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REARING TROUT IN RACEWAYS SUPPLIED BY WATER FROM THE HYPOLIMNION OF A STRIP-MINE POND

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NUMEROUS PONDS, ranging in size from a fraction of an acre to 15 or more acres, are formed during the surface mining of coal (figure 1). These bodies of water exhibit several unique physical features. Typically, they are deep in relation to their surface area, steep-sided, and often protected from prevailing winds by high spoil banks. These conditions contribute to seasonal thermal stratification that is unusually well defined and quite stable during the period of summer stagnation.

The last ponds formed in the stripping operation usually produce the largest and most accessible bodies of water. They are also most apt to be next to flat, undisturbed land that is suitable for pond or raceway construction. Thus, this type of pond is usually of most value for the purpose proposed here.

In the use of strip-mine ponds as proposed here, water would be pumped from the ponds continuously in considerable quantities; therefore, the sustained production characteristics of the ponds are of interest. Typically, one or more of the final cuts (ponds) of a stripped area overflow into a natural drainage. This overflow probably represents internal drainage of the precipitation over the stripped area; that is, it is questionable that this water represents spring water except to the extent that it travels underground from pond to pond. Strip-mine ponds would probably receive some spring water if they were pumped down, but under normal water-level conditions the many ponds of a stripped area probably function as a single large reservoir. The

FIGURE 1.--Aerial view of strip-mine area near DeSoto, Jackson County, Illinois.

TABLE 1.--The chemical characteristics of a 15-acre strip-mine pond located in Jackson County, Illinois, near the town of Desoto

Chemical characteristics[1/]	Sampling depth[2/] 5 feet	15 feet	20 feet	30 feet
Conductivity--------------micromhos per centimeter[3/]--	3,090	3,400	3,520	3,640
Mg-------------milligrams per liter--	236	243	228	238
Ca----------------------------do.----	432	480	516	532
Total hardness-----degrees hardness--	205	220	223	231
Chlorides------milligrams per liter--	17.7	16.5	17.7	17.7
PO_4--------------------------do.----	.001	.001	.001	.001
Mn----------------------------do.----	.003	.05	5.75	6.50
Fe----------------------------do.----	.0	.0	.07	.80
NH_3---------------------------do.----	.003	.003	1.7	2.0
SiO_2--------------------------do.----	2.25	5.0	5.5	6.0

[1/]Analyses made July 28, 1962.

[2/]At the location in the lake when these samples were taken and at the season taken, the 5-, 15-, 20-, and 30-foot depths represented the epilimnion, thermocline, upper hypolimnion, and lower hypolimnion, respectively.

[3/]At 25° C.

situation is such that it is difficult to estimate how much water could be removed from a large strip-mine pond without exceeding the supply. In many ponds there is probably enough to supply a fish rearing unit of practical size. In the present study the water was permitted to flow back into the pond after being used; however, it is questionable that this would be desirable as a permanent arrangement.

Chemical and Physical Characteristics of the Water Supply

As a result of the exposure of great quantities of unweathered rock and minerals in the spoils surrounding and in the basin of strip-mine ponds, these waters are characterized by unusual chemical conditions.

Consideration of the chemical characteristics of the pond used in the present study (table 1) points up this situation. The conductivity of the water was very high as compared to that of typical farm ponds of the southern Illinois region. The water of the strip-mine pond was hard, owing primarily to sulfates. Chlorides, although above normal, were not high enough to be of any known importance to fish. Phosphates were very limited. Manganese was extremely high in the hypolimnion. Iron was fairly high in the lower hypolimnion; but, of course, the water can be taken from the upper hypolimnion to avoid any problem the iron might produce. Ammonia was high in the hypolimnion, probably because of organic decay. The pH of the water 5 feet below the surface showed seasonal variation of 7.3 to 8.3. The higher values occurred during the warmer months. In the thermocline, at 15 feet of depth, the values showed a seasonal variation from 6.9 to 7.9, with the higher values occurring in the colder months. In the hypolimnion, at 26 feet, the pH was 6.7 to 6.9 during the warm months and 7.1 to 7.6 in the colder months. The lower pH values in the deeper water were due to the high carbon dioxide concentrations. In the spring the methyl orange alkalinity at all levels ranged from 311 to 361. After thermal stratification became established, the methyl orange alkalinity of the epilimnion dropped to a low of 107 and that of the lower hypolimnion rose to a high of 424. After the fall overturn, the values ranged from 220 to 245 at all depths. Thermal stratification was evident by the last of April and continued until the third week of September (table 2). The thermocline was established between 10 and 20 feet of depth. Dissolved oxygen disappeared from the hypolimnion soon after establishment of thermal stratification (table 2). During most of the period of summer stagnation the free carbon dioxide of the hypolimnion was above 30 p.p.m., which is regarded as the safe threshold for fish (table 2). The erratic values for free carbon dioxide at the March 20 sampling (table 2) were associated with both the spring overturn of the pond and the occurrence of heavy rainfall. An increase in free carbon dioxide appeared to be associated with heavy rainfall. It is speculated that acid drainage and seepage may have reacted with carbonates to produce the free carbon dioxide.

Table 3 shows a comparison of the chemical characteristics of water from the pond used for the present study and water from similar ponds in two other strip-mined areas in southern Illinois. The point of greatest difference for these three ponds appeared in the dissolved oxygen and

TABLE 2.--Some physical and chemical variables of a strip-mine pond used as a water supply for rearing rainbow trout

Date	Sampling depth, in feet						
	0	5	10	15	20	25	30
				Temperature, ° F.			
1962							
Feb. 24	41	41	41	40	40	40	40
Mar. 20	44	44	44	44	44	43	43
Mar. 29	52	52	52	50	49	48	48
Apr. 5	51	51	51	49	48	48	47
Apr. 26	67	67	63	58	54	53	53
May 31	78	77	77	58	58	58	56
June 26	82	81	79	60	55	54	53
July 23	84	84	84	66	55	54	53
Aug. 23	85	85	84	77	60	55	53
Sept. 19	74	74	74	73	64	56	56
Oct. 26	60	60	59	59	59	58	52
Dec. 5	45	46	46	46	46	46	46
1963							
Jan. 8	35	35	35	35	37	37	37
				Dissolved oxygen, p.p.m.			
1962							
Feb. 24	9.2	9.6	----	9.6	9.2	10.0	8.8
Mar. 20	9.4	14.0	8.2	10.2	14.0	7.6	8.0
Apr. 5	9.9	9.5	8.6	5.5	3.7	2.4	2.0
Apr. 26	9.8	10.0	9.8	10.2	8.8	5.2	4.2
May 31	8.4	8.1	8.4	11.6	5.4	1.3	1.2
June 26	9.2	9.2	9.2	7.2	3.0	.0	.0
July 23	9.0	8.9	9.2	5.9	.2	.0	.0
July 26	----	9.7	----	6.6	1.0	-----	.0
Aug. 23	8.4	9.4	11.0	17.6	.5	.0	.0
Sept. 19	9.4	9.4	9.3	9.2	.3	.0	.0
Oct. 26	9.7	9.4	9.2	9.4	9.4	6.6	.0
Dec. 5	11.0	----	----	10.8	----	-----	10.8
1963							
Jan. 8	14.0	13.4	14.4	12.8	13.8	13.6	12.2
				Free carbon dioxide, p.p.m.			
1962							
Feb. 24	4	4	3	3	5	3	13
Mar. 20	27	16	19	20	18	15	20
Mar. 29	4	4	3	5	19	13	12
Apr. 5	2	2	4	7	16	27	29
Apr. 26	0	1	3	8	13	38	38
May 31	0	0	0	30	48	79	90
June 26	0	0	0	26	50	100	95
July 23	0	0	0	35	75	90	99
July 26	0	0	0	50	93	-----	112
Aug. 23	0	0	0	18	80	105	110
Sept. 19	0	0	0	0	54	96	113
Oct. 26	6	6	7	8	8	17	105
Dec. 5	4	----	----	3	----	-----	3
1963							
Jan. 8	0	0	0	0	0	1.0	2

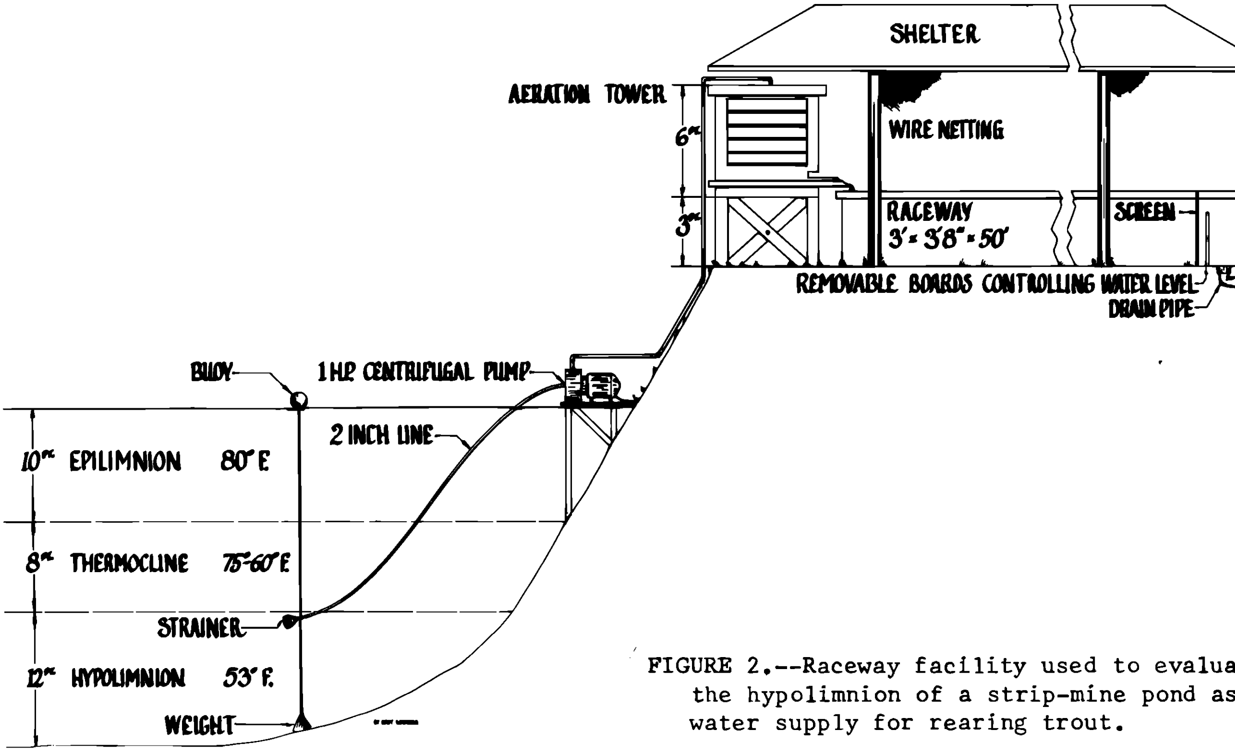

FIGURE 2.--Raceway facility used to evaluate the hypolimnion of a strip-mine pond as a water supply for rearing trout.

carbon dioxide of the hypolimnion. The hypolimnion of the pond representing the DuQuoin area had a dissolved oxygen content of 9 to 11.4 p.p.m. and a low carbon dioxide content. In fact, this pond seemed to be truly oligotrophic and apparently would support fish in the hypolimnion.

Physical Facilities

Trout were held in two above-ground concrete raceways (figure 2), each 50 feet long and 3.7 feet wide with a water depth of 18 inches. Water was supplied to the raceways by a 1-horsepower centrifugal pump with an intake at a depth of 17 feet in the spring and 20 feet in the summer. Before the water was turned into the raceways, it was sprayed into an aerating tower to reduce the carbon dioxide and increase dissolved oxygen content. Water flowed from the aerating towers directly into the raceways. Approximately 25 gallons per minute flowed into each raceway. In preliminary work, mechanical agitators were tried but did not satisfactorily remove the excess carbon dioxide.

Results

Temperature conditions in the raceways were satisfactory during the spring, summer, and fall. During the latter part of March and throughout April the temperature of the water at the inlet ranged from 44° to 55° F. It ranged from 54° to 59° during May and June and thereafter from 57° to 64° F. During midsummer, as a result of going through the aerating tower, the temperature of the water increased by 0 to 2°. An additional increase of 0 to 2° occurred between the inlet and outlet of the raceway.

The study was not continued through the winter. It is doubtful that the raceways could be operated in winter, because even the water of the hypolimnion may drop to 33° F. On January 31, 1963, after an extended period in which the air temperature was between 10° and 30° F. during the day and as low as 18° below zero at night, the temperature of the hypolimnion was 33° F. Trout were satisfactorily overwintered in a 1/3-acre pond with a water depth of 4 feet. The pond was filled and

TABLE 3.--Comparison of the physical and chemical characteristics of strip pits of three different stripped areas in southern Illinois

	Desoto area Jackson County Sept. 19, 1962			Pyatt area Perry County Sept. 11, 1962			DuQuoin area Perry County Sept. 21, 1962		
Area, acres:		15			6.3			60+	
Maximum depth, feet:		40			30			49	
Sample depth, feet:	0	20	30	0	20	28	0	23	30
Temperature---° F.--	74	64	56	79	69	60	73	61	50
pH------------------	7.9	6.9	6.7	7.5	6.8	6.8	7.7	7.5	7.5
D.O.---------p.p.m.--	9.4	.3	.0	8.4	5.6	.2	8.9	9.0	11.4
CO_2-----------do.---	0	54	113	2	50	127	0	6.5	8.5
M.O. alkalinity-----	134	319	410	110	236	400	190	203	223
Ca^{++}----------------	-----	-----	-----	372	372	500	424	489	503
Mg^{++}----------------	-----	-----	-----	90	100	158	279	304	294
Total hardness------	-----	-----	-----	130	134	190	220	246	245

the water level maintained with strip-mine water pumped from the same pond that supplied the raceways.

The aerating towers (figure 2) were very effective in removing carbon dioxide and increasing the dissolved oxygen of the water supply. Water entering the tower contained free carbon dioxide concentrations as high as 103 p.p.m.; values of 50 to 60 p.p.m. were typical for June and July, and values of 80 to 90 p.p.m. for August to October. After the water had gone through the towers, carbon dioxide concentrations were reduced to 4 to 17 p.p.m. during June and July, and to 6 to 20 p.p.m. during August to October. The dissolved oxygen concentration of water entering the tower was 0.2 to 5.4 p.p.m. during June and July, 0.3 to 0.5 p.p.m. during August to October. At the head of the raceway, after the water had passed through the tower, the concentration was from 7 to 9 p.p.m. during June and July, and from 4 to 10 p.p.m. during August through October. The minimum (4 p.p.m.) occurred only once in one raceway when the water supply was reduced.

The minimum pH recorded in the raceways was 7.3 and the maximum 7.9, but the most typical value was 7.5.

Of the 959 trout placed in the raceways in March 1962, 26 died by October 1. Except for four that died soon after the fish were stocked, mortality was evenly spread over the 6-month period. An accidental shut-down of the water supply on October 8 resulted in a known loss of 27 fish and an additional loss of an undetermined number at the overflow. When the fish were harvested, there remained 818 fish.

The fish were fed twice daily at a rate of approximately 3 percent of body weight. The feeding of 750 pounds of Purina Trout Chow and 60 pounds of liver resulted in a gain of 461 pounds (based on only the fish actually harvested). The overall food conversion was 1.8. The average weight of the fish at time of harvest was 258 grams.

Discussion

Strip-mine ponds do not constitute a very important potential as waters to be managed for fishing. Water areas are very limited, accessibility is often a problem, and physical features of the ponds make it difficult to use conventional pond-management techniques. However, some of the features that make these ponds unattractive for use in producing recreational fishing result in their being more suited to use as a water supply for fish culture or fish-farming interests. With the increasing interest in producing bait species, fingerling channel catfish, and other fishes, there is a growing demand for water suitable for hatchery and rearing units. Water for such work should be inexpensive and available in considerable quantity; at least some of it should be cold; and, of course, it should be demonstrated to be chemically suited for fishes.

As some strip-mine ponds in southern Illinois meet these requirements better than any other available water supply, it seemed desirable to investigate this potential of the ponds. Trout were used as the experimental fish because it was felt that results could be better evaluated in raceways than in ponds and the rearing of trout is better standardized. The study showed that strip-mine ponds constitute a satisfactory supply of cool water that can be made suitable for fish by tower aeration.

We believe that the potential of these ponds as a water supply for hatchery and rearing units should receive attention, possibly in preference to management for fishing.

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ADDENDUM

Attention is called to the weakness of any system dependent on electrical power. The accidental shut-off of the water supply in the present study emphasizes this point. However, supplementary power, warning systems, and a gravity-feed storage reservoir are all satisfactory safeguards.

ESTIMATION OF THE NUMBER OF EGGS IN NINE FEMALES OF THE "BOCACHICO," A COLOMBIAN CHARACINID

During a recent study of the biology and migrations of the San Jorge River "Bocachico" (Prochilodus reticulatus magdalenae), I estimated the number of eggs in the ovaries of nine females approaching maturity. I used a slight modification of Lagler's volumetric method ("Freshwater Fishery Biology," W. C. Brown and Co., Dubuque, Iowa, 421 pages, 1959).

After counting the eggs in a sample that displaced a known volume of water, I measured the water displaced by the whole ovary and then estimated the total number of eggs by using the formula

$$X:n=V:v,$$

where X is the unknown total number of eggs in the ovary, n the number of eggs displacing 1 cc. of water, V the total volume of water displaced by the ovary (including the 1 cc. displaced by the sample), and v the 1 cc. displaced by the sample. After measuring their displacement, I put the eggs into boiling water for 1 minute to facilitate their separation for counting.

Data on eggs estimated in nine female "Bocachico"

Standard length (cm.)	Total weight (gm.)	Ovarian weight (mg.)	Number
29.7	450	71,500	149,890
29.8	450	76,500	147,700
--------	------	-------	106,952
32.7	675	92,950	94,300
25.0	230	49,400	80,852
28.5	450	36,500	70,590
24.5	------	--------	61,500
33.0	560	27,550	51,075
19.7	110	-------	31,605

The numbers obtained appear in the accompanying table.

In all nine females, the eggs were nearly ripe.

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