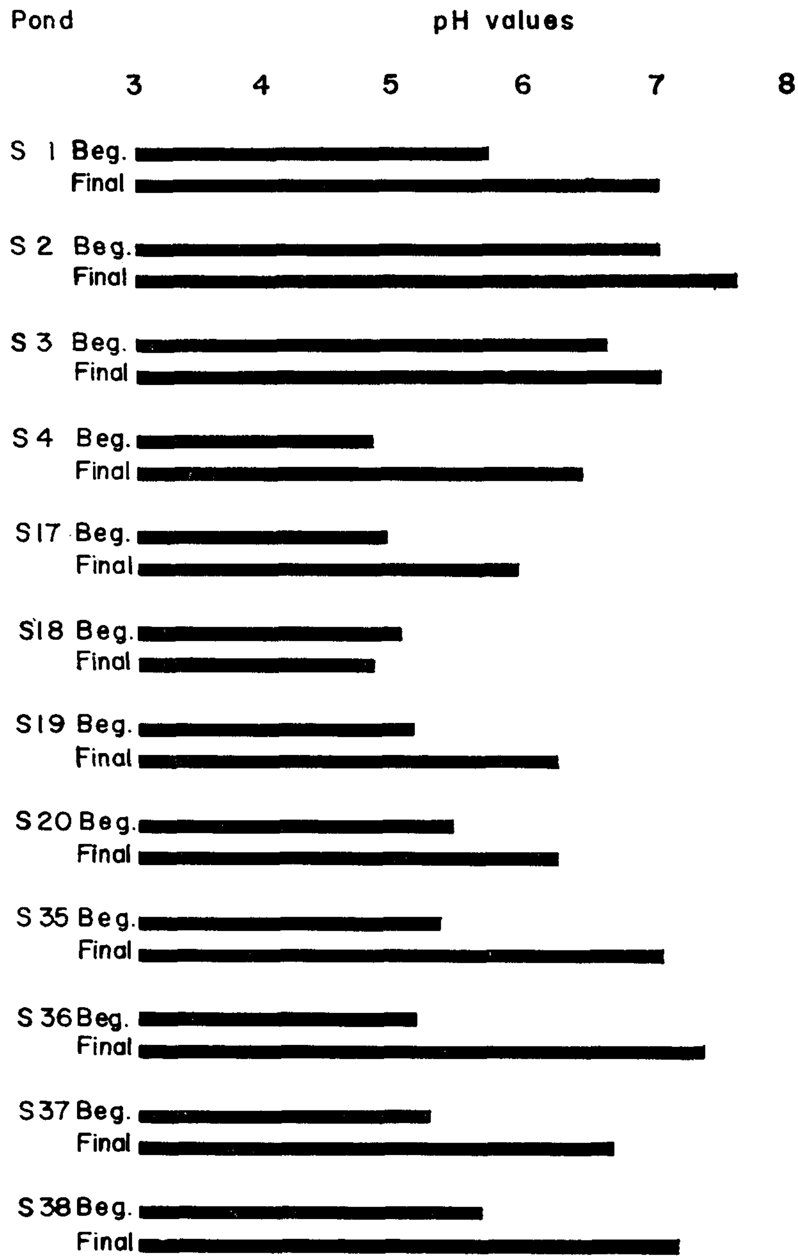

FIGURE 3. Beginning, final and range of pH values of samples of bottom soil from 12 study ponds.

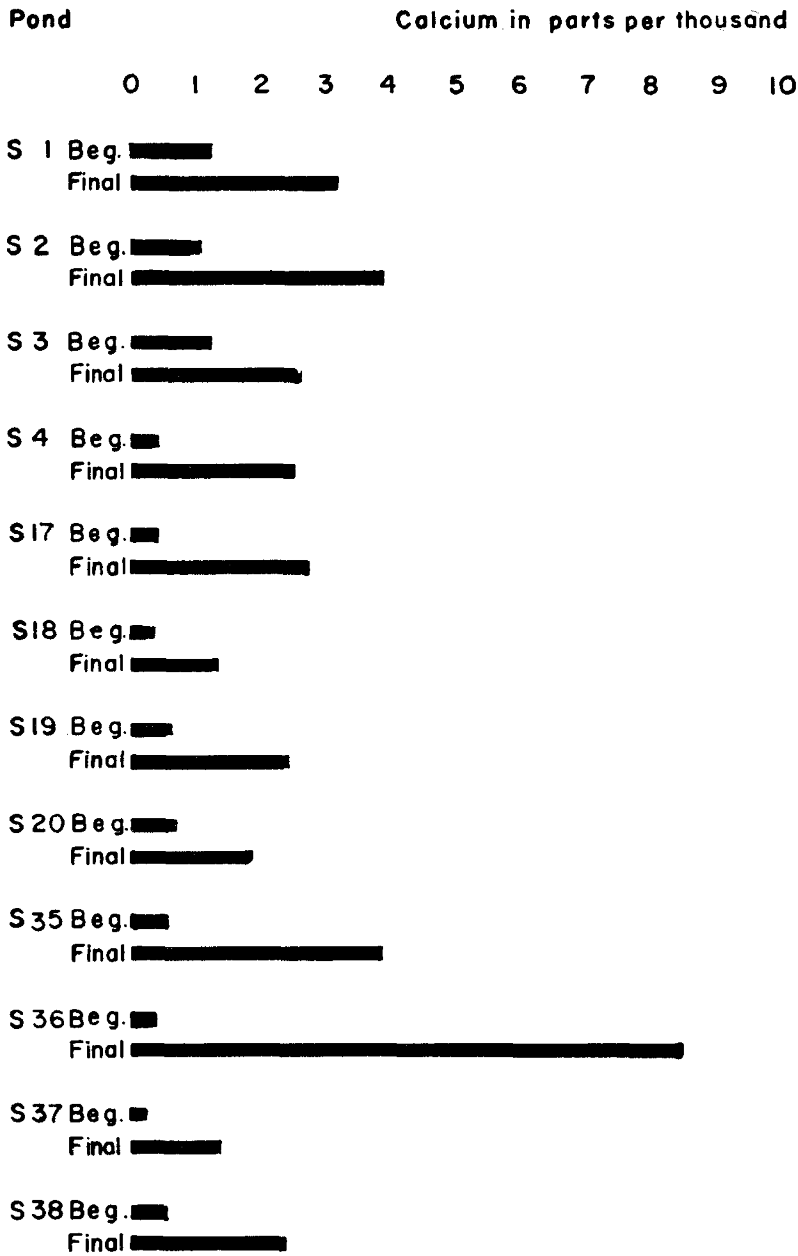

FIGURE 4. Beginning and final levels of calcium in samples of bottom soil from 12 study ponds.

FIGURE 5. Beginning and final levels of phosphorus in samples of bottom soil from 12 study ponds.

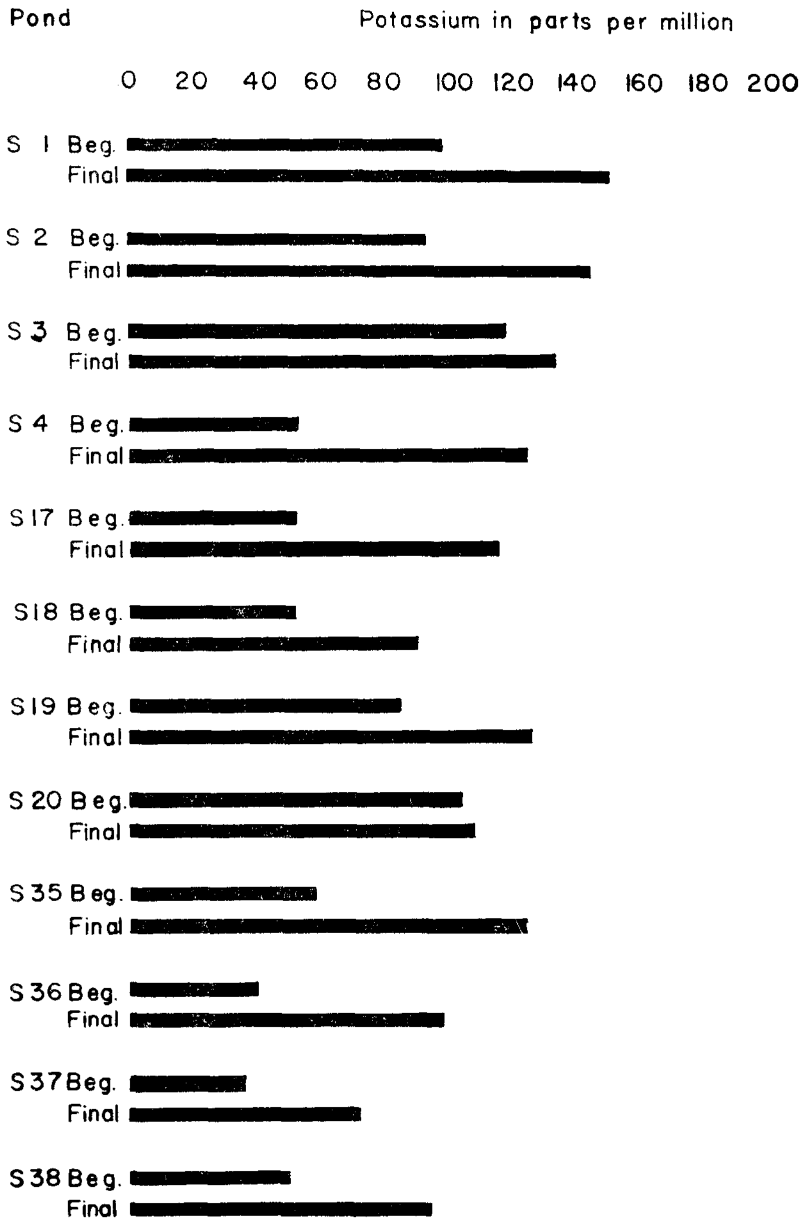

FIGURE 6. Beginning and final levels of potassium in samples of bottom soil from 12 study ponds.

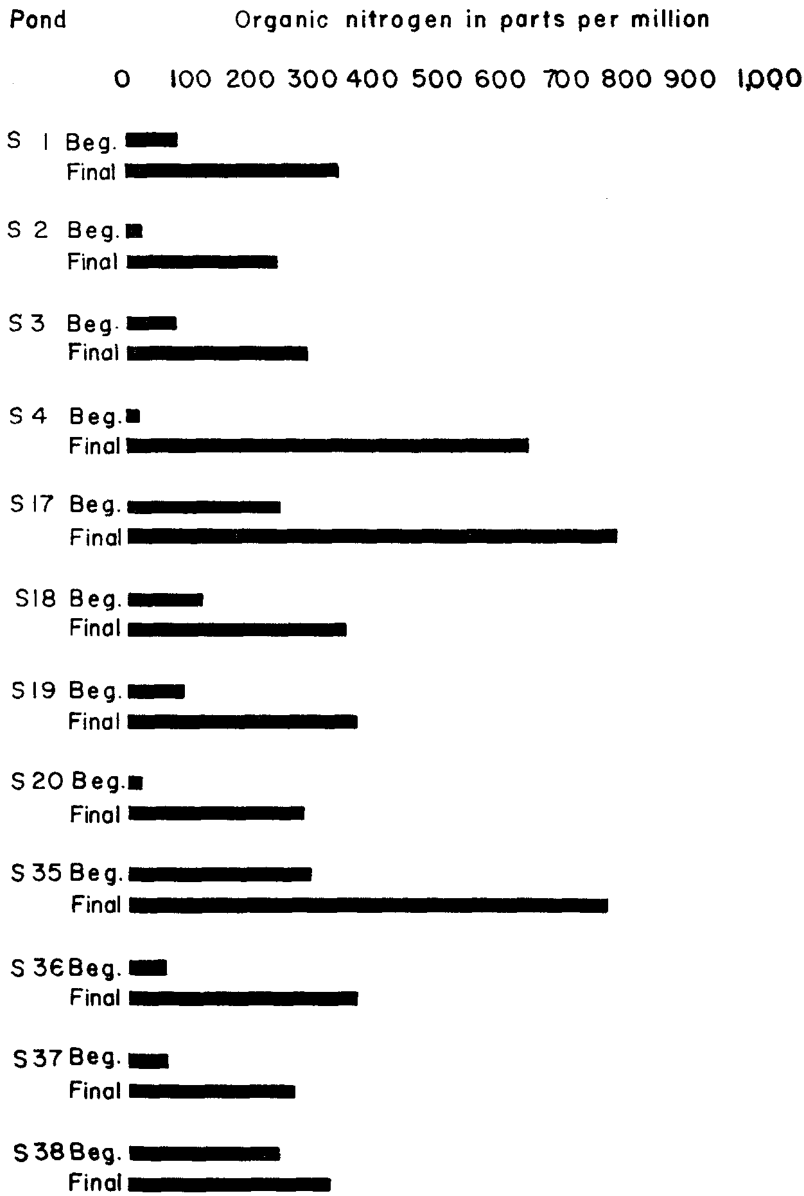

FIGURE 7. Beginning and final levels of organic nitrogen in samples of bottom soil from 12 study ponds.

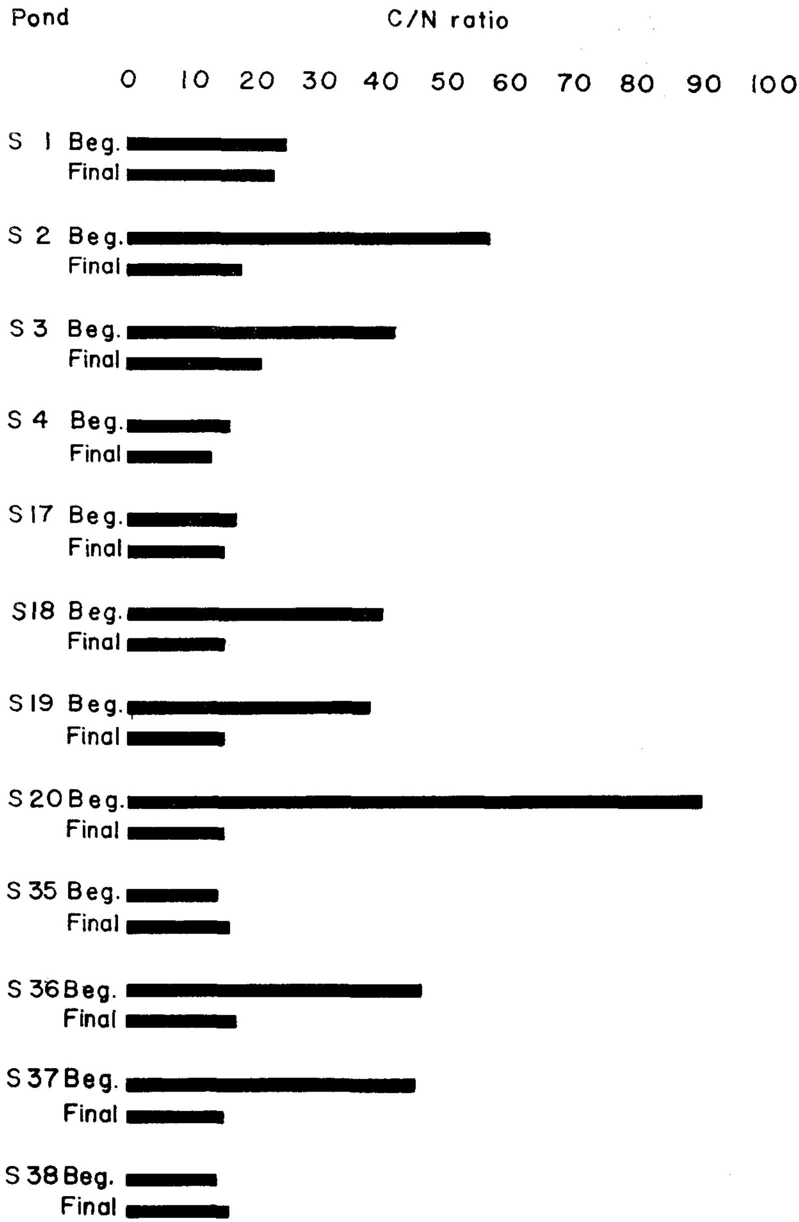

FIGURE 8. Beginning and final C/N ratios in samples of bottom soil from 12 study ponds.