SUMMARY

1. The native fishery of Arkansas environmentally degraded delta region has essentially been lost to intensive agricultural endeavor and federal water management projects while accompanying dredging, drainage, and agricultural pollution have reduced recreational opportunities to a fraction of the former potential.

2. The need for outdoor recreation has increased more rapidly than the human population. The problem: More fishermen and fewer fishable bodies of water.

3. The solution: Replace the native fishery (streams and overflow lakes) with man-made reservoirs designed for absolute topographic isolation from unfavorable environmental factors.

Natural lakes in the delta to be managed only on a "short term" basis.

CONCLUSIONS

Much effort and material expense can be put forth in an effort to restore a native fishery in a ruined environment with extremely low returns. The angler must be acclimatized to the fact that attempted maintenance of a fishery that has been lost through environmental destruction can be extremely extravagant and that the answer to meeting his recreational needs lies in a somewhat unique man-made substitute.

A satisfactory substitute for the native fishery can best be provided in heavily farmed delta regions in eastern Arkansas with the topographically isolated reservoir.

THE EFFECTS OF INORGANIC FERTILIZERS AND ORGANIC MATTER UPON THE PRODUCTION OF MACROBENTHOS IN PONDS [1]

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INTRODUCTION

Numerous investigators, including Smith and Swingle (1939), Surber (1943), Swingle (1947), and Ball (1949), have demonstrated an increase in fish biomass in North America associated with the addition of inorganic fertilizers to ponds. These same authors and others reported increases in phytoplankton after the addition of inorganic nutrients, a phenomenon so well established that it is common practice in pond management today.

Patriarche and Ball (1949) used four ponds, two fertilized and two unfertilized, in a study of the effects of fertility on the increase of benthos. A definite increase was shown in only one of two fertilized ponds.

Howell (1941) reported an increase in benthos in one pond fertilized for three years in comparison to an unfertilized pond. However, Howell observed that the concentration of bottom organisms increased in the experimental pond as the water level of the pond decreased.

McIntire and Bond (1962) more clearly demonstrated that both plankton and benthos were increased by the use of inorganic fertilizers. When compared to a control pond, nitrate plus phosphate distinctly increased the benthos in two experimental ponds.

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In each of the studies by Patriache and Ball (1949), Howell (1941), and McIntire and Bond (1962), filamentous algae and higher plants were not controlled. The growth of these plants occurred in various densities and at various times during the studies.

An increase in the density of benthos has been shown to be associated with an increase in organic material (Harp and Campbell, 1964; Burgess, 1965). Harp and Campbell killed aquatic vegetation with a herbicide (Silvex) in plastic enclosures placed in a pond containing dense vegetation. As organic matter from the dead plants accumulated on the bottom of the enclosures, a corresponding increase in benthos occurred.

Burgess (1965) studied the macroinvertebrates of five Florida lakes of similar geologic origin and the results of the study were grouped according to the bottom types. Burgess observed that benthic organisms were confined to rather well-defined bottom types and that productive capacity varied with the degree of sedimentation. There was some indication that the physical texture or firmness of the substrate was one of the determining factors, if not the most important. The substrate appeared to be the cause of failure of most invertebrate forms as fertility increased.

From the above studies, it seems that general productivity is increased in aquatic environments when fertility is increased. It is unclear whether higher densities of macrobenthos result from a simple increase of plankton density or whether organic matter from higher plants is necessary in the food chain. The present study is an attempt to determine whether inorganic fertilization will increase benthic productivity when filamentous algae and higher plants are controlled and whether organic matter alone will increase benthic productivity.

METHODS AND MATERIALS

Eight experimental ponds, located below the dam at the Carbondale City Reservoir, Carbondale, Illinois and three hatchery ponds, located at Little Grassy Fish Hatchery, 10 miles southeast of Carbondale, were used for the present study. Each of the ponds at the city reservoir was approximately one-tenth acre and the depth of the water was 3 feet at one end and increased gradually to 4 feet at the other end. The ponds at Little Grassy Hatchery each had approximately a one-third acre surface area and the depth of the water increased gradually from 3.5 feet at one end to 5 feet at the other end.

On April 18, 1967, the ponds listed above were treated experimentally according to the following design:

Pond location	Pond number	Treatment
Below Carbondale City Reservoir	1	Control
	2	Control
	3	Ground corn cobs spread over entire pond bottoms
	4	
	5	Inorganic fertilizer added
	6	
	7a	2/3 pond bottom covered with sewage sludge
	7b	1/3 of pond bottom not covered with sewage sludge
	12	1/2 cubic yard of sewage sludge scattered over pond bottom[1]
Little Grassy Hatchery	9	Control
	10	Inorganic fertilizer added
	11	Sewage sludge spread over entire bottom of pond

Hydrated lime was added to any pond in which the methyl orange reading was below 50. Bennett (1962) recommended a minimum methyl orange reading of 40.

It was determined by pilot studies in 1966 that diuron (Karmex), used at the beginning of the growing season, would prevent the growth of filamentous algae and higher plants without preventing the growth of plankton. Diuron was added at the rate of one pound per surface acre to each pond at the time they were filled.

Each pond was innoculated with bottom muds from two lakes and one pond.

Soil samples were taken from each pond prior to filling with water and phosphorus and potassium contents were determined.

Those ponds which were treated with inorganic fertilizers received an initial treatment of 6-24-24 at the rate of 150 pounds per acre. Subsequently, these ponds were treated with triple super phosphate at times when the plankton density began to decrease. On the average, fertilizer was added once a month.

Stratified random bottom samples were taken from each pond every two weeks from May 1 through October 15, 1967. The samples were

1 Pond 12 was set up and treated on August 1, 1967.

taken with a 6 by 6 inch Ekman dredge and formalin was added to each sample immediately. The organisms were partially separated from the detritus in the samples by sieving and by flotation. Later, the organisms were individually picked out of the remaining detritus and preserved in 70% alcohol.

Plankton densities were determined by the use of a Sedgwick-Rafter counting cell as described by Welch (1948).

RESULTS

The diuron was effective in controlling plant growth other than phytoplankton. One exception was in pond 11 where the aquatic sedge, *Eleocharis acicularis*, grew to the extent that it covered the bottom of the pond.

Ponds 3 and 4, which contained corn cobs, underwent severe changes due to the decay of the cobs. Initial decay of the fresh organic material was expected, but the massive decay period lasted approximately 4 months. The ponds were void of oxygen and had a high level of hydrogen sulfide. The plankton and benthos populations were reduced to zero in some samples and to very low densities in others (Tables 1 and 2). Although the ponds recovered from the massive decay during the last two months of the experiment, as revealed by measurable oxygen, plankton, and benthos densities, the data from these ponds did not seem meaningful when compared to the data from the other ponds.

An interesting observation of the initial plankton populations in ponds 3 and 4 was that dense populations of large zooplankters developed without any prior development of phytoplankters. The zooplankters were mostly large Copepoda and Cladocera.

Pond 6, containing inorganic fertilizer, was turbid with clay during most of the study period and this pond exhibited lower plankton and benthos densities than did pond 5. Apparently the clay turbidity was caused by the presence of crayfish.

The plankton density averaged higher in the fertilized ponds and in the ponds containing organic matter than it did in the control ponds (Table 1). Plankton densities in all ponds were low compared to those obtained by Ball (1949).

All the ponds containing sewage sludge had higher benthos densities than did either the controls or the fertilized ponds (Table 2). The fertilized ponds had higher benthos densities than did the control ponds with the exception of the turbid pond 6.

At the time that relatively few organisms were being found in the central, flat bottom of the ponds containing cobs, incidental sampling at the edges of the ponds in August revealed an abundance of chironomids. The chironomid species were *Chironomus fulvipilus* Rempel, *C. attenuatus* Walker, and *Procladius* sp., as determined by J. B. Stahl.

Chaoborus sp. were much smaller than any of the other organisms and occurred sporadically in such large numbers that they appeared to have an undue influence upon the results. Removal of the number of *Chaoborus* from the results revealed a closer approximation of biomass. Table 2 shows totals and averages with and without *Chaoborus*. Large numbers of *Chaoborus* occurred primarily in the ponds containing organic matter.

Of the variety of benthic organisms present in the ponds, the oligochaetes were by far the most abundant, and this group tended to increase more than any other group when fertilizer or organic matter was added to a pond (Figure 1). After the oligochaetes, the groups of benthic organisms in order of abundance were Chironomidae, Chaoborus, Ceratopogonidae, and Ephemerotpera. A total of nine different groups of benthos was present in the ponds.

TABLE 1. Plankton densities in ponds containing various additives. Density (in hundreds) expressed as number of plankters per liter of water

Sample date (1967)	Pond number and additive										
	Control			Corn cobs		Inorganic fertilizer			Sewage sludge		
	1	2	9	3	4	5	6	10	7	11	12
5 May	27	27	....	27	133	53	53	....	27	....	...
25 May	53	187	480	107	107	187	454	133	240	107	...
10 June	133	133	214	27	0	187	214	80	854	320	...
20 June	53	80	160	53	27	160	240	427	294	1360	...
29 June	614	320	160	0	....	160	427	292	374	347	...
14 July	160	240	187	27	80	5576	480	454	667	507	...
29 July	212	427	292	934	27	1092	614	1334	1949	80	...
14 Aug.	133	480	53	427	53	614	720	240	373	80	...
25 Aug.	240	400	80	320	80	240	534	213	347	107	160
14 Sept.	133	374	80	746	320	214	427	80	800	454	107
1 Oct.	53	107	13	694	214	53	187	80	214	16	80
13 Oct.	53	214	....	267	214	107	13	....	294	....	85
Total	1866	2988	1799	3628	1254	8642	4363	3333	6462	3377	432
Mean	156	249	180	302	114	720	364	333	539	338	108

TABLE 2. Density of benthic organisms in ponds containing various additives. Density expressed as number of organisms per square meter of pond bottom

Sample date (1967)	Control			Corn cobs		Inorganic fertilizer			Control[1]	Sewage sludge		
	1	2	9	3	4	5	6	10	7b	7a	11	12
5 May	71	57	245	29	29	288	259	4105	.....	2938	1512	.....
25 May	288	188	332	43	202	2203	274	1555	4910	3356	821	.....
10 June	144	43	1123	0	0	648	274	590	5140	4780	1123	.....
20 June	316	172	533	101	43	432	187	460	6019	6307	1037	.....
29 June	345	86	633	129	....	130	331	662	4262	6034	1209	.....
14 July	302	432	1210	158	29	402	201	461	5385	5889	1210	.....
29 July	229	316	879	57	14	489	1396	1008	12369	5069	1556	.....
14 Aug.	274	432	274	71	43	562	115	158	5807	4768	1903	1108
25 Aug.	202	360	259	14	57	418	116	431	7820	8409	923	2851
14 Sept.	258	258	245	72	129	304	144	906	7028	8151	1786	7819
1 Oct.	172	288	72	2232	2578	288	86	519	6455	7127	3196	3211
13 Oct.	303	230	....	2779	6897	388	244	.....	7172	7804	.....	4493
Grand total	2890	2862	5805	5685	10021	6552	3627	10855	72377	66598	12276	19482
Mean	241	239	528	474	911	546	302	987	6580	5550	1480	3896
Grand total less *Chaoborus*	2790	2415	5330	935	662	5845	2159	10711	62139	65015	10289	5285
Mean	233	202	485	78	60	487	180	974	5649	5418	935	1057

Column header spanning all pond columns: Pond number and additive.

[1] That portion of the bottom of pond 7 not covered with sludge.

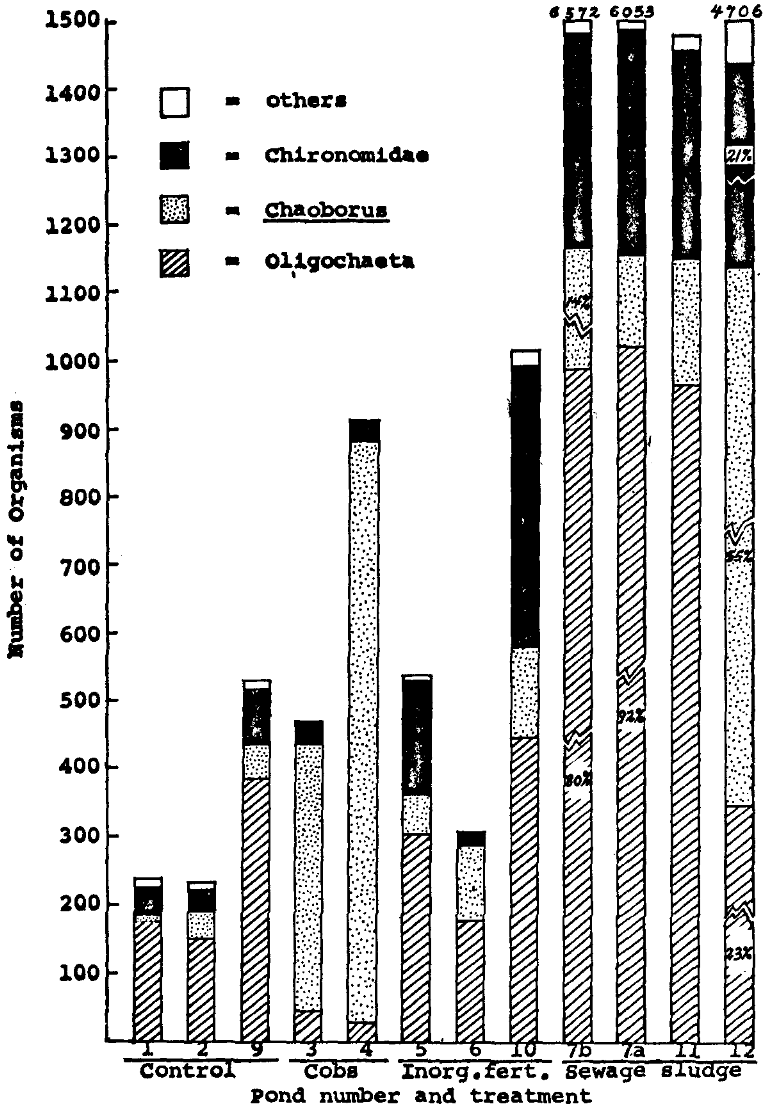

Figure 1. Comparison of densities of benthos, by taxonomic groups, in ponds containing various additives.

DISCUSSION

Burgess (1965) was of the opinion that the physical hardness of the pond bottom was the most important factor limiting benthos production as fertility increased. Soft bottom muds commonly contain organic matter (Burgess 1965). Conversely, firm clay bottoms generally have very little organic matter, therefore, a lack of benthos on firm bottoms could be due to either the physical hardness or the lack of organic matter.

In the two sampling areas in pond 7, 7a had the consistency of the bottom changed by covering the bottom with sewage sludge whereas 7b remained a clay bottom with no additive. There was essentially no difference in the density of benthos in the two areas (Table 2).

In pond 12, the relatively small amount of sludge (0.5 cubic yard) was scattered lightly over the pond bottom with the intention of not adding enough to alter the consistency of the pond bottom. The results showed a definite increase in benthos in pond 12 when compared to the control and fertilized ponds. The results in pond 12 indicate further that the organic matter *per se* plus whatever nutrients were present were responsible for the increase in benthos as opposed to a changed physical consistency of the bottom.

Ball (1949), and McIntire and Bond (1962) concluded that fertiilzation increased benthos. It should be noted that Ball applied barnyard manure at the rate of 1400 pounds per acre at the beginning of his experiment and subsequently used inorganic fertilizers. In both of these studies, filamentous algae were not controlled, and there was a dense growth of algae in various ponds. The present study involved only inorganic fertilizer, and filamentous algae were controlled. The results showed a definite increase in benthos associated with the addition of fertilizers when no higher plants or filamentous algae were present. The control of vegetation other than phytoplankton was considered important because it gave a clearer indication of the direct association among inorganic fertilizers, plankton, and benthos.

An increase in benthos density is not necessarily associated with a similar increase in plankton density. In ponds 7 and 12, both containing sludge, the benthos increase was relatively much greater than the plankton increase. These ponds indicate that production of benthos may have come as a direct result of food provided either directly or indirectly from the organic material in the sludge instead of from a simple food chain beginning with inorganic nutrients and going through plankton. That benthic organisms can live by feeding upon decaying material has been demonstrated in the laboratory. Chironomids, with only bits of dead leaves or yeast as the ultimate source of food, are commonly reared through several generations in the laboratory. Burgess (1965) stated that fragments of vegetation in the early stages of decay supported approximately one-third more organisms than the living plants.

Lellak (1965) offered evidence that when the organic matter of muds in natural lakes was determined quantitatively by measuring organic nitrogen and carbon, no positive correlation existed between the amount of organic material in the mud and standing crops of benthos. In the same article, Lellak later stated that apparently an increase in fish excrement on the bottom of fenced areas increased benthos. Those seemingly paradoxical conclusions by the same author may indicate that organic matter is important, but that there are different qualities of organic matter and some kinds may increase benthos more than others. Lellak also concluded that benthos, especially chironomids, were dependent upon a continuous supply of fresh food descending from the water column. Chironomids utilize planktonic algae directly (Provost and Branch, 1959) and oligochaetes and chironomids utilize detritus (Harp and Campbell, 1964).

As fresh organic matter decays, the density of benthos increases (Harp and Campbell, 1964; Burgess, 1965). Decaying organic matter releases inorganic nutrients and the nutrients in turn may increase plankton. Furthermore, decaying organic matter is a direct source of food for some organisms. The question is posed as to which of these two pathways is responsible for the increase of benthos when organic matter decays. Results of the present study indicate that a combination of plankton in the water column and organic detritus on the bottom both contribute to the production of benthos. Apparently, benthic organisms may subsist at the end of a food chain from inorganic nutrients to plankton to benthos, or they may subsist in a detritus food web consisting of decomposing organic matter, bacteria, fungi and protozoans.

Inorganic fertilizers are sometimes added to ponds without an increase in productivity or the amount of increase is less than would be expected. An answer to this puzzling lack of increase in productivity may be in the relationship between organic matter and inorganic phosphorus. Published information in the fields of agriculture and microbiology provide a postulate as to how organic matter may affect the fertility of water, and the factors are discussed below.

Iron, aluminum, and magnesium are the elements that most commonly combine with the phosphate to render it insoluble and unavailable to plants for primary productivity (Dalton, *et al.*, 1952; Himes and Barber, 1957; Khanna and Stevenson, 1962). Easily decomposed forms of organic matter, such as glucose and sucrose, added to soil increase phosphorus uptake and growth by plants. Oxidation of organic materials by microorganisms produces a series of organic acids such as tartaric, oxalic, citric, etc. (Taylor, 1949). These organic acids are known to chelate iron, aluminum, magnesium, and other multivalent cations. The chelation may result in either (1) freeing of insoluble phosphorus already present, or (2) preventing added soluble phosphorus from combining with the multivalent cations (Hayes and Phillips, 1958). This described relationship between phosphorus and organic matter could very well explain how the addition of only organic matter could increase productivity in a pond in a manner other than by the organic matter serving directly as food.

Pennak (1955) offered evidence indicating that zooplankters feed upon products of organic decay (tripton), but Davis (1958) refuted Pennak's conclusion and stated that zooplankters feed upon phytoplankton as in the classic food chain. The early development of zooplankton populations in the ponds containing cobs indicates that zooplankters may live on tripton or associated decomposers. At least on a temporary basis, phytoplankton is not prerequisite for the development of some zooplankton populations if certain organic materials are available.

The analysis of bottom soils as a part of a controlled pond experiment is not frequently performed, but its results may be an important indicator of the similarity or difference between ponds. In the control ponds 1, 2, and 9, there were differences in the densities of plankton and benthos. Pond 9 had the highest available phosphorus in the soil and produced the highest density of benthos. Pond 2 had the second highest available phosphorus in the soil and produced the highest density of plankton. Pond 9 had been fertilized the previous three years and pond 2 had been fertilized one year prior to the present experiment.

One weakness of the present study was the use of too large quantities of ground corn cobs. The objective was to alter the consistency of the pond bottom, but the decay was too massive and prolonged.

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