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FISH POPULATIONS IN FIVE POLLUTED STREAMS OF SOUTHERN MICHIGAN[1]

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Biologists of the Institute for Fisheries Research sampled the fish populations in five polluted streams in the summer of 1963 at the request of the Water Resources Commission (WRC) who allocated $6,600 to help defray the expense. The WRC needed information on the fish fauna to supplement other information previously obtained by their investigators.

The following streams were selected by the Commission's technical staff:

1. Chippewa River, which originates from various sources in Clare, Osceola, and Mecosta counties, traverses the full breadth of Isabella County, and joins the Pine River about 2 miles west of Midland in Midland County.
2. Pine River, which rises on the east side of Montcalm County, flows across the northwest quadrant of Gratiot County, and enters the Tittabawassee River at Midland.

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[1] A contribution from Dingell-Johnson Project F-27-R, Michigan.

3. Cedar Creek, which begins about 3 miles east of Cedar Springs in north-central Kent County, and flows into the Rogue River about 10 miles southwest of Cedar Springs.
4. Rogue River, whose sources lie at the south edge of Newaygo County and in northwest Kent County, and which joins the Grand River in central Kent County.
5. White Pigeon River, which flows northward out of Indiana, thence across the southwest corner of St. Joseph County, and joins the St. Joseph River just above the Indiana border.

Methods

The collecting was done by three men with electrofishing gear powered by a 230-volt d-c generator.[2] The procedures generally employed in Michigan for sampling sizable streams with electric shockers were used in these surveys. While wading upstream, two men probed the stream from bank to bank with two electrodes. A third man pulled a boat carrying the generator and a tub of water for holding the catch. All the larger sized fish were identified, measured, weighed, and returned to the stream alive. Small specimens were preserved in 10% formalin for subsequent identification and measurements.

To permit valid comparisons of the populations between streams, and among stations in each stream, the catches are

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[2] E. E. Schultz, the crew leader, and B. R. Miller participated in all the surveys. F. Kent, P. W. Laarman, and J. C. Schneider assisted at various times.

expressed as numbers of fish caught per hour of collecting effort and as pounds per surface acre of water. Because only a portion of the total population in each sampling area was captured, the catch figures represent indices of fish abundance only, rather than actual abundance. However, the objective was to collect as many fish as possible and, because conditions for collecting were generally good, the data should provide a reasonably good comparison of fish population size in these streams. These catch data are especially useful for drawing comparisons between populations in the polluted and unpolluted areas. As a further aid, the fish were grouped into three categories (game, coarse, and forage) to afford evaluation of the effects of pollution on each category.

First, the streams will be considered individually, with comments on sources of pollution, the fish they contain, records of mortalities, and finally the results of the survey. The figures given for distances between points on the streams were determined from county maps with a map measurer; probably in most instances they are somewhat shorter than the actual distances because not all the irregularities of the courses appear on these maps.

Chippewa River

The Chippewa River becomes polluted when it reaches Mt. Pleasant. A plating industry has been an important source of contamination. The municipal sewage disposal plant, built in 1958 to provide primary treatment, also discharges its effluent into the stream.[3]

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[3] Letter from J. G. Robinson (Water Resources Commission) to C. M. Taube, March 24, 1966.

Fish mortalities that have occurred within and below Mt. Pleasant were investigated in September 1948 [11], October 1952 [12], June 1953 [13], and October 1957 [5, 15, 16]; symptoms of fish distress were checked in September 1955 [14]. In each case the cause of the trouble evidently was cyanide that entered the stream from the plating plant. From sampling done for bottom fauna after the fish kill in 1957, it was discovered that there were fewer numbers of the more important invertebrates where the river was polluted than where it was uncontaminated [5].

General creel census records for the Chippewa River show that anglers have caught trout, smallmouth bass, rock bass, crappies, and suckers. Trout have been planted annually at several locations above Mt. Pleasant. Introductions in 1962 amounted to 1, 200 legal-size brown trout and 1, 000 legal rainbow trout in Sherman Township, Isabella County, and 1, 500 legal rainbows in the North Branch, Fork Township, Mecosta County. Releases in 1963 consisted of 2, 000 legal rainbow trout at the first location, and 1, 500 at the latter. These stocked areas were not sampled in 1963, but two collections were taken with a d-c shocker in Sherman Township in 1964. One thousand feet of stream above the Rolland Road bridge was sampled on July 12, 1964. Ten brown trout (6-13 inches), 8 rainbow trout (7-9 inches), sunfish, rock bass, and 10 other kinds of fish were captured. The other collection was taken on August 12 between the Rolland Road and Drew Road bridges, a distance of about 1/2 mile. The catch consisted of 69 brown trout (6-15 inches), 34 rainbow trout (6-12 inches), smallmouth bass, bluegill and rock bass, plus 14 coarse and forage species.

The stations used in 1963 are shown in Figure 1 and described in Table 1; detailed data on the catches appear in Table 2.

Station 1 was established below the M-20 bridge, about 15 miles above Mt. Pleasant and about 10 miles below the lowermost point where trout have been planted in recent years. This water apparently was unpolluted. Game fish (mostly rock bass) comprised 18% of the total weight of the collection. Coarse fish (mainly suckers) predominated by weight, contributing 45% of the total catch, and forage fish, 37%.

Station 2 extended from 400 feet below to 700 feet above the Lincoln Road bridge, which is approximately 2 1/2 miles above Mt. Pleasant. The water was assumed to be unpolluted but it was turbid. Rainfall which preceded the sampling may have caused this turbidity. Only half as many fish were caught here as at Station 1 and they were smaller, weighing about one-third as much as the other collection. However, the numbers and weights of the game fish caught were nearly the same as at Station 1, and the total number of species was only one less. Probably the scarcity of cover accounted for the smaller sample at Station 2. By poundage, game species comprised 38% of the collection, coarse species, 49%, and forage species, 13%.

The area just below Mission Road (old US-27) was the site of Station 3. This section lies about 2 miles downstream from the plant of the Ferro Stamping and Manufacturing Corporation (where plating was done), and 1/10 of a mile below the municipal sewage plant. The smaller size of this collection reflected the effects from pollution. Only one-eighth as many fish were obtained here as at Station 1, and

one-fourth as many as at Station 2. The seven carp made up nearly 90% of the total catch, and the six rock bass were the only game fish captured.

Station 4 bracketed Shepherd Road and is about 6 1/2 miles below Station 3. Investigations conducted by the WRC in 1957 indicated that here the river had largely recovered from effects of wastes introduced at Mt. Pleasant [5, 16]. As many species of fish were found here as in the unpolluted areas, and twice as many as at Station 3. The collection was nearly as large as that from Station 2, but fewer game fish were taken. Game, coarse, and forage species respectively comprised 15%, 68%, and 17% of this collection by weight.

Instead of an expected further increase, fewer numbers of game and coarse fish were found at Station 5, about 17 miles below Mt. Pleasant. Five carp comprised two-thirds of the weight of the entire collection. Fewer game fish (7% of the total poundage) were captured than at Station 4. Excluding carp, coarse fish comprised 12% of the total weight; forage fish, 13%. Twice as many forage fish were caught here than at the preceding location, but the total weights were almost identical.

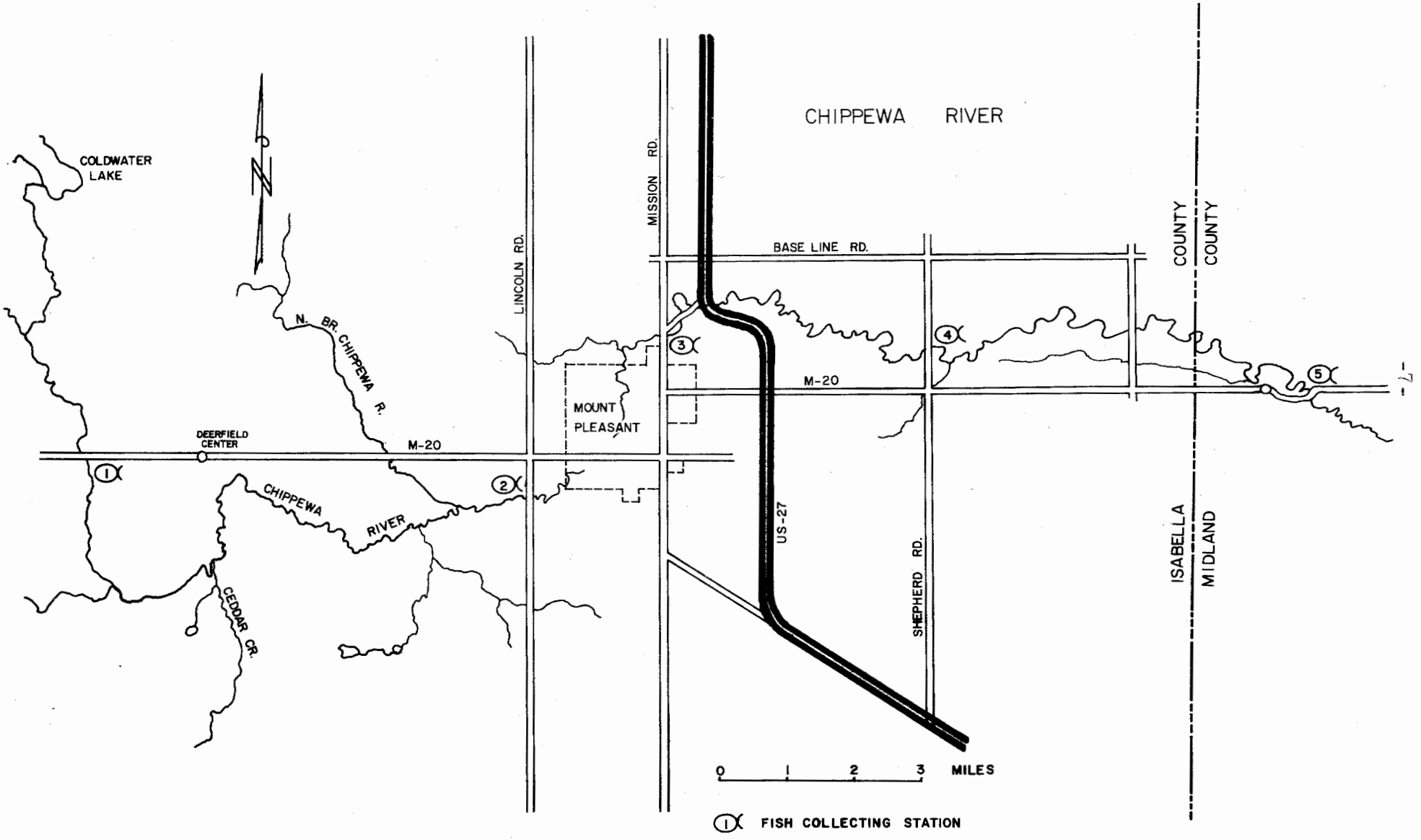

Figure 1.--The Chippewa River in Isabella and Midland counties, showing sites where fish were collected in July and August 1963.

Table 1.--Miscellaneous descriptive data for fish-collection stations on the Chippewa River, 1963

Item	Station				
	1	2	3	4	5
Location of station (Town [N] - Range [W] - Section)	14-5-20	14-4-20, 21	14-4-2	14-3-8, 9	14-2-8
Date	8-12	8-2	7-23	8-5	8-12
Sampling time, minutes	60	60	60	60	60
Length of station, feet	1,000	1,100	900	1,100	1,400
Area, acres	1.49	1.77	1.86	2.27	2.89
Mean depth, inches	7	10	8	16	10
Mean width, feet	65	70	90	90	90
Current flow	Moderate	Moderate	Moderate	Moderate	Moderate
Water clarity	Clear	Turbid	Turbid	Turbid	Turbid
Conductivity [a]	420	410	1,520	430	440
Air temperature (°F)	64	74	81	84	68
Water temperature (°F)	64	71	78	76	68
Bottom soils, estimated percentage:					
Clay	...	...	...	20	...
Silt	5	5	...	5	20
Sand	75	80	95	40	75
Gravel	20	10	5	20	5
Rubble	...	5	...	15	...
Dissolved oxygen, ppm	...	9.4	...	9.6	...
pH	...	7.8	...	7.9	...
Aquatic vegetation	Common	Sparse	Common	Common	Sparse
Fish cover	Fair	Poor	Poor	Poor	Poor

[a] Reciprocal ohms (18 C).

Table 2.--Number of fish caught per hour of shocking at five sampling stations on the Chippewa River, 1963; and the pounds per acre for three groups of fish

Species	Station				
	1	2	3	4	5
Game fish					
Northern pike	...	4	...	9	...
Smallmouth bass	5	1	...	1	3
Largemouth bass	1	1	...	...	...
Bluegill	3	...	...	4	1
Black crappie	...	...	...	2	1
Rock bass	37	37	6	17	17
Yellow perch	3	...	...	...	...
Totals	49	43	6	33	22
Pounds per acre	4.0	3.4	0.3	1.6	1.0
Coarse fish					
Golden redhorse	1	4	...	...	...
White sucker	26	11	14	71	48
Hog sucker	46	18	1	9	48
Black bullhead	...	...	...	352[a]	...
Yellow bullhead	...	...	4	24	1
Stonecat	5	11	1	1	6
Carp	...	...	7	...	5
Silver lamprey	...	...	...	1	...
Totals	78	44	27	458	103
Pounds per acre	9.9	4.2	20.3	7.2	1.8
Forage fish					
Creek chub	34	5	6	34	58
Hornyhead chub	209	31	...	14	30
River chub	88	47	...	6	85
Blacknose dace	1	...	...	3	2
Longnose dace	...	...	27	6	1
Common shiner	72	50	14	49	116
Sand shiner	...	1	...	...	65
Mimic shiner	...	...	...	...	9
Bluntnose minnow	...	5	...	68	36
Fathead minnow	3	...	...	...	...
Stoneroller	21	3	...	3	...

(continued)

Table 2.--concluded

Species	Station 1	2	3	4	5
Forage fish					
Johnny darter	20	26	1	22	10
Blackside darter	38	19	...	...	...
Rainbow darter	1	28	...	2	...
Fantail darter	3	9	...	...	...
Logperch	...	...	...	1	...
Mudminnow	...	...	1	...	...
American brook lamprey	21	30	...	...	...
Lamprey (Ichthyomyzon spp.)	7	3	...	...	...
Totals	518	257	49	208	412
Pounds per acre	8.3	1.1	0.1	1.8	1.9
Totals, all species	645	344	82	699	542
Pounds per acre, all species	22.2	8.6	20.7	10.6	15.9
Total number of species	22	21	11	22	19

[a] Included in this number were 351 recently hatched black bullheads.

Pine River

The Pine River has carried a heavy load of pollutants below the town of St. Louis. Sources of contamination include the sewage disposal plants at Alma and St. Louis, and an oil refinery and chemical plant at St. Louis. The sewage plants at St. Louis and Alma were constructed in 1955 and 1960, respectively, and provide primary treatment [letter, op. cit.]. Although fish mortalities were reported from this stream as early as 1935 [17], there is only one on record since 1953. In January 1955 about 100 dead fish were observed near M-30 [letter, op. cit.]. Rock bass, bluegills, and many small carp were found.

Staff members of WRC conducted several water quality surveys on the Pine River in which water samples from various locations were tested for evidence of contamination [3, 10]. The most significant finding from these studies was that there were large quantities of chlorides in the stream below St. Louis.

Department of Conservation personnel collected fish with an electric shocker in October 1962 at four locations on the main stream of the Pine River above Alma Pond in Gratiot County. Most of the fish obtained were coarse species, but small numbers of northern pike, yellow perch, largemouth bass, rock bass, bluegills, and green sunfish also were found. General creel census records suggest that rock bass and northern pike are the principal game species in the Gratiot County portion of the stream, and that suckers and bullheads are caught oftener than game fish.

The portion of the river investigated in 1963 is shown in Figure 2; Tables 3 and 4 present descriptive data on the fish collection stations and the catches.

Station 1 was established near the headwaters of the Pine River, about 30 miles above Alma. The water at this point was clear and unpolluted. This section of the stream was fairly productive of fish but the collection was almost entirely composed of coarse and forage species--two-thirds and one-third, respectively, by weight.

The second station was selected below the bridge on Tyler Road, about 5 miles above Alma. The water was unpolluted but turbid. A few more game fish were captured here than at Station 1, but the total catch was only half as large in number and about 60% smaller by weight. The difference in weight was due mostly to the smaller size of the coarse fish and nearly 60% fewer forage fish. By weight, the catch consisted of 15% game fish, 56% coarse fish, and 29% forage fish.

An attempt was made to collect fish within St. Louis, but the shocker shorted out when the electrodes were put into the stream, so this site was abandoned. Tests showed an excess of 6,000 ppm of chlorides at this location. Therefore the next station (No. 3) was established 2 miles downstream from St. Louis and below the bridge on McGregor Road. The conductivity of the water also was high here, as well as at the next two stations. Besides carp, only a few minnows and small bullheads were captured at Station 3, which indicated that the area was strongly contaminated.

Deleterious effects from pollution were still plainly evident at Station 4, located below the bridge on Redstone Road which is approximately 9 miles downstream from St. Louis. No game fish were obtained here either, and nearly 90% of the catch consisted of small carp.

The increased number of species collected at Station 5 (below the bridge on Gordonville Road and about 25 miles from St. Louis), indicated that conditions were more tolerable for fish here than at the two preceding stations. However, two rock bass were the only game fish taken and the total poundage was the smallest among the five stations. These facts suggest that the stream still carried some pollutants. The distribution of the catch by weight was: carp, 42%; other coarse fish, 5%; forage fish, 53%.

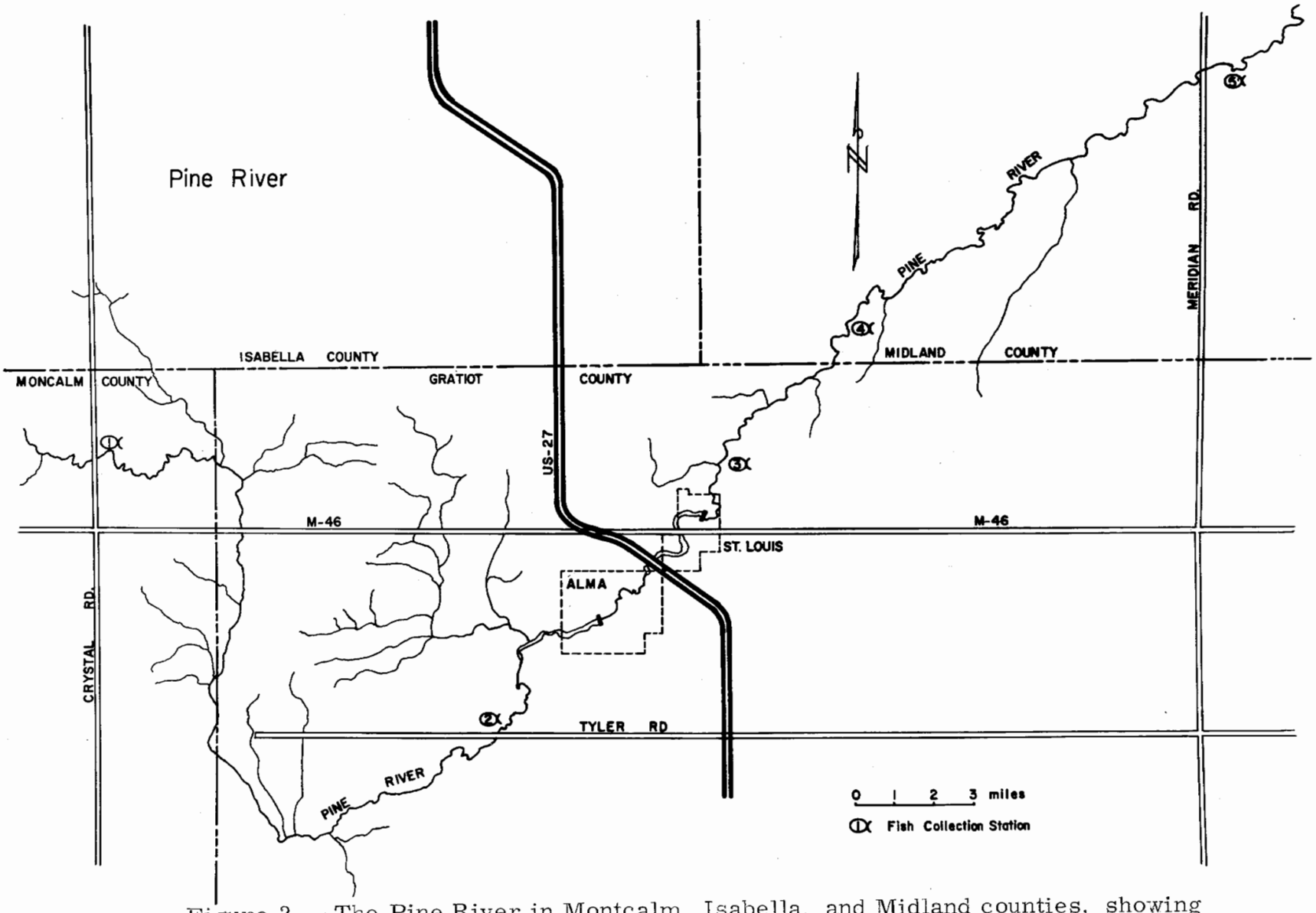

Figure 2.--The Pine River in Montcalm, Isabella and Midland counties, showing sites where fish were collected in August 1963.

Table 3.--Miscellaneous descriptive data for fish-collection stations on the Pine River, 1963

Item	Station				
	1	2	3	4	5
Location of station (Town [N] - Range-Section)	12-5W-15, 16	11-3W-18	12-2W-18	13-2W-27	13-1E-3
Date	8-13	8-6	8-6	8-7	8-8
Sampling time, minutes	60	60	30	30	30
Length of station, feet	1,100	1,100	650	700	600
Area, acres	1.77	1.90	1.27	1.61	1.38
Mean depth, inches	6	8	8	5	3
Mean width, feet	70	75	85	100	100
Current flow	Moderate	Slow	Slow	Slow	Slow
Water clarity	Clear	Turbid	Very turbid	Very turbid	Very turbid
Conductivity [a]	400	440	1,660	1,730	1,820
Air temperature (°F)	59	82	82	76	76
Water temperature (°F)	64	76	82	78	80
Bottom soils, estimated percentage:					
Clay	...	...	10	...	...
Silt	10	10	15	15	20
Sand	75	75	40	50	40
Gravel	10	10	15	15	15
Rubble	5	5	20	20	25
pH	...	7.9	8.3	8.1	7.8
Aquatic vegetation	Common	Sparse	Common	Abundant	Sparse
Fish cover	Fair	Fair	Poor	Poor	Poor

[a] Reciprocal ohms (18 C).

Table 4.--Number of fish caught per hour of shocking at five sampling stations on the Pine River, 1963; and the pounds per acre for three groups of fish

Species	Station				
	1	2	3	4	5
Game fish					
Brown trout	7	...	...	...	...
Northern pike	...	1	...	...	...
Smallmouth bass	2	2	...	...	...
Bluegill	...	1	...	...	...
Rock bass	...	11	...	...	2
Totals	9	15	...	...	2
Pounds per acre	0.3	1.3	...	...	...
Coarse fish					
Golden redhorse	...	17	...	...	4
White sucker	32	52	...	...	10
Hog sucker	97	55	...	...	...
Black bullhead	...	2	...	...	...
Yellow bullhead	...	1	22	16	...
Stonecat	48	11	...	...	4
Carp	...	1	372	904	70
Totals	177	139	394	920	88
Pounds per acre	14.0	4.9	10.6	2.3	0.9
Forage fish					
Creek chub	107	13	10	32	32
Hornyhead chub	29	13	...	...	2
River chub	28	...	...	...	...
Blacknose dace	636	...	...	...	46
Common shiner	45	160	4	24	272
Spotfin shiner	...	...	4	30	96
Sand shiner	...	...	...	...	6
Rosyface shiner	...	1	...	...	...
Bluntnose minnow	2	83	2	4	12
Fathead minnow	...	...	...	4	...
Brassy minnow	1	...	...	...	...
Stoneroller	26	...	...	8	28

(continued)

Table 4.--concluded

Species	Station				
	1	2	3	4	5
Forage fish					
Johnny darter	66	12	...	...	2
Blackside darter	13	125	...	...	...
Mudminnow	1	1	...	...	...
Brook stickleback	1	...	...	...	2
American brook lamprey	31	...	...	...	...
Lamprey (Ichthyomyzon spp.)	9	...	...	...	...
Totals	995	408	20	102	498
Pounds per acre	7.0	2.6	0.1	0.5	1.0
Totals, all species	1,181	562	414	1,022	588
Pounds per acre, all species	21.3	8.8	10.7	2.8	1.9
Total number of species	19	19	6	8	15

Cedar Creek

Cedar Creek received effluent from the municipal sewage plant on the west side of Cedar Springs. There are records in the Institute files on fish mortalities below this point for June 1955, May 1958, and June 1961. Following the catastrophe of 1955, dead trout and minnows were found for a distance of 3 miles downstream from the outlet of the sewage plant. The kill reported in May 1958 occurred in the same area and involved brook trout, white suckers, and minnows. Counts of brook trout totaled 80 fish that were 7 to 10 inches long, 200 between 4 and 7 inches, and 120 under 4 inches. The mortality in June 1961 involved mostly chubs and suckers (apparently no trout), and evidently was due to cyanide in the sewage effluent [18].

Water samples were collected from Cedar Creek in June and July 1963 for bacteriological and chemical analyses. Dissolved oxygen was rather low 1/4 mile below the outfall of the sewage plant on three dates in July [8].

General creel census records indicate that this stream provides fairly good fishing for trout. Brook trout outnumber rainbows and browns in the catches. Four hundred legal-size brook trout were released within the town of Cedar Springs in 1962, and 450 in 1963.

Station 1 was located just below White Creek Avenue, about a mile from the source of pollution (Figure 3). Although the bottom soils at this point were primarily sand and gravel, these materials

were covered by a layer of sludge (Table 5). No game fish were captured here (Table 6). Coarse fish (nearly all suckers) accounted for 87% of the catch by weight, and forage fish, 13%.

Station 2 was located immediately below the bridge on Algoma Avenue, approximately 4 miles below the sewage plant outfall. Coliform bacteria counts and BOD in water samples collected in July 1963 were much lower here than in those from the preceding station [8]. Also, more fish were caught. The rate of catch was over four times greater than that at the first station, weight was almost twice as great, and 17% (215) of the fish were trout (Table 6). Over 95% of the trout were brook trout less than 4 inches long, indicating that this species reproduces successfully in Cedar Creek. The distribution of the collection by weight was 28% trout, 44% white suckers, and 28% forage fish.

Station 3 was situated about 9 miles below the treatment plant and about 1/2 mile upstream from the junction of Cedar Creek with the Rogue River. Less than half as many fish were obtained at this location as at Station 2, but the poundages per acre were nearly equal. This collection was about 70% larger by number and nearly 50% greater by weight (on a per-acre basis) than the collection from Station 1. By poundage, the sample consisted of 10% game fish, 69% coarse fish, and 21% forage fish.

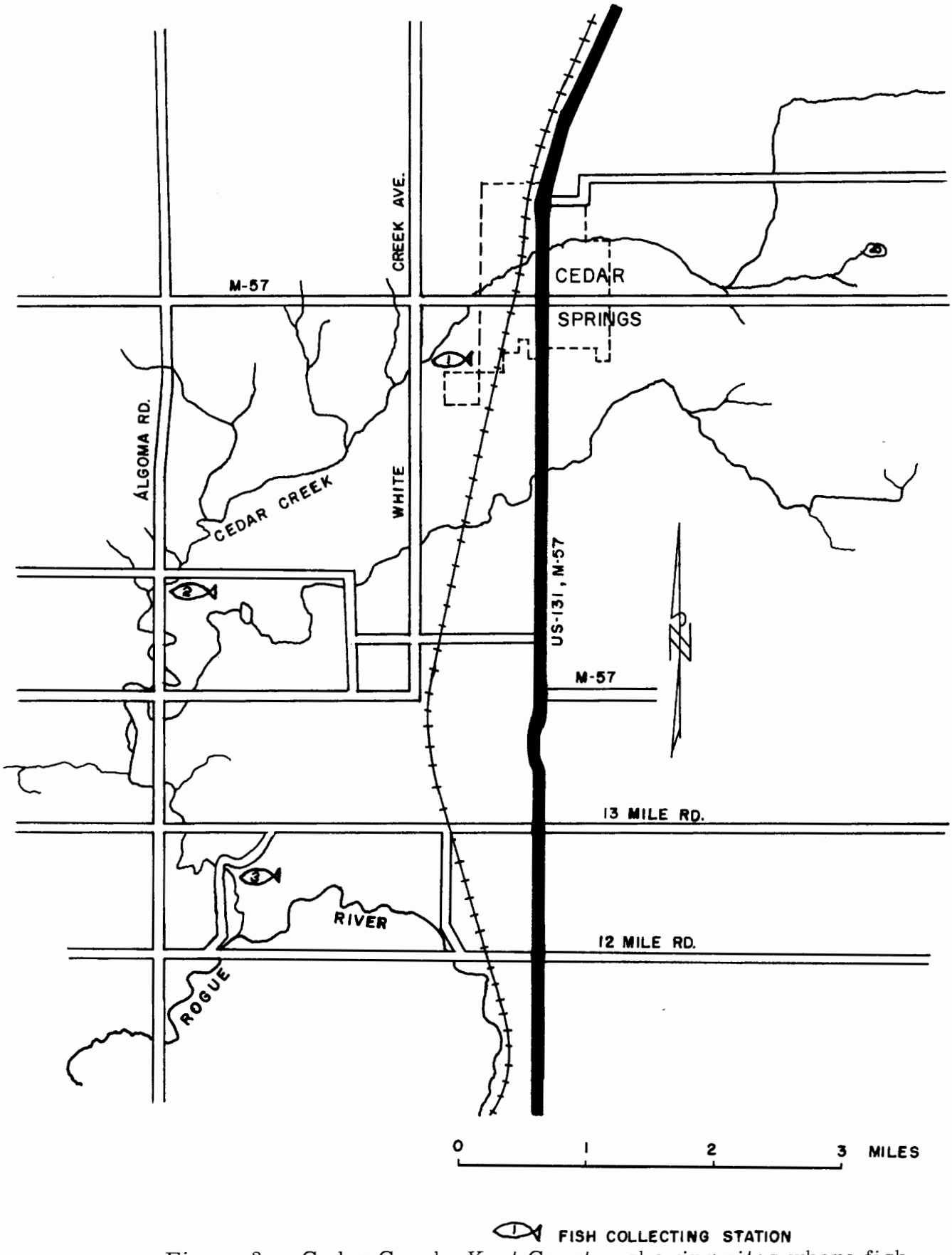

Figure 3.--Cedar Creek, Kent County, showing sites where fish were collected in August 1963.

Table 5.--Miscellaneous descriptive data for fish-collection stations on Cedar Creek, 1963

Item	Station		
	1	2	3
Location of station (Town [N] - Range [W] - Section)	10-11-35	9-11-9, 10	9-11-22
Date	8-20	8-22	8-22
Sampling time, minutes	30	30	30
Length of station, feet	400	300	350
Area, acres	0.230	0.104	0.137
Mean depth, inches	5	3	4
Mean width, feet	25	15	17
Current flow	Slow	Moderate	Moderate
Water clarity	Turbid	Clear	Clear
Conductivity [a]	460	470	440
Air temperature (°F)	73	76	75
Water temperature (°F)	67	62	63
Bottom soils, estimated percentage:			
Silt	...[b]	15	5
Sand	75	75	70
Gravel	20	10	20
Rubble	5	...	5
Aquatic vegetation	Common	Abundant	None
Fish cover	Fair	Good	Good

[a] Reciprocal ohms (18 C).

[b] Entire bottom of stream covered with sludge.

Table 6.--Numbers of fish caught per hour of shocking at three sampling stations on Cedar Creek, 1963; and the pounds per acre for three groups of fish

Species	Station 1	Station 2	Station 3
Game fish			
Brook trout	...	424	2
Brown trout	...	2	4
Rainbow trout	...	4	...
Northern pike	...	...	8
Totals	...	430	14
Pounds per acre	...	33.2	10.5
Coarse fish			
White sucker	254	512	182
Black bullhead	2	...	...
Burbot	...	...	50
Totals	256	512	232
Pounds per acre	60.1	53.1	69.6
Forage fish			
Creek chub	74	364	322
Blacknose dace	...	936	336
Redbelly dace	14	...	...
Common shiner	10	48	36
Blacknose shiner	2	...	2
Bluntnose minnow	...	...	6
Mudminnow	206	8	...
Mottled sculpin	...	56	...
Johnny darter	...	...	50
Brook stickleback	36	24	...
American brook lamprey	2	126	28
Totals	344	1,562	780
Pounds per acre	8.7	34.0	21.5
Totals, all species	600	2,504	1,026
Pounds per acre, all species	68.8	120.3	101.6
Total number of species	9	11	12

Rogue River

The communities of Sparta and Kent City, near the headwaters of the Rogue River, give their sewage secondary treatment [letter, op. cit.]. The three principal sources of pollution in the Rogue River lie below Rockford, and are the city's sewage plant, a tannery and shoe factory, and a paper mill. The wastes from these facilities receive primary treatment [1]. The combined effluents from the tannery and sewage plant empty into the stream from an enclosed sewer pipe about a quarter of a mile below Rockford; the paper mill's effluent enters about 1 3/4 miles farther downstream. [1].

Recent fish mortalities in the polluted areas were investigated in August 1958, June 1963, and June 1964. The one in 1958 apparently was limited to a 1-mile stretch of stream below Rockford, and minnows, suckers, and a few rock bass were killed [6]. The mortality in 1963 occurred below the paper mill; about 200 suckers and chubs, and one trout were found from above Packer Drive to below Rogue River Road [7]. The die-off in 1964 was observed in the paper mill pond and extended upstream as far as the Jerico Road (Oak Street) bridge. It was estimated that about 5,000 fish were involved, 98% of which were suckers and carp, but also including some pike, rock bass, and minnows [9]. The cause of each of these mortalities was oxygen depletion.

Only trout are shown on recent creel census records, and most of the catches were taken a short distance above Rockford at the beginning

of the fishing season. Since planting of trout was resumed in the Rogue River in 1954, anglers have caught a considerable number of trout, mainly browns, but also some rainbows and a few brooks. A few brown trout, crappies, channel catfish, suckers, and a fair number of pike were recorded in the census before 1954.

Data obtained in the 1963 survey appear in Tables 7 and 8. Figure 4 is a map of the stream.

Station 1 was established immediately above the 12 Mile Road bridge, about a mile upstream from Rockford. Game fish caught here were brown trout, pike, and rock bass, but most of the sample consisted of burbot. The weight of the entire collection was distributed as follows: game fish, 11%; coarse fish, 82%; forage fish, 7%.

Station 2 extended from 200 feet below the dam in Rockford to the first bridge downstream from the dam. The large population of trout found here probably was trapped between the 14-foot dam and wastes from the tannery and sewage plants which entered the river about 1/2 mile below the dam. On a per-acre basis, the poundages of coarse and forage species caught here and at Station 1 were similar. The breakdown of the collection from Station 2 was: game fish, 46%; coarse fish, 50%; forage fish, 4%.

Station 3 was located in the vicinity of the Jerico or Oak Street bridge 1/2 mile below the Rockford sewage plant outfall. The water contained much suspended flocculent material, and the river bed was covered with sludge. Aquatic vegetation was very dense. No game fish were found. White suckers comprised 94% of the weight of the entire collection.

The fourth collection site was established just above Packer Drive, which is located about 1 1/2 miles below the paper mill and 3 miles below the sewage outfall. The stream was characterized by blue-green turbidity and contained dense beds of vegetation. Some game fish were found. Although three times as many species were obtained here than at the preceding station, the total number and poundage of fish were appreciably smaller. By weight, the collection consisted of 7% game fish, 92% coarse fish, and 1% forage fish.

At Station 5 (above the Rogue River Road and about a mile downstream from Station 4) the stream was still highly colored from paper mill wastes. Virtually the same species were caught here as at the preceding station, but far fewer suckers and more game and forage fish were taken. Game fish contributed 31% of the total weight, coarse fish, 43%, and forage fish, 26%.

The last and lowermost station was established on the upstream side of West River Drive, about 4 miles below the paper mill and about 1/2 mile above the point where this stream enters the Grand River. The water was still very turbid, and cover for fish was scarce. The collection indicated, however, that appreciably less contamination was present here than at Stations 4 and 5. Of the six collections taken on the Rogue River, this one contained the most species. It ranked second in number of fish and third in poundage per acre. Its distribution by weight was game fish, 29%, coarse fish, 61%, and forage fish, 10%.

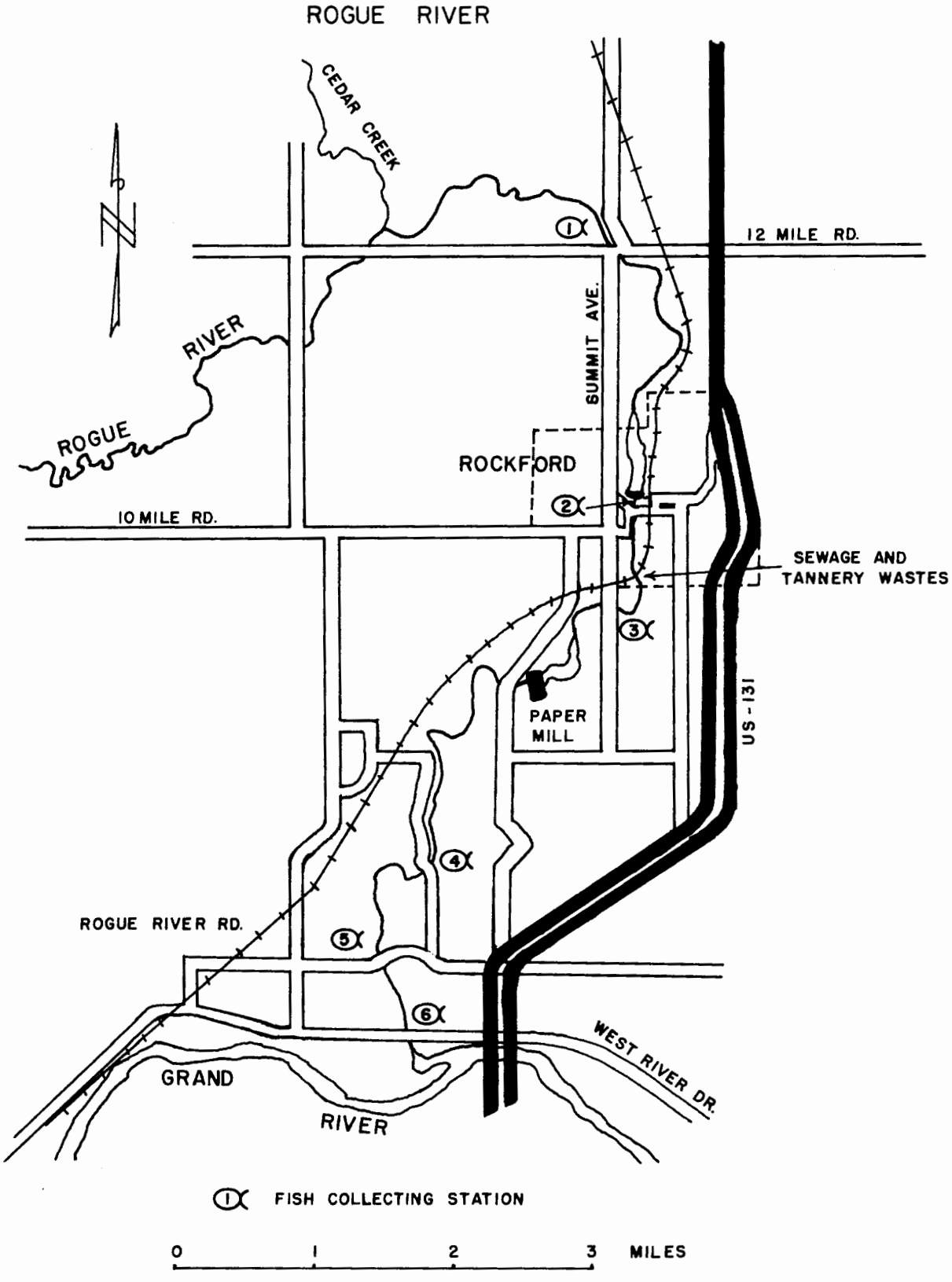

Figure 4.--The lower portion of the Rogue River, Kent County, showing sites where fish were collected in August 1963.

Table 7.--Miscellaneous descriptive data for fish-collection stations on the Rogue River, 1963

Item	Station					
	1	2	3	4	5	6
Location of station (Town[N]-Range[W]-Section)	9-11-24	9-11-36	8-11-1	8-11-14	8-11-15	8-11-22
Date	8-19	8-19	8-20	8-20	8-21	8-21
Sampling time, minutes	60	60	45	60	60	60
Length of station, feet	800	600	600	900	800	1,000
Area, acres	1.47	0.92	1.65	2.07	1.47	2.07
Mean depth, inches	8	12	15	10	10	12
Mean width, feet	80	67	120	100	80	90
Current flow	Moderate	Fast	Moderate	Moderate	Fast	Moderate
Water clarity	Slightly turbid	Slightly turbid	Turbid	Very turbid	Very turbid	Very turbid
Conductivity[a]	430	470	540	530	600	510
Air temperature (°F)	76	76	74	80	80	86
Water temperature (°F)	65	60	62	69	68	72
Bottom soils, estimated Percentage:						
Silt	15	5	b	25	15	5
Sand	65	15	20	60	65	65
Gravel	15	10	50	10	15	20
Rubble	5	70	30	5	5	10
Aquatic vegetation	Common	Common	Abundant	Abundant	Common	Common
Fish cover	Poor	Fair	Good	Good	Fair	Poor

[a] Reciprocal ohms (18 C).

[b] Entire bottom of stream covered by a layer of sludge.

Table 8.--Number of fish caught per hour of shocking at six sampling stations on Rogue River, 1963, and the pounds per acre for three groups of fish

Species	Station					
	1	2	3	4	5	6
Game fish						
Brown trout	12	71	...	...	...	...
Northern pike	2	1	...	1	10	3
Smallmouth bass	...	...	...	...	...	13
Bluegill	...	...	...	1	...	...
Pumpkinseed	...	2	...	...	...	...
Longear sunfish	...	...	...	4	7	3
Rock bass	8	6	...	9	9	38
Green sunfish	...	...	...	9	8	8
Totals	22	80	...	24	34	65
Pounds per acre	2.5	15.5	...	1.0	1.7	4.3
Coarse fish						
Golden redhorse	...	...	...	4	2	12
White sucker	81	32	93	102	8	26
Hog sucker	1	2	...	...	...	1
Lake chubsucker	...	5	...	...	...	...
Yellow bullhead	...	...	...	1	...	...
Brown bullhead	...	...	...	1	...	5
Burbot	218	86	...	...	...	3
Grass pickerel	1	...	...	...	...	...
Carp	...	...	23	3	3	6
Chestnut lamprey	1	...	...	...	...	...
Totals	302	125	116	111	13	53
Pounds per acre	17.6	17.0	33.1	12.5	2.3	8.8
Forage fish						
Creek chub	18	16	7	1	30	14
Hornyhead chub	2	1	...	...	1	6
Blacknose dace	...	38	1	1	6	1
Common shiner	7	15	105	...	10	12
Rosyface shiner	...	...	...	1	...	7

(continued)

Table 8.--concluded

Species	Station					
	1	2	3	4	5	6
Forage fish						
Bluntnose minnow	2	4	...	7	31	223
Stoneroller	...	8	...	1	1	...
Johnny darter	21	17	...	...	...	1
Blackside darter	28	16	...	1	2	25
Rainbow darter	3	4	...	...	...	...
American brook lamprey	11	...	...	...	...	...
Northern brook lamprey	...	...	...	...	...	2
Totals	92	119	113	12	81	291
Pounds per acre	1.3	1.5	1.2	0.1	1.4	1.5
Totals, all species	416	324	229	147	128	409
Pounds per acre, all species	21.4	34.0	34.3	13.6	5.4	14.6
Total number of species	16	17	5	16	14	20

White Pigeon River

Paper mill wastes, which enter the White Pigeon River about 3/4 of a mile upstream from the US-131 crossing, are the only known pollutants in this stream. Septic tanks service the homes in the town of White Pigeon [letter, op. cit.]. Although large quantities of materials with a high BOD have been discharged into the stream from the paper mill, neither our agency nor the Water Resources Commission has any records of fish mortalities in this river.

Employees of the WRC conducted successive 24-hour waste surveys at the paper mill on April 30 and May 1-2, 1963. The subsequent report [2] concluded that (1) the discharge of oxygen-consuming material was excessive; (2) the discharge of 5-day BOD material from all sources in the White Pigeon area during periods of drought flow should not exceed 2, 400 pounds per day; and (3) the amount of oxygen-consuming material released from the paper plant in 1963 should be reduced 60%.

That agency made another survey of water-quality conditions on the White Pigeon River in November and December 1964. High BOD values and serious discoloration of the water due to discharges from the paper mill were noted, and again the industry was urged to reduce its releases of oxygen-consuming substances and suspended solids [4].

We have very little information on the make-up of the fish population in this stream before 1963. Creel census records obtained in White Pigeon Township on one day only in 1945 and 1947 show catches of pike, smallmouth bass, bluegills, sunfish, rock bass, white suckers, and bullheads.

In 1963, the first fish collection was taken above the bridge on Sevison Road, about 3 miles above the entry of the paper mill wastes (Fig. 5). A moderate amount of aquatic vegetation occurred here, but cover for fish was generally poor (Table 9). This collection was the largest of the three taken on this stream. Game fish (mostly rock bass) comprised 21% of the poundage, coarse fish, 55%, and forage fish, 24% (Table 10).

Station 2 was established above the bridge on Blue School Road, approximately 3 miles below White Pigeon. The water here was very turbid. Cover was fair. More coarse fish but considerably fewer game and forage fish were caught here than at the first station. The composition of the sample, by poundage, was: game fish, 11%; coarse fish, 82%; forage fish, 7%.

The last collection was taken at Station 3 above the bridge on M-103, about 13 miles below White Pigeon and 1 mile above the mouth of the stream. The water at this location was still turbid but clearer than at Station 2. Although vegetation was common, cover for fish was generally poor. The BOD values recorded in 1964 indicated the pollutants were largely dissipated by the time the flow reached this point [2]. However, the numbers and weights of game and forage fish captured here in 1963 were virtually the same as those obtained at the second station, but the weight of the coarse fish was only one-third of that at Station 2. On the other hand, the largest number of species was collected at Station 3, including hog suckers and darters which apparently are especially sensitive to pollutants. The composition of this collection by weight was 41% game fish, 24% coarse fish, and 35% forage fish.

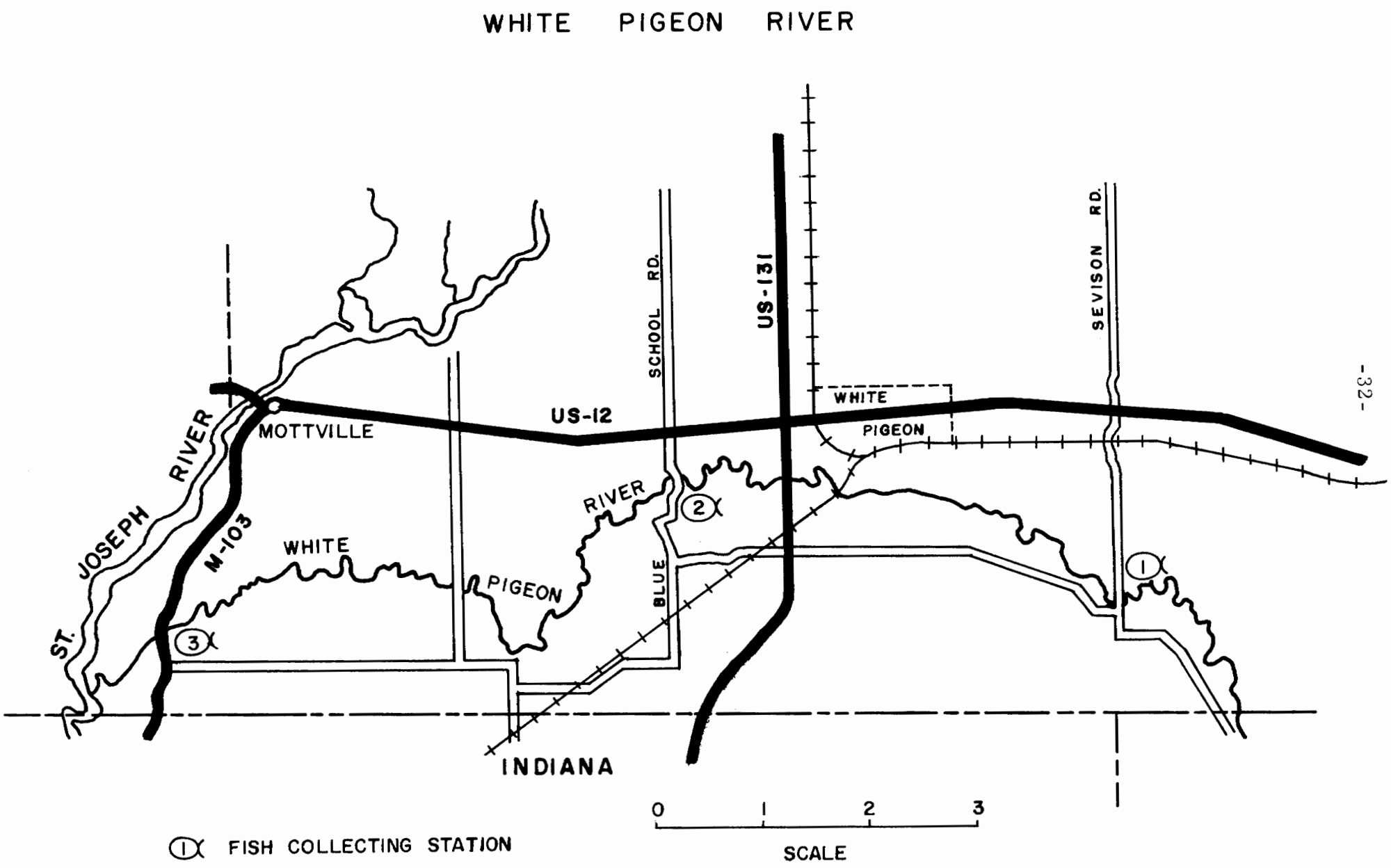

Figure 5.--The White Pigeon River, St. Joseph County, showing sites where fish were collected in August 1963.

Table 9.--Miscellaneous descriptive data for fish-collection stations on the White Pigeon River, 1963

Item	Station		
	1	2	3
Location of station (Town [S] - Range [W] - Section)	8-11-16	8-12-11	8-13-13
Date	8-27	8-27	8-28
Sampling time, minutes	60	60	60
Length of station, feet	1,500	1,400	1,500
Area, acres	3.10	2.89	3.44
Mean depth, inches	10	10	28
Mean width, feet	90	90	100
Current flow	Moderate	Moderate	Moderate
Water clarity	Slightly turbid	Very turbid	Turbid
Conductivity [a]	480	480	450
Air temperature (°F)	72	74	67
Water temperature (°F)	65	69	66
Bottom soils, estimated percentage:			
Silt	10	20	20
Sand	30	70	75
Gravel	50	10	5
Rubble	10	...	...
Aquatic vegetation	Common	Common	Common
Fish cover	Poor	Fair	Poor

[a] Reciprocal ohms (18 C).

Table 10.--Number of fish caught per hour of shocking at three sampling stations on the White Pigeon River, 1963; and the pounds per acre for three groups of fish

Species	Station 1	Station 2	Station 3
Game fish			
Northern pike	...	1	...
Smallmouth bass	4	...	14
Largemouth bass	...	2	...
Bluegill	7	...	2
Rock bass	45	22	9
Yellow perch	...	3	1
Totals	56	28	26
Pounds per acre	2.0	0.6	0.7
Coarse fish			
Northern redhorse	24	54	24
White sucker	13	93	4
Hog sucker	32	...	12
Grass pickerel	...	...	2
Yellow bullhead	3	8	2
Stonecat	3	...	...
Tadpole madtom	...	4	...
Chestnut lamprey	1	1	...
Totals	76	160	44
Pounds per acre	5.1	4.7	0.4
Forage fish			
Creek chub	...	...	6
Hornyhead chub	73	17	33
Common shiner	105	6	16
Sand shiner	32	...	1
Mimic shiner	2	...	4
Spotfin shiner	22	4	1
Rosyface shiner	9	...	1
Bluntnose minnow	36	...	51
Stoneroller	27	2	...

(continued)

Table 10.--concluded

Species	Station 1	Station 2	Station 3
Forage fish			
Johnny darter	13	...	11
Blackside darter	36	63	6
Rainbow darter	63	...	3
Logperch	16	9	6
American brook lamprey	...	...	2
Lamprey (Ichthyomyzon spp.)	...	1	2
Totals	434	102	143
Pounds per acre	2.2	0.4	0.6
Totals, all species	566	290	213
Pounds per acre, all species	9.3	5.7	1.7
Total number of species	21	16	23

Discussion

Besides examining the data for the individual streams, it is of interest to determine the effects of pollution on fish abundance and population structure when the data for the five streams are combined. Therefore the converted weights of the fish collected at the 22 sampling sites are presented in Table 11. The sampling areas have been grouped according to their pollution status (unpolluted, polluted, and recovery) as determined by the numbers, weights, and kinds of fish that were found in them.

The three stations on Cedar Creek and one station on the Rogue River were omitted from the averages to eliminate bias caused by exceptionally large collections from these locations. Unusually high fertility of the stream may have accounted for most of the abundance of fish in Cedar Creek. On the Rogue River, a dam just above the upper end of Station 2 and heavily polluted water immediately below the station probably trapped large numbers of trout at this site.

As expected, the poundages of game and forage fish were largest in unpolluted areas, smallest in polluted areas, and intermediate in the recovery areas. For coarse fish, the mean poundage was greatest in polluted water and least in the recovery zone, but the differences among the three areas were not great. When carp are omitted, the average weight of coarse fish was greatest in the clean water and least in recovery water. On a percentage-by-weight basis, the populations

Table 11.--Pounds per acre of three categories of fish collected from five polluted streams in 1963

Stations	Pounds per acre		
	Game fish	Coarse fish	Forage fish
Unpolluted			
Chippewa River #1	4.0	9.9	8.3
Chippewa River #2	3.0	4.2	1.1
Pine River #1	0.3	14.0	7.0
Pine River #2	1.3	4.9	2.6
Rogue River #1	2.5	17.6	1.3
Rogue River #2	15.5	17.0	1.5
White Pigeon River #1	2.0	5.1	2.2
Mean (Rogue River #2 omitted) [a]	2.2	9.3	3.7
Polluted			
Chippewa River #3	0.3	20.3	0.1
Pine River #3	...	10.6	0.1
Pine River #4	...	2.3	0.5
Pine River #5	...	0.9	1.0
Cedar Creek #1	...	60.1	8.7
Rogue River #3	...	33.1	1.2
Rogue River #4	1.0	12.5	0.1
Rogue River #5	1.7	2.3	1.4
White Pigeon River #2	0.6	4.7	0.4
Mean (Cedar Creek #1 omitted) [a]	0.4	10.8	0.6

(continued)

Table 11.--concluded

Stations	Pounds per acre		
	Game fish	Coarse fish	Forage fish
Recovery zone			
Chippewa River #4	1.6	7.2	1.8
Chippewa River #5	1.0	12.1	1.9
Cedar Creek #2	33.2	53.1	34.0
Cedar Creek #3	10.5	69.6	21.5
Rogue River #6	4.3	8.8	1.5
White Pigeon River #3	0.7	0.4	0.6
Mean (Cedar Creek #2 and #3 omitted) [a]	1.9	7.1	1.4

[a] See text for explanation of omission.

in clean water consisted of 15% game fish, 61% coarse fish, and 24% forage fish; polluted water: 4%, 91%, and 5%, respectively; and recovery water: 18%, 68%, and 14%, respectively.

Apparently several species of stream fish are highly intolerant of pollution, particularly the darters and hog sucker (Table 12). Only one hog sucker was captured in polluted areas, whereas 251 specimens were taken in unpolluted water. Darters were abundant in all clean-water areas, but extremely scarce in all but one of the polluted areas. These fish could be used as indicators of the extent of contamination (or recovery) from pollutants.

Since the fish surveys were made in 1963, corrections either have been made or planned for the reduction of contamination in these streams.[4] On the Pine River, the Michigan Chemical Company in St. Louis has added a manufacturing process which substantially reduces the volume of brine discharged to the stream. Also, the Leonard Refining Company has installed oxidation ponds with mechanical aeration which remove most of the waste constituents from their waste water.

Discharge of sewage into Cedar Creek at Cedar Springs ceased in 1964 after an oxidation lagoon was provided. However, this lagoon may fill to capacity in 1966, requiring a discharge in the fall.

The paper company which owns a mill on the White Pigeon River has planned to improve the method of handling their waste water, including new equipment that is to become operational in September 1966.

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[4] Letter from J. G. Robinson (Water Resources Commission) to C. M. Taube, April 21, 1966.

Table 12.--Numbers of hog suckers and darters collected at each of the stations sampled on five polluted streams in 1963

Stations	Hog suckers	Darters
Unpolluted		
Chippewa River #1	46	62
Chippewa River #2	18	82
Pine River #1	97	79
Pine River #2	55	137
Rogue River #1	1	52
Rogue River #2	2	37
White Pigeon River #1	32	128
Totals	251	577
Polluted		
Chippewa River #3	1	1
Pine River #3	0	0
Pine River #4	0	0
Pine River #5	0	1
Cedar Creek #1	0	0
Rogue River #3	0	0
Rogue River #4	0	1
Rogue River #5	0	2
White Pigeon River #2	0	72
Totals	1	77
Recovery zones		
Chippewa River #4	9	25
Chippewa River #5	48	10
Cedar Creek #2	0	0
Cedar Creek #3	0	25
Rogue River #6	1	26
White Pigeon River #3	12	26
Totals	70	112

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