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THE EFFECTS OF HEATED EFFLUENT FROM THE DAIRYLAND POWER PLANT AT GENOA ON WATER TEMPERATURES AND FISH OF THE MISSISSIPPI RIVER

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INTRODUCTION

The Dairyland Power Cooperative has produced electricity at a plant near Genoa since 1942. The first plant was a small installation (Genoa 1 with 14.7 megawatt output) compared to two additional plants built in recent years to meet increasing demands for electric power. Genoa 1 operated at varying output levels until the new units replaced it. It presently operates only during periods of power shortage.

All three of the Dairyland plants produce electricity by means of steam powered turbines. Steam is generated by heating water. The required heat is produced by burning coal in Genoa 1 and Genoa 3, a new 350 megawatt plant. Genoa 2, also known as the La Crosse Boiling Water Reactor (LACBWR), is an experimental 60 megawatt atomic plant. Heat for steam is produced by controlled nuclear fission in Genoa 2.

The 350 megawatt fossil fuel plant began full-scale operation on June 17, 1969. The atomic plant began operating in mid-January, 1969, but a self-sustained nuclear chain reaction was first achieved on July 11, 1969 and full power was not attained until August 1, 1969. Genoa 3 experienced several shutdowns during its first months of operation due to various equipment failures but has operated at near full capacity since then except for occasional routine maintenance and repair. A total of 11 shutdowns occurred from June, 1969 through December, 1970 with the plant operating during 78 percent of this period (Table 1). Operation of the nuclear plant has been more intermittent with frequent periods of below normal or no power production. The plant shut down 17 times during 1969 and 1970 and was in operation during only 35 percent of this period. Since Genoa 3 began operating, at least one of the two plants was producing power during 91 percent of the period ending December 31, 1970. Genoa 3 operated alone during half of this period.

A large volume of water is required to cool the plant's condensors. This is accomplished through a pair of pumps in each plant. The Genoa 3 pumps each have a capacity of 200 cubic feet per second and the LACBWR pumps 71 cubic feet per second. Therefore, effluent discharge rate may vary from 71 to 542 c.f.s. depending on whether one or four pumps are in operation. The two separate condensor discharges are combined and released into the river through a single outlet. The objectives of this study were to determine the influence of the heated effluent on water temperatures in the Mississippi River and to observe the types and numbers of fish utilizing the area where thermal changes were most pronounced.

METHODS

Water temperatures were recorded with an electric thermometer and Ryan recording thermographs. A hand held mercury thermometer was used to take temperatures of the heated effluent when these exceeded the upper limits of the electric thermometer which registers a maximum of 90°F.

Table 1.

OPERATIONAL HISTORY OF LACBWR AND GENOA 3 PLANTS DURING 1969 AND 1970[1/]

	LACBWR		Genoa 3		Both Plants	Days LACBWR On Genoa 3	Days Genoa 3 On LACBWR	Days Both Plants
	Days On	Days Off	Days On	Days Off	Days On	Off	Off	Off
Jan. 1 - 15, 1969	-	15	-	-	-	-	-	-
Jan. 16 - 18	3	-	-	-	-	-	-	-
Jan. 19 - 30	-	12	-	-	-	-	-	-
Jan. 31	1	-	-	-	-	-	-	-
Feb. 1 - Mar. 20	-	48	-	-	-	-	-	-
Mar. 21 - 22	2	-	-	-	-	-	-	-
Mar. 23 - 26	-	4	-	-	-	-	-	-
Mar. 27 - Apr. 3	8	-	-	-	-	-	-	-
Apr. 4 - 28	-	25	-	-	-	-	-	-
Apr. 29 - May 3	5	-	-	-	-	-	-	-
May 4 - June 16	-	44	-	-	-	-	-	-
June 17	-	1	1	-	-	-	1	-
June 18 - 19	-	2	-	2	-	-	-	2
June 20 - 29	-	10	10	-	-	-	10	-
June 30 - July 2	-	3	-	3	-	-	-	3
July 3 - 14	-	12	12	-	-	-	12	-
July 15 - 19	-	5	-	5	-	-	-	5
July 20	1	-	-	1	-	1	-	-
July 21 - 25	5	-	5	-	5	-	-	-
July 26 - 27	-	2	2	-	-	-	2	-
July 28 - Aug. 8	12	-	12	-	12	-	-	-
Aug. 9 - 13	-	5	5	-	-	-	5	-
Aug. 14 - 22	9	-	9	-	9	-	-	-
Aug. 23 - 28	6	-	-	6	-	6	-	-
Aug. 29 - Sept. 6	9	-	9	-	9	-	-	-
Sept. 7	1	-	-	1	-	1	-	-
Sept. 8 - 13	6	-	6	-	6	-	-	-
Sept. 14 - 25	-	12	12	-	-	-	12	-
Sept. 26 - 27	2	-	2	-	2	-	-	-
Sept. 28 - Oct. 13	16	-	-	16	-	16	-	-
Oct. 14	1	-	1	-	1	-	-	-
Oct. 15 - Dec. 7	-	54	54	-	-	-	54	-
Dec. 8 - 9	2	-	-	2	-	2	-	-
Dec. 10, 1969 - Feb. 28, 1970	-	81	81	-	-	-	81	-
Mar. 1 - 8	-	9	-	9	-	-	-	9
Mar. 9 - Apr. 25	-	48	48	-	-	-	48	-
Apr. 26 - May 10	-	15	-	15	-	-	-	15
May 11 - 15	5	-	-	5	-	5	-	-
May 16	-	1	-	1	-	-	-	1
May 17 - June 6	21	-	-	21	-	21	-	-
June 7	-	1	-	1	-	-	-	1
June 8 - 18	11	-	-	11	-	11	-	-
June 19 - 30	-	12	-	12	-	-	-	12
July 1 - 2	-	2	2	-	-	-	2	-
July 3 - 21	19	-	19	-	19	-	-	-
July 22	-	1	1	-	-	-	1	-
July 23 - Aug. 3	12	-	12	-	12	-	-	-
Aug. 4	-	1	1	-	-	-	1	-
Aug. 5 - Sept. 1	28	-	28	-	28	-	-	-
Sept. 2 - 4	-	3	3	-	-	-	3	-
Sept. 5 - 28	24	-	24	-	24	-	-	-
Sept. 29 - Oct. 11	13	-	-	13	-	13	-	-
Oct. 12 - 31	20	-	20	-	20	-	-	-
Nov. 1 - Dec. 10	-	40	40	-	-	-	40	-
Dec. 11 - 12	-	2	-	2	-	-	-	2
Dec. 13 - 19	-	7	7	-	-	-	7	-
Dec. 20 - 31	12	-	12	-	12	-	-	-
Total Days	254	477	438	126	159	76	279	50
Percent of Total Days	35	65	78	22	28	13	50	9

[1/] Last four columns apply to the period June 17, 1969 to December 31, 1970, since Genoa 3 was not operative until June 17, 1969.

The electric thermometer was used to map water temperatures from immediately above the point of heated effluent discharge to approximately 2½ miles downstream from the plant (Figure 1). This was accomplished by traversing the area by boat with the thermometer's temperature-sensitive probe attached to a weighted line and suspended beneath the water surface. Water temperatures were continuously monitored on a calibrated scale and recorded in the appropriate locations on a map of the area. Vertical temperature profiles were also taken by raising and lowering the thermometer probe by means of a weight attached to a calibrated sounding line. Water temperatures were generally mapped in this manner once or twice per month.

Ryan recording thermographs were installed at various times during the study at points above, in, and below the plant outlet to obtain continuously recorded water temperature data. The thermographs were suspended approximately 2½ feet beneath the water surface on chains attached to stationary objects in the river including barge mooring cells, the heated water outlet structure, and a channel marker buoy. The thermographs were suspended in protective metal frames between bands of rubber inner tube. This was necessary because excessive jarring of the instruments could prevent their successful operation when turbulent currents and wave action repeatedly knocked them against the structures to which they were attached. The thermograph tapes on which the water temperatures were recorded were changed after the instrument had recorded for approximately one month.

Fish samples were collected from the upper portion of a side channel or chute of the river known as Thief Slough which received the heated effluent discharged from the plant. A 230 volt A. C. boomshocker was used to take these samples once per month from August, 1969 through March, 1970. The length of the area electrofished was approximately 600 feet on its western border and 500 feet on its eastern border. A rock closing dam delineated most of the western border, and the eastern border was rock riprapped. The width of the sampling area was approximately 20 feet at the mouth of the outlet and widened to 230 feet at its lower end (Figure 2). Both shorelines dropped off rapidly to depths exceeding 20 feet, and in some areas, depths exceeding 50 feet. The velocity of water flow was high (estimated 5 to 10 feet per second depending on the river flow rate) with a high degree of turbulence. Attempts to sample fish in this area with anchored and drifted gill nets and trammel nets were unsuccessful because the turbulent currents and snag-filled bottom prevented their effective use.

RESULTS

The study area was divided into four general zones on the basis of water temperature characteristics (Figure 1). Zone A can be described as a mixing zone where the heated effluent and river water combine in Thief Slough (Figure 2). In general, this is the same upper section of the chute described earlier as the fish sampling area. The rock closing dam along the western border of the fish sampling area extends approximately 450 feet from the northern tip of Island 126 toward a point 100 feet above the plant outlet. It closes off about 60 percent of the mouth of the slough and leaves an opening 90 feet wide.

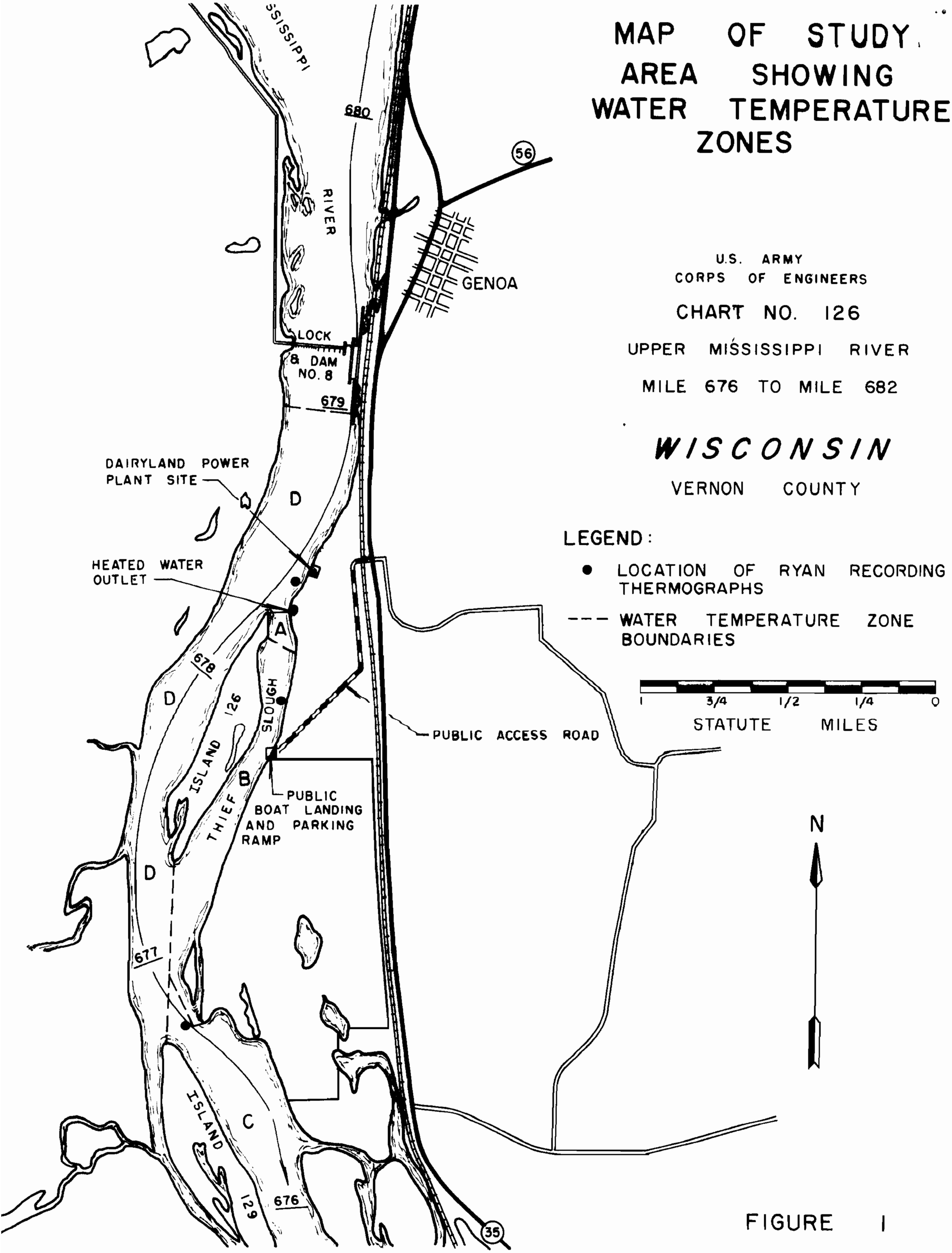
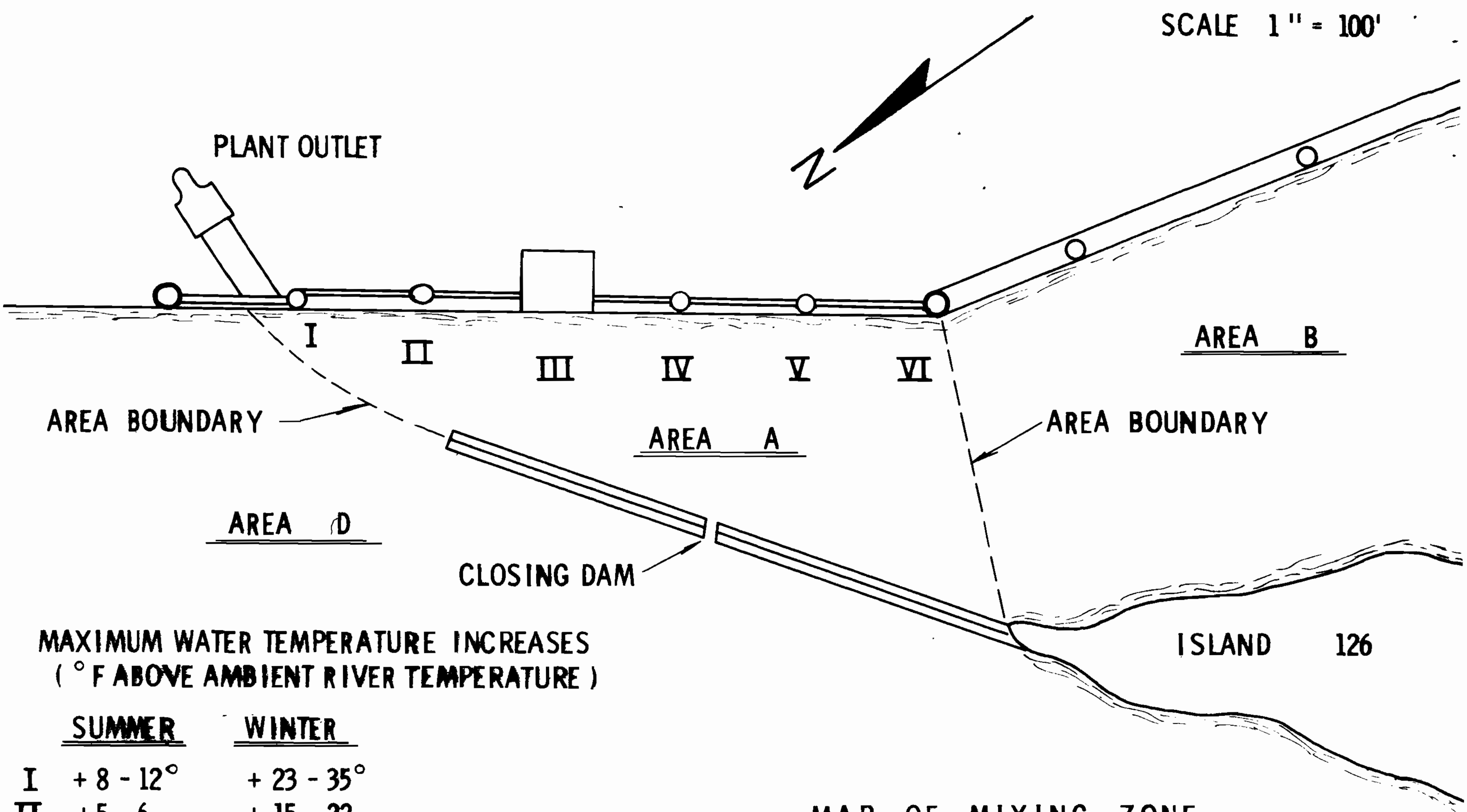

MAP OF STUDY AREA SHOWING WATER TEMPERATURE ZONES
U.S. ARMY
CORPS OF ENGINEERS
CHART NO. 126
UPPER MISSISSIPPI RIVER
MILE 676 TO MILE 682
WISCONSIN
VERNON COUNTY
LEGEND:
● LOCATION OF RYAN RECORDING THERMOGRAPHS
--- WATER TEMPERATURE ZONE BOUNDARIES
1 3/4 1/2 1/4 0
STATUTE MILES
N
MISSISSIPPI RIVER
680
56
GENOA
LOCK & DAM NO. 8
679
DAIRYLAND POWER PLANT SITE
D
HEATED WATER OUTLET
A
678
D
ISLAND 126
SLOUGH
THIEF
B
PUBLIC ACCESS ROAD
PUBLIC BOAT LANDING AND PARKING RAMP
D
677
ISLAND 129
C
676
35

FIGURE 1



MAXIMUM WATER TEMPERATURE INCREASES
(°F ABOVE AMBIENT RIVER TEMPERATURE)

	SUMMER	WINTER
I	+ 8 - 12°	+ 23 - 35°
II	+5 - 6	+ 15 - 22
III	+ 4 - 6	+ 5 - 12
IV	+ 2 - 6	+ 5 - 7
V	+ 2 - 5	+ 4 - 6
VI	+ 2 - 3	+ 3 - 5

MAP OF MIXING ZONE
SHOWING
WATER TEMPERATURE INCREASES

FIGURE 2

This constriction creates the strong turbulent flow which characterizes the upper portion of the slough and is responsible for rapid mixing of the heated effluent and river water within 500 to 600 feet of the outfall. Completion of thermal mixing was determined by the presence of uniform water temperatures over a brief period of time at a given location vertically from the surface to the bottom. Within the mixing zone, water temperatures generally decreased with increasing depth and fluctuated at a given location as masses of relatively cool or warm water passed through it. The extent of vertical stratification and range of temperature fluctuations at a given point were most extreme at the outfall and decreased progressively downstream to the point where mixing was complete. Water temperatures were increased by the plant effluent throughout practically the entire slough (Zones A and B), but the amount of increase varied somewhat with location.

In Zone A, the heated effluent is distributed in a band. Highest temperatures are located in the center and they decrease toward the edges. Location of the center of this band of heated water in the slough varied somewhat. On most of the dates when water temperatures were mapped, the warmest water was nearer to the Wisconsin shoreline than to the closing dam, but in four cases the reverse was true. Turbulence prevented any clearly defined thermal stratification from forming. However, some increases in water temperatures were generally detected to a depth of 10 to 15 feet near the outlet to a depth of 20 to 30 feet at a point 100 feet downstream and from the surface to the bottom below 200 feet downstream. Figure 2 illustrates the variation in water temperature increase in the mixing zone moving downstream from the plant outlet.

Water temperatures were essentially homogeneous since they did not vary more than 1°F. within Zone B, which is the remainder of Thief Slough downstream from Zone A. Generally water temperatures increased slightly moving from the west bank of the slough (Island 126) toward the Wisconsin shoreline, but at times, very little difference in water temperature could be detected across the width of the slough.

Water from the main river channel and Thief Slough combines between Islands 126 and 129. Downstream from this confluence (Zone C), water temperatures between Island 129 and the Wisconsin shoreline varied from ambient river temperature to 2°F. above it. Temperatures generally increased moving from Island 129 toward the Wisconsin shoreline as the warmer water tended to follow the eastern river bank. On most sampling dates, the temperature of the middle of the river was 1°F. above the ambient river temperature. A band of ambient water was located adjacent to Island 129, and a band of warmer water (over 1°F. above ambient river temperature) was located adjacent to the Wisconsin shoreline. On some sampling dates, ambient temperatures existed under a layer of warmer water in the western part of the river.

Both plants were in operation on four of the first five dates when water temperatures were mapped (July 24 through September 11, 1969) and also on four of the last five (July 14 through December 30, 1970) (Tables 1 and 2). When water temperatures were mapped on August 27, 1969, and the LACBWR plant was operating alone, the temperature of the heated effluent was 5°F. above the ambient river temperature.

Table 2.

WATER TEMPERATURES OF HEATED EFFLUENT FROM THE DAIRYLAND POWER PLANTS NEAR GENOA AND AMBIENT RIVER TEMPERATURES OF POOL 9, MISSISSIPPI RIVER

Date	WATER TEMPERATURE (°F.)							
	Station Locations							
	Plant Outlet			Zone B	Zone C	Zone D		
	Recording Agencies							
	DNR	Genoa 3	LACBWR 1/	DNR	DNR	DNR	Genoa 3	LACBWR 1/
1969								
July 24	92	100	90	79	79	78	77	79
Aug. 7	90	98	90	79	79	78	76	78
Aug. 19	89	96	89	79	79	77	76	77
Aug. 27 2/	82	-	88	78	78	77	-	75
Sept. 11	80	87	80	69	69	68	66	67
Sept. 23	79	86	-	68	67	66	64	-
Oct. 21	63	69	-	49	48	47	45	-
Nov. 7	65	70	-	44	43	42	41	-
Nov. 17	58	70	-	37	36	35	35	-
Dec. 2	57	67	-	34	34	32	32	-
Dec. 17	60	69	-	34	33	32	32	-
1970								
Jan. 28	59	67	-	33	33	32	32	-
Feb. 9	60	61	-	34	34	32	32	-
Feb. 23	73	76	-	34	34	32	32	-
Mar. 11	64	68	-	34	34	32	32	-
Mar. 24	62	70	-	37	37	36	36	-
Apr. 7	60	65	-	42	42	41	40	-
July 14	93	100	87	82	81	80	80	80
Aug. 28	93	91	91	79	78	77	74	74
Oct. 16	69	73	78	52	52	51	52	51
Nov. 30	53	74	-	33	33	32	32	-
Dec. 30	62	74	70	34	33	32	32	32

1/ La Crosse Boiling Water Reactor Plant

2/ Nuclear plant only in operation

Table 2 (Appendix).

WATER TEMPERATURE DIFFERENTIALS BETWEEN STUDY AREAS

Date	MAXIMUM WATER TEMPERATURE DIFFERENTIAL (°F.)				
	Station Locations				
	Normal River D to Plant Effluent			Normal River D to Thief Slough B	Normal River D to Main River C
	Recording Agencies				
	DNR	Genoa 3	LACBWR[1]	DNR	DNR
1969					
July 24	+14	+23	+11	+1	+1
Aug. 7	+12	+22	+12	+1	+1
Aug. 19	+12	+20	+12	+2	+2
Aug. 27[2]	+ 5	-	+13	+1	+1
Sept. 11	+12	+21	+13	+1	+1
Sept. 23	+13	+22	-	+2	+1
Oct. 21	+16	+24	-	+2	+1
Nov. 7	+23	+29	-	+2	+1
Nov. 17	+23	+35	-	+1	+1
Dec. 2	+25	+35	-	+2	+2
Dec. 17	+28	+37	-	+2	+1
1970					
Jan. 28	+27	+35	-	+1	+1
Feb. 9	+28	+29	-	+2	+2
Feb. 23	+41	+44	-	+2	+2
Mar. 11	+32	+36	-	+2	+2
Mar. 24	+26	+34	-	+1	+1
Apr. 7	+19	+25	-	+1	+1
July 14	+13	+20	+ 7	+2	+1
Aug. 28	+16	+17	+17	+2	+1
Oct. 16	+18	+21	+27	+1	+1
Nov. 30	+21	+42	-	+1	+1
Dec. 30	+30	+42	+38	+2	+1

[1] La Crosse Boiling Water Reactor Plant

[2] Nuclear plant only in operation

At this time the mixing zone was 250 feet long. Below the mixing zone in Areas B and C, river temperatures were 1°F. above the ambient river temperature. On November 30, 1970, and on the 12 sampling dates within the period September 23, 1969 through April 7, 1970, Genoa 3 only was in operation. No significant differences in the temperature of the effluent or the river below the outlet were apparent between the dates when Genoa 3 only was operating and when both plants were operating. The pattern of thermal distribution was the same as that described in the preceding paragraph. Since LACBWR had a smaller volume of effluent, it had less influence. The volume of effluent from LACBWR can range from 18 to 71 percent of that from Genoa 3 depending on the number of pumps each plant is operating. On the sampling dates when both plants were operating, LACBWR contributed from 15 to 26 percent of the effluent volume. On most sampling dates, the temperature of the effluent from LACBWR was lower than that from Genoa 3 (from 4°F. to 13°F. lower; average 8°F.). There were two exceptions; the effluent from both plants was the same temperature on August 28, 1970, and LACBWR effluent was 5°F. warmer than that from Genoa 3 on October 16, 1970.

Continuous recordings of water temperatures with Ryan thermographs were collected at 4 sites as shown in Figure 1: 1) a barge mooring cell above the heated water outlet; 2) the outlet structure itself; 3) a barge mooring cell in Zone B; 4) a channel marker buoy in Zone C. Problems were encountered involving the accuracy and consistent operation of most of the instruments. As a result, temperature data were collected only during limited periods of time during the study, particularly at certain sites. The most consistently successful recordings were made in the outlet from September, 1969 to October, 1970. Interruptions in continuity of outlet recordings were brief and occurred in May, July, August, and October, 1970. Recordings were made in Thief Slough from February to April and from August through December of 1970. Data were collected February through May, 1970 from the river below Thief Slough and in February and March, 1970 from above the plant outlet.

Both Dairyland plants kept records of their inlet and condensor discharge water temperatures. These should serve as reasonable estimates of ambient river and outlet temperatures during periods when Ryan thermometers were not operating. Water temperatures 1°F. to 2°F. above ambient river temperatures were consistently observed in Zones B and C on the 22 dates of temperature mapping with the electric thermometer. Ryan thermograph records substantiated this during the periods in which they were operating in these zones. Therefore, it appears that this condition continuously exists downstream from Zone A while heated effluent is being discharged. The continuously recorded temperature data from the Ryan thermographs and Dairyland's inlet and condensor discharge records are given in Table 3.

In general, the difference between the ambient river temperature and heated effluent from the plant was considerably greater in winter than in summer. This resulted from recycling the heated effluent back through the cooling water intake to prevent ice from forming on the grate and clogging it. The maximum effluent temperature recorded with the electric thermometer during winter was 73°F. in February, a difference of 41°F. from an ambient river temperature of 32°F.

Table 3.

MONTHLY MAXIMUM AND MINIMUM INSTANTANEOUSLY RECORDED TEMPERATURES (°F.) OF HEATED PLANT EFFLUENT AND AMBIENT RIVER TEMPERATURES

Date	Genoa 3 Effluent		LACBWR Effluent		Combined Effluent From Both Plants In Outlet		Ambient River	
	Min.	Max.	Min.	Max.	Min.[1/]	Max.	Min.	Max.
1969								
January	-	-	38	56	-	-	32	32
February	-	-	-	-	-	-	32	32
March	-	-	42	63	-	-	32	37
April	-	-	54	67	-	-	32	53
May	-	-	70	76	-	-	54	57
June	74	85	-	-	-	-	63	67
July	87	100	78	97	-	-	68	79
August	90	99	79	90	-	-	74	78
September	79	94	73	88	63	86	58	75
October	63	76	70	92	54	88	40	66
November	63	75	-	-	50	66	32	40
December	63	88	-	-	50	77	32	32
1970								
January	61	79	-	-	50	70	32	32
February	57	76	-	-	50	70	32	32
March	64	73	-	-	50	64	32	39
April	59	71	-	-	50	66	36	47
May	-	-	63	80	72	78	54	64
June	-	-	78	85	71	86	64	75
July	91	100	80	93	82	97	71	81
August	91	100	80	96	78	96	71	81
September	76	91	73	93	60	89	59	74
October	67	80	71	94	50	75	40	60
November	66	80	-	-	-	-	32	40
December	65	85	66	74	-	-	32	32

1/ A 50°F. reading on the Ryan thermograph in the outlet is the lowest temperature the instrument could record and therefore actually means 50°F. or less.

Table 3 (Appendix).

MONTHLY MAXIMUM TEMPERATURE DIFFERENTIALS BETWEEN HEATED EFFLUENT AND AMBIENT RIVER TEMPERATURES (°F.) INSTANTANEOUSLY RECORDED ON A GIVEN DATE

Date	MAXIMUM TEMPERATURE DIFFERENTIALS		
	Ambient River To Genoa 3 Effluent	Ambient River To LACBWR Effluent	Ambient River to Combined Effluent From Both Plants In The Outlet
1969			
January	-	+24	-
February	-	-	-
March	-	+31	-
April	-	+33	-
May	-	+20	-
June	+18	-	-
July	+25	+21	-
August	+23	+14	-
September	+23	+28	+28
October	+34	+28	+27
November	+40	-	+30
December	+56	-	+45
1970			
January	+47	-	+38
February	+44	-	+38
March	+41	-	+32
April	+31	-	+26
May	-	+18	+13
June	-	+18	+14
July	+25	+17	+22
August	+20	+20	+15
September	+23	+29	+18
October	+27	+54	+35
November	+45	-	-
December	+49	+42	-

The maximum summer temperature recorded with the hand held mercury thermometer was 93°F. in both July and August. This was 13°F. above a river temperature of 80°F. in July and 16°F. above a 77°F. reading in August. The Ryan recording thermometer indicated a high of 70°F. in the winter (a 38°F. increase in January and February) and 97°F. in the summer (a 22°F. increase in July). The maximum difference between inlet and condensor discharge temperatures recorded was 25°F. in the summer and 56°F. in the winter for Genoa 3. And, the maximum difference between inlet and condensor discharge temperature was 28°F. in summer and 54°F. in winter for LACBWR. Peak condensor discharge temperatures were 100°F. for Genoa 3 and 97°F. for LACBWR in the summer and 88°F. for Genoa 3 and 74°F. for LACBWR in winter.

However, these outlet temperatures fell rapidly as the effluent mixed with river water. Figure 2 shows the maximum temperature at various locations downstream from the outlet within the mixing zone. The 1°F. to 2°F. increase in the temperature of Thief Slough below the mixing zone apparently was not affected by seasonal changes in the ambient river and plant outlet temperatures. The maximum summer temperature in Thief Slough after mixing was 82°F. and the maximum winter temperature was 34°F. After the mixing of heated water from Thief Slough with water from the main channel, the maximum temperature of the river in summer was 81°F. and 34°F. in winter.

Fish sampling with a 230 volt A.C. boomshocker produced a total of 559 fish including 27 species (Table 4 and Figure 3). Schools of small minnows were occasionally observed, but their species and numbers were not determined. The composition of monthly samples collected from August, 1969 through March, 1970 varied considerably with seasonal changes in water temperatures. The greatest total numbers of fish and fish species were taken during the period of warmest water temperatures in August and September. Samples collected in early fall and spring were of similar size and complexity and showed a slight decline from summer samples in number of fish and species taken. Late fall and early winter samples had substantially fewer numbers of fish and a lower species diversity. Only a few fish were taken in mid- and late winter samples. Ratios of 64 percent sport fish to 36 percent nonsport fish and 42 percent sport species to 58 percent nonsport species were observed for all fish collected. The following sport fish species are ranked in decreasing order according to percent by number of the total catch: walleye (19 percent), white bass (13 percent), sauger (11 percent), bluegill (10 percent), black crappie (6 percent), and largemouth bass (2 percent). The most abundant nonsport fish were carp (12 percent), gizzard shad (8 percent), mooneye (6 percent), northern redhorse (4 percent), and freshwater drum (4 percent). Walleye and sauger were taken mainly in spring and fall samples. White bass, bluegill, black crappie, and largemouth bass were taken mainly in summer samples. Carp were common in all samples except late fall and winter. Gizzard shad and mooneye appeared mainly in summer while drum and redhorse appeared mainly in spring samples.

Table 4.

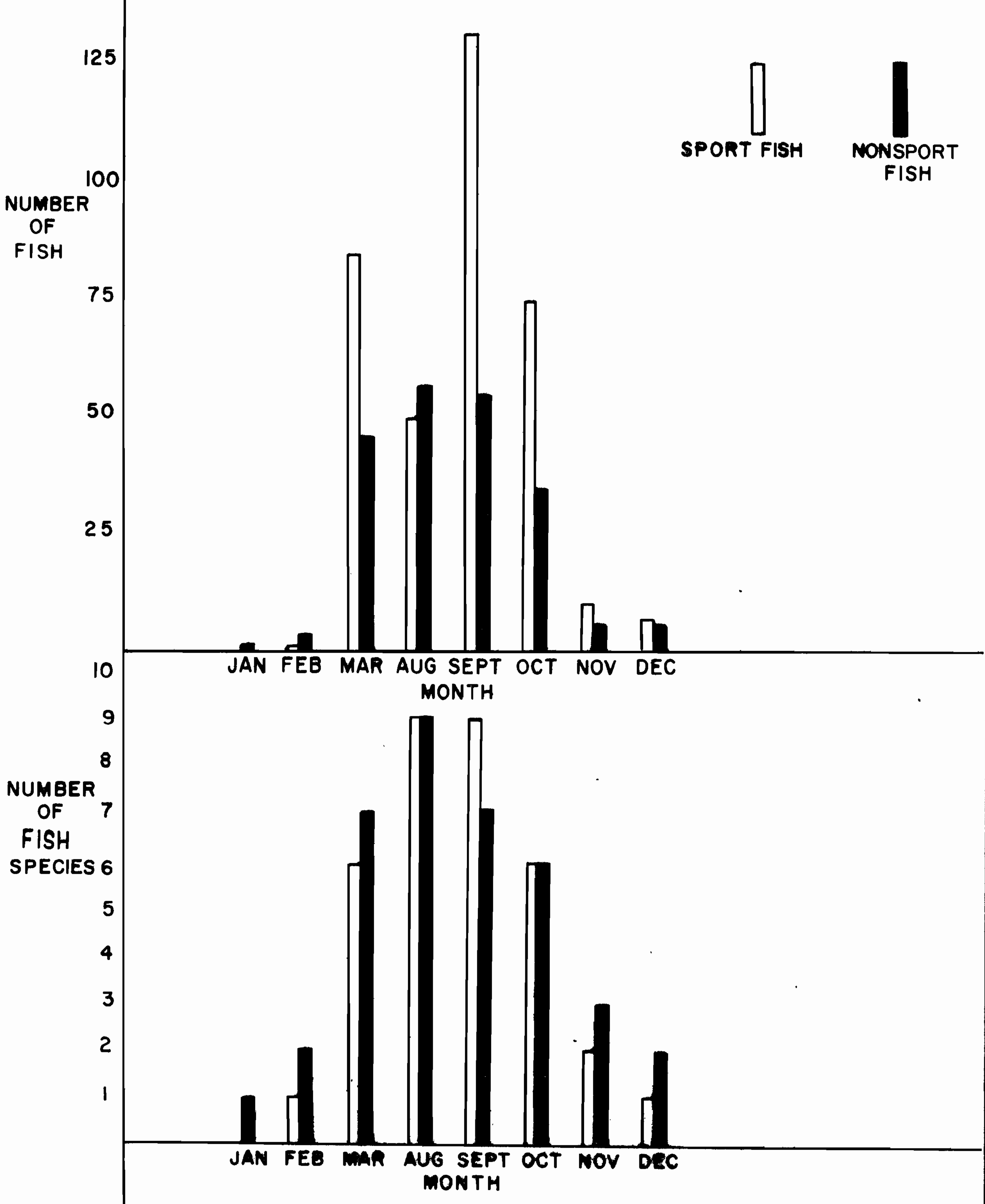
TOTAL NUMBER OF SPORT AND NONSPORT FISH COLLECTED IN MIXING ZONE A

Fish Species	Jan.	Feb.	Mar.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Sport Fish									
Northern pike	-	-	1	1	1	-	-	-	3
White bass	-	-	1	9	51	11	-	-	72
Rock bass	-	-	2	1	-	-	-	-	3
Warmouth	-	1	-	-	-	-	-	-	1
Pumpkinseed	-	-	-	-	-	1	-	-	1
Bluegill	-	-	-	15	40	-	-	-	55
Smallmouth bass	-	-	-	3	4	-	-	-	7
Largemouth bass	-	-	-	5	5	1	-	-	11
White crappie	-	-	-	-	4	-	-	-	4
Black crappie	-	-	2	8	23	1	-	-	34
Sauger	-	-	14	1	1	37	6	-	59
Walleye	-	-	64	2	5	23	4	7	105
Total Number of Sport Fish Combined	-	1	84	49	130	74	10	7	355

Table 4 (Continued).

Fish Species	Jan.	Feb.	Mar.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
<u>Nonsport Fish</u>									
Shovelnose sturgeon	-	-	-	1	-	-	-	-	1
Longnose gar	-	-	-	-	1	-	-	-	1
Shortnose gar	-	-	-	1	-	-	-	-	1
Gizzard shad	1	-	-	19	15	2	2	4	43
Mooneye	-	-	4	14	17	-	-	-	35
Carp	-	-	15	12	11	24	2	1	65
White sucker	-	-	-	-	-	1	-	-	1
Bigmouth buffalo	-	-	-	-	-	1	-	-	1
Spotted sucker	-	-	1	-	-	-	-	-	1
Northern redhorse	-	-	13	3	6	2	-	-	24
Channel catfish	-	1	-	2	1	-	-	-	4
Flathead catfish	-	-	-	2	-	-	-	-	2
Burbot	-	-	1	-	-	-	-	-	1
Trout perch	-	-	1	-	-	-	-	-	1
Freshwater drum	-	2	11	2	3	4	1	-	23
Total Number of Nonsport Fish Combined	1	3	46	56	54	34	5	5	204
Total Number of Sport and Nonsport Fish Combined	1	4	130	105	184	108	15	12	559

FIGURE 3. NUMBERS OF FISH AND FISH SPECIES TAKEN IN MONTHLY SAMPLES



DISCUSSION AND CONCLUSIONS

The relative magnitude of heated water discharge from the power plant outlet to Thief Slough and the entire river determined how much increase in ambient river temperatures the Dairyland plants produced. This was the case because current velocity and water turbulence in the area of the outfall were sufficient to insure rapid thermal mixing. As a result, significant stratification which could produce surface water temperatures well above normal over a considerable area was prevented.

The Army Corps of Engineers measures the discharge rate of the entire Mississippi River through Lock and Dam 8. The lowest river flow rate recorded in the last ten years was 6,400 cubic feet per second. The fraction of the total river flow which passes through Thief Slough at various discharge rates has not been accurately determined by the Corps. The lowest plant discharge rate of 71 c.f.s. (one LACBWR pump operating) is 1 percent of this amount, and the maximum discharge rate of 542 c.f.s. (both Genoa 3 and both LACBWR pumps operating) is 8 percent of it. During the study period, the lowest river flow rate recorded was 7,700 c.f.s. At this time, the plant effluent was 7 percent of the river flow. River flow rates over which water temperatures were mapped ranged from 8,500 to 37,800 c.f.s. Plant effluent discharge was 5.5 percent of the low flow and 1.0 percent of the high flow. It can be concluded that the hot water discharge from the plant is a small fraction of the total river flow even under low flow conditions. It makes up a larger portion of the Thief Slough flow, but the flow rate of heated effluent is not sufficient to raise slough temperatures more than 2°F. after mixing.

Water temperature is known to be an important factor influencing aquatic life. It affects fish through direct influence on their physiology and indirectly by influencing the physiology of organisms in their food chains and other competing fish species.

Each species has a preferred temperature at which it is most successful. This temperature varies seasonally and may differ with the size of the fish. A range of temperatures called the tolerance limits exists within which a species will be able to survive. Outside of these tolerance limits, thermal stress acts in combination with a variety of other factors to cause mortality.

The small water temperature increase produced by the Dairyland plant effluent after mixing does not produce river temperatures outside the tolerance limits of ~~its~~ fish species. However, a possible long-term influence of raising river temperatures could be to improve conditions for certain species with preferred temperatures higher than the normal river temperatures and to decrease the quality of the environment for other species with temperature preferences at or below the normal temperature. The beneficial or detrimental influence of such shifts in species composition would depend upon the relative desirability of the fish involved. Sport fish preferring relatively high temperatures include largemouth bass and bluegill.

Walleye, sauger, and yellow perch prefer somewhat lower temperatures. Carp prefer higher temperatures than freshwater drum and gizzard shad. The possibility also exists that an exotic fish species with a temperature preference higher than normal river temperatures may become established if introduced into a heated river situation. Such establishment of an exotic species could directly influence native fish populations.

There are several specific harmful effects to fish which could result from raising river temperatures. One of these is thermal shock induced when fish are subjected to rapid temperature changes. It is possible that effluent from the Dairyland plant could create a situation where this occurs, particularly, during winter months when a large temperature differential exists between effluent and ambient river temperatures. Rapid temperature changes are frequently more harmful to fish than prolonged exposure to increased temperatures. Fish can adapt faster to a temperature increase than to a temperature decrease. The greatest danger would exist if fish were to move into the heated effluent near the outlet and then return to the colder ambient river temperatures. The magnitude of this problem would depend on the number of fish entering and leaving the heated water area.

Increasing water temperatures up to a critical level increases the metabolic rate of fish. If increased metabolism is not compensated for by increased energy intake through feeding, impaired growth and even starvation may result. High water temperatures have been shown to impair the ability of some fish to capture food. Increased energy requirements may create a situation where more energy is required to capture additional food than the additional food can supply resulting in an energy deficit. Vital fat and protein reserves must then be used.

The susceptibility of fish to adverse effects from pollutants and diseases is generally increased with increasing water temperatures. Thus, heated water could be a contributing factor to damage of a fish population easily attributed to other causes. It has been demonstrated that detrimental influences can be additive or synergistic.

Successful reproduction, growth, and survival of young fish are generally more sensitive to the adverse effects of increased water temperatures than are adult fish. Adult fish may also be more capable of avoiding areas of unfavorable changes in temperature than are pelagic eggs and fry. Due to their small size, large losses of eggs and fry could easily occur without being visually obvious. The fraction of the total number of eggs and fry passing through the condensor cooling water system and the outfall would be important considerations in determining if the plant could significantly influence fish populations in this manner.

Sampling indicated that many fish species common to this portion of the river are found in the area where the greatest water temperature increases occur. Lack of fish in winter samples may reflect inefficiency of electrofishing at this time of year rather than that fish avoided the area. The boomshocker was effective in sampling only the shallow water along the shoreline which left most of the area almost entirely unsampled. It is probable that small winter catches can be attributed in part to the movement of fish into the deeper water where the shocker was not effective.

The species and numbers of fish taken did not indicate that the heated effluent was producing any unusual concentrations or exclusions of fish species commonly occurring in this type of habitat during particular seasons of the year. The numbers of sport fish and nonsport fish in the catch were fairly similar; a situation which is typical of boomshocker samples from similar river habitat not influenced by heated effluent.

SUMMARY

The heated effluent from the condensors of two new power plants near Genoa enters Thief Slough of the Mississippi River at temperatures considerably above those of the river itself. Rapid mixing by strong turbulent currents quickly drops the water temperature to one to two degrees above ambient river temperatures. This absence of stratification eliminates the possibility of surface water temperatures well above ambient river temperatures persisting over large areas. The thermal influence of the plant was detected 2½ miles below the outlet. However, the volume of heated water discharged by the plant is small relative to the total flow of the river and does not have a dominant influence on Thief Slough which receives only a fraction of the total river flow. These conditions existed for river flow rates as low as 8,500 c.f.s. The lowest flow rate in the last ten years was 6,400 c.f.s.

Fish samples collected in the area most strongly influenced by the heated water appeared to be typical of samples collected by the same method in similar river habitat. No unusual exclusions or concentrations of any types of fish were apparent.

Effluent from the plant creates conditions that could potentially have adverse effects on some types of fish. Thermal stress may occur when fish (particularly those in egg or fry stages) are subjected to rapid and drastic temperature changes, especially, if fish re-enter the river at ambient water temperatures after being subjected to heated effluent. The temperature of the plant effluent during the period of peak normal river temperatures in mid- and late summer approaches or exceeds the tolerance limits of some species of river fish. Additive or synergistic adverse effects may result if increased water temperatures are combined with other environmental detriments such as pollution and disease producing agents. Modifying the thermal environment may have harmful affects on the physiological processes of fish or aquatic organisms in their food chains.

The area where drastic temperature changes occur includes a relatively small part of the river, and its importance is dependent upon the numbers of fish utilizing this area. The much larger area where a small water temperature increase occurs may produce changes in fish populations of equal or even greater importance than those resulting from the drastic temperature differences in the vicinity of the outlet. The changes there may be subtle and indirect such as the decline of a species through decreased growth rates and recruitment rather than massive die-offs or complete disappearance.

Similarly, it is also possible that the status of some species may increase as a direct result of increased water temperatures or indirectly from the decline of other competing species. If the status of a particular species does decline or increase, it will very likely be the result of a combination of environmental changes rather than modification of the thermal water quality or of any other factor acting alone.

The impact of small increases in river temperature over extensive areas will probably become increasingly important as the electric power industry expands with more and larger power plants warming an increasingly greater portion of the river. Alterations of a small segment of an aquatic environment generally will not greatly change the structure of its fish populations unless a particularly strategic area such as a critical spawning or feeding habitat happens to be involved. Modification of an aquatic environment need not be drastic to bring significant changes in its fish populations when an extensive part of the habitat is affected. The heated water from the two new plants at Genoa is producing a small change in water temperatures in a small part of a large river. Large water temperature differentials exist only in the upper end of one slough where effluent mixing is occurring. An increasing number of plants similar to, or larger than, those at Genoa could change the thermal environment of a much more significant portion of the Mississippi River.

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