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Electrical Installation for Control of the Northern Squawfish

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CONTENTS

	Page
Introduction	1
Experimental site and installation	2
Electrode array and traps	2
Power source	4
Electronic equipment	5
Method of energizing array	5
Electrical conditions	6
Physical quality of water	8
Resistivity	8
Temperature	8
Method of testing effectiveness of installation	8
Testing the installation	9
Conclusions and recommendations	14
Acknowledgments	14
Literature cited	14

Electrical Installation for Control of the Northern Squawfish

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ABSTRACT

Electricity was used experimentally to divert and trap squawfish during their spawning migration in 1958 at Cascade Reservoir, Idaho. Electrical fields, created by sequentially energizing a V-shaped array of vertically suspended round electrodes with square-wave, d.c. pulses, were evaluated as a means of diverting squawfish into traps.

Three test conditions of varied pulse frequency, pulse duration, and voltage were tested. Two sets had a pulse frequency of 10 pulses per second (2 per field per second when five fields were pulsed in sequence), a pulse duration of 50 msec., and voltages of 140 and 180 v.; one set had a pulse frequency of 15 pulses per second (3 per field), a pulse duration of 25 msec., and a voltage of 180 v. One set (pulse frequency, 10 pulses per second; pulse duration, 50 msec.; and voltage, 180 v.) was repeated.

The electrical fields of the electrode array were effective in diverting squawfish into traps. The test condition with pulse frequency of 15 pulses per second, pulse duration of 25 msec., and voltage of 180 v. was less effective than the other test conditions.

INTRODUCTION

The northern squawfish, Ptychocheilus oregonensis (Richardson), a predator on young salmon and trout in the major river systems of the Pacific Northwest (Lindsey, 1956), is also a serious competitor of the desirable food and game fishes in many of the lakes and tributary streams of these systems. For example, in northern Idaho, squawfish--together with other native cyprinids, the peamouth Mylocheilus caurinus (Richardson), and longnose dace Rhinichthys cataractae (Valenciennes)--and suckers (Catostomidae) have become the dominant fishes in waters that formerly produced trout. The principal cause of this increase in rough-fish populations has been the changes in stream environment--warmer water, reduced bank cover, siltation, and intermittent flow (Jeppson, 1957).

In 1957, fishery biologists of the State of Idaho Department of Fish and Game began to investigate the life histories of the rough fishes and to experiment with partial control measures that could be used when fish are concentrated and thus vulnerable to destruction in large numbers. Jeppson (1957) used gill nets to reduce the number of northern squawfish in 32-hectare Hayden Lake. He also learned that squawfish congregated along a 1.6-km. stretch of rocky shoal as spawning time approached; dynamite was effective in dispersing or destroying these schools; Fish Tox[2] and rotenone killed fry, small young-of-the-year, and yearling squawfish; and slight reduction of the lake level during the incubation period killed the eggs that had been laid in shallow areas and subsequently exposed to air when the water level dropped.

Following Jeppson's work, Richards[3] began to study the spawning habits of squawfish at

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[2]Trade names referred to in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

[3]Richards, Monte. 1958. Experimental rough-fish control. Idaho Dep. Fish Game [Boise], Annu. Progr. Rep. Fed. Aid Fish Restoration Proj. F 22-R-3, 17 pp. [Processed.]

Cascade Reservoir, Idaho, to determine how to control the extremely large population there. He found that:

- Squawfish migrated from the reservoir into two of the larger tributaries to spawn (North Fork of the Payette River and Lake Fork Creek).
- No evidence of spawning existed in Cascade Reservoir proper.
- Squawfish spawned in the two tributaries in late June and early July; after spawning, the fish returned to the reservoir immediately.
- Squawfish fry drifted gradually from the spawning stream to the backwaters of the reservoir throughout the summer and fall.
- Control of squawfish in Cascade Reservoir appeared possible by trapping or treating them with rotenone while they were concentrated during the spawning run.

Hasselman and Garrison[4] found that the squawfish of Lookout Point Reservoir on the Middle Fork of the Willamette River, Oreg., migrated to the upper end of the reservoir to spawn. The authors reported that four small tributaries which empty into the reservoir are probably too small to provide areas with requirements for large concentrations of spawning squawfish.

In 1953-57 the Bureau of Commercial Fisheries Biological Laboratory, Seattle, Wash., studied in the laboratory the use of electricity to control northern squawfish. This research was directed toward (1) preventing adult squawfish from moving into the areas where hatchery-reared salmon fingerlings were released, so that the young salmon could safely disperse,[5] and (2) catching adult squawfish by using sequentially pulsed d.c. fields to lead them into enclosures or traps (Maxfield, Liscom, and Lander, 1959).

In the spring of 1958, the Bureau and the Idaho Department of Fish and Game agreed to install an experimental electrical structure (electrode array and appurtenances) at Cascade Reservoir and to estimate the structure's effectiveness in diverting northern squawfish into traps.

EXPERIMENTAL SITE AND INSTALLATION

Cascade Reservoir (fig. 1) is 1,473 m. above sea level in Valley County, Idaho. When full, it is about 42 km. long and covers 14,528 ha. The experimental site for the electrical installation was at the North Fork bridge that crosses the reservoir (at what was formerly Tamarack Falls) on the North Fork of the Payette River. Here the reservoir is constricted to a 31-m.-wide channel by the two concrete abutments of the bridge; depth at peak level ranges from about 3 m. at the abutments to 5 m. at midstream. The reservoir at peak level widens considerably on the upstream side of the bridge and to a lesser degree on the immediate downstream side.

The experimental installation consisted of (1) a V-shaped electrode array in the center of the stream and (2) two nonelectrified traps at the water's edge--one at each end of the electrode array. The installation and its operation are described in five sections: (1) electrode array and traps, (2) power source, (3) electronic equipment, (4) method of energizing array, and (5) electrical conditions.

Electrode Array and Traps

The V-shaped electrode array, with apex downstream, consisted of three parallel rows of vertical electrodes (2.6-cm. thin-wall electrical conduit) spaced 0.6 m. apart in each row (figure 2). The downstream and middle rows of electrodes were 1.5 m. apart, and the middle and upstream rows were 0.6 m. apart.

We assembled the electrodes in sections, which consisted of either two or four electrodes inserted at 0.6-m. intervals in an upper and a lower 5.1- by 10.2-cm. "spacer" board, which maintained the correct spacing of the electrodes during and after installation. The lower spacer (fig. 3) was about 1.2 m. from the lower ends of the electrodes. The upper spacer boards were mounted on a floating support structure that was not secured to the electrodes; therefore, the support structure moved freely up and down the electrodes when the water level changed. The lower ends of the vertical electrodes, the lengths of which were from 3.7 to 6.1 m. depending upon the water depth, were embedded in the stream bottom.

The support structure for the electrode array was built by joining balsa wood liferafts with planks, or stringers, in two sections that were floated into position and joined in a V-shape (fig. 2). The structure was held in position by a vertical 10.2- by 30.6-cm. plank secured to the bridge at each wing of the V in such a manner that it was free to rise and fall with change in water level. The apex of the support structure was 21.3 m. downstream from the bridge; the length of each arm of the V-shaped electrode array was 20.7 m.

A 4.6- by 6.1-m. rectangular screen of galvanized hardware cloth (4 meshes per 2.5 cm.), mounted on a frame of 2.5-cm. galvanized pipe, was positioned in the water from each upstream end of the electrode array to the closest trap lead. The two screens (fig. 2)

[4] Hasselman, Ronald, and Robert Garrison. 1957. Studies on the squawfish, Ptychocheilus oregonense, in Lookout Point and Dexter reservoirs, 1957. Joint research study, U.S. Fish Wildl. Serv., Portland, and Dep. Fish Game Manage., Oreg. State Coll., Corvallis, 41 pp. [Processed.]

[5] Maxfield, Galen H., and C. D. Volz. An electrical barrier for controlling squawfish (Ptychocheilus oregonesis) predation. Bur. Comm. Fish., Biol. Lab., Seattle, Wash. [Unpublished manuscript, 41 pp.]

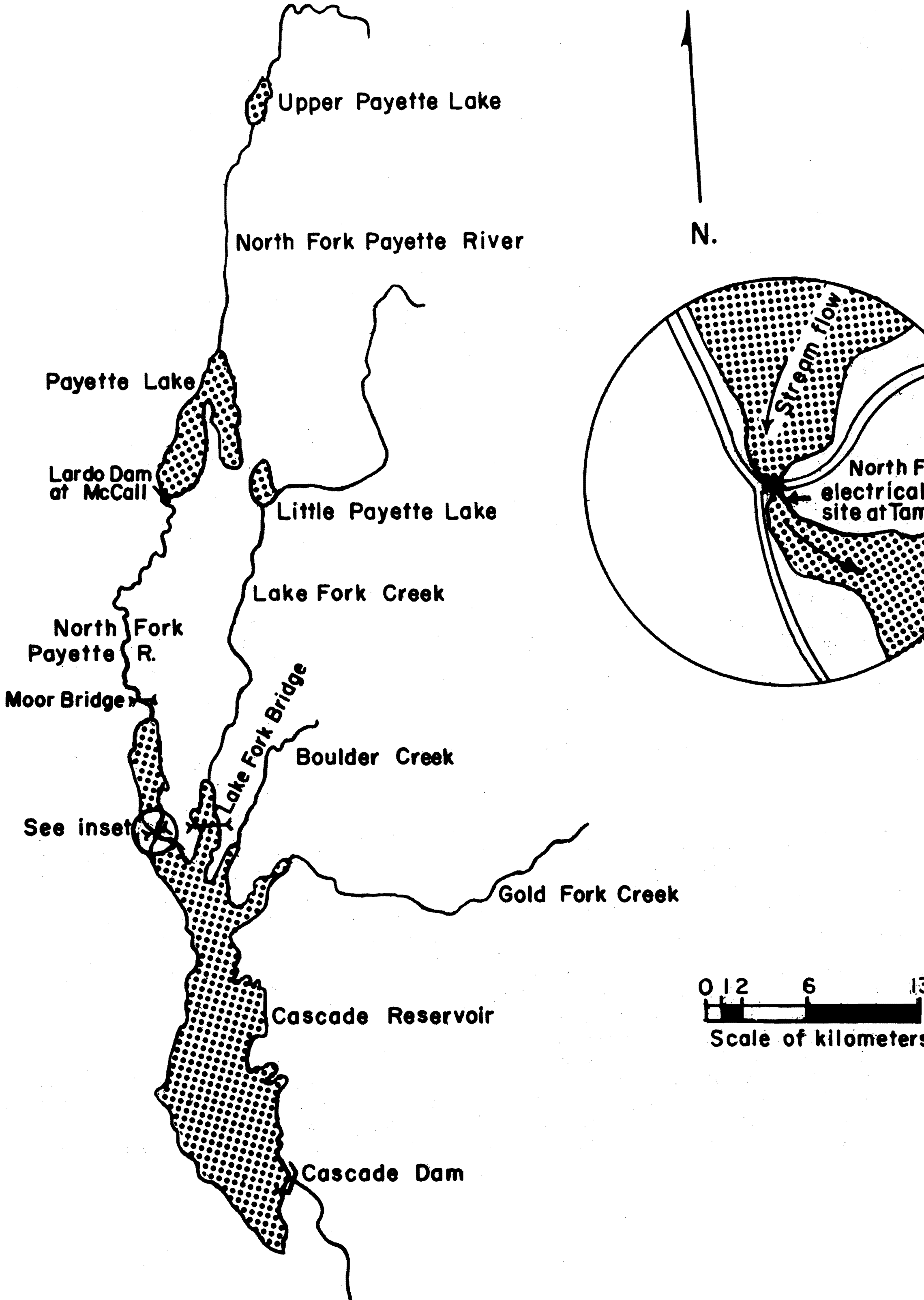

Figure 1.--Map of Cascade Reservoir and tributaries.

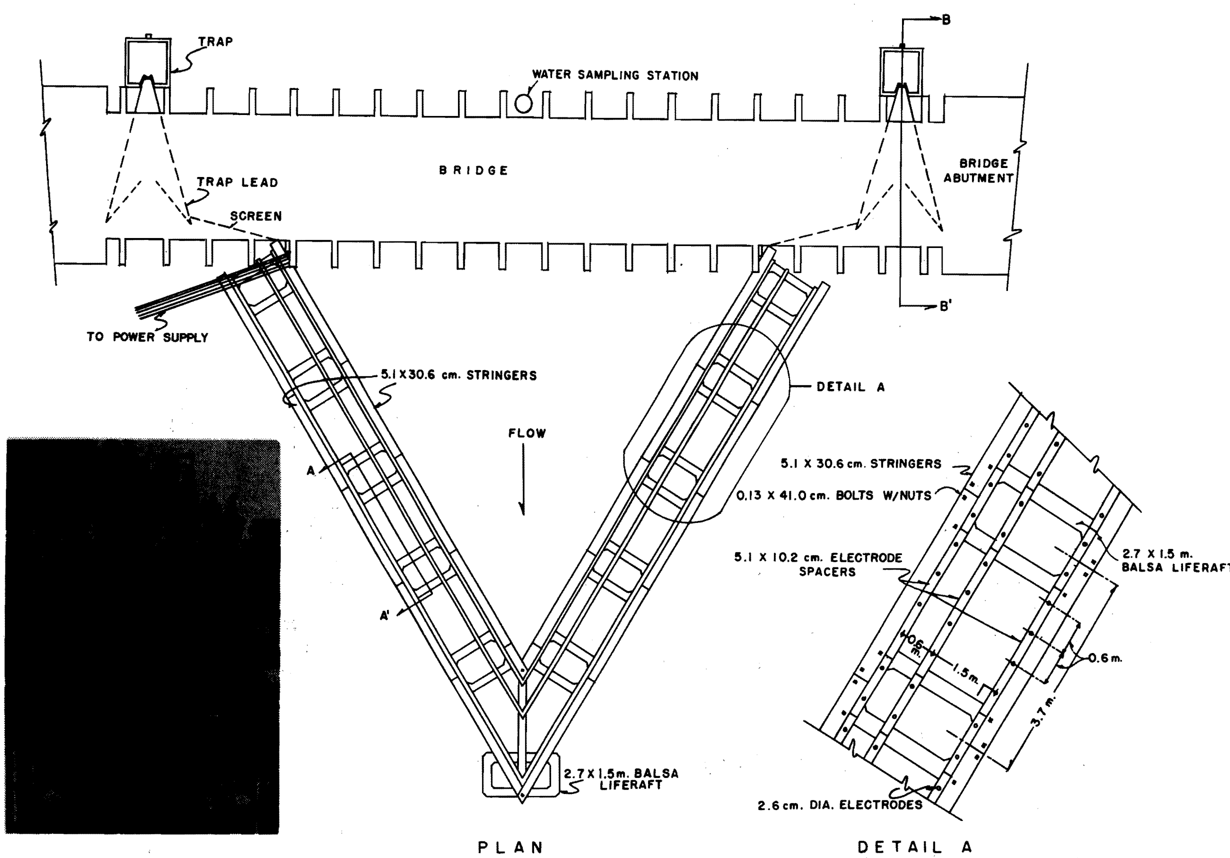

Figure 2.--Plan view and construction details of support structure for electrode array, including traps.

prevented the fish from escaping through the unenergized space between the end of the array and the lead of the traps. Two wooden traps (figs. 2 and 3) caught the fish at either end of the array. Each trap had a wooden V-shaped opening, which extended from bottom to surface.

The two trap leads were of 12-thread cotton netting of 3.8-cm. mesh (stretched measure, center of knot to center of knot). A throat extending from the bottom to the surface reduced the width of the opening to 45.7 cm. The bottom to the trap leads, which were of the same netting material, extended as an apron downstream on the streambed for an additional 3 m. to prevent the fish from escaping under the trap (figs. 2 and 3).

The two traps were each emptied with a net brail of 3.8-cm. mesh, 15-thread cotton netting fastened to a metal frame designed to fit the inside of the trap. To remove the fish from the trap, the entrance was blocked and the brail, which rested on the bottom, was lifted with a pulley.

Power Source

The direct current for the electrode array was provided by a 50-kw., 250-v., diesel-driven generator. A 10-kw., 110/220-v., gasoline-driven generator supplied the 60-cycle alternating current for the electrical and electronic equipment and utilities.

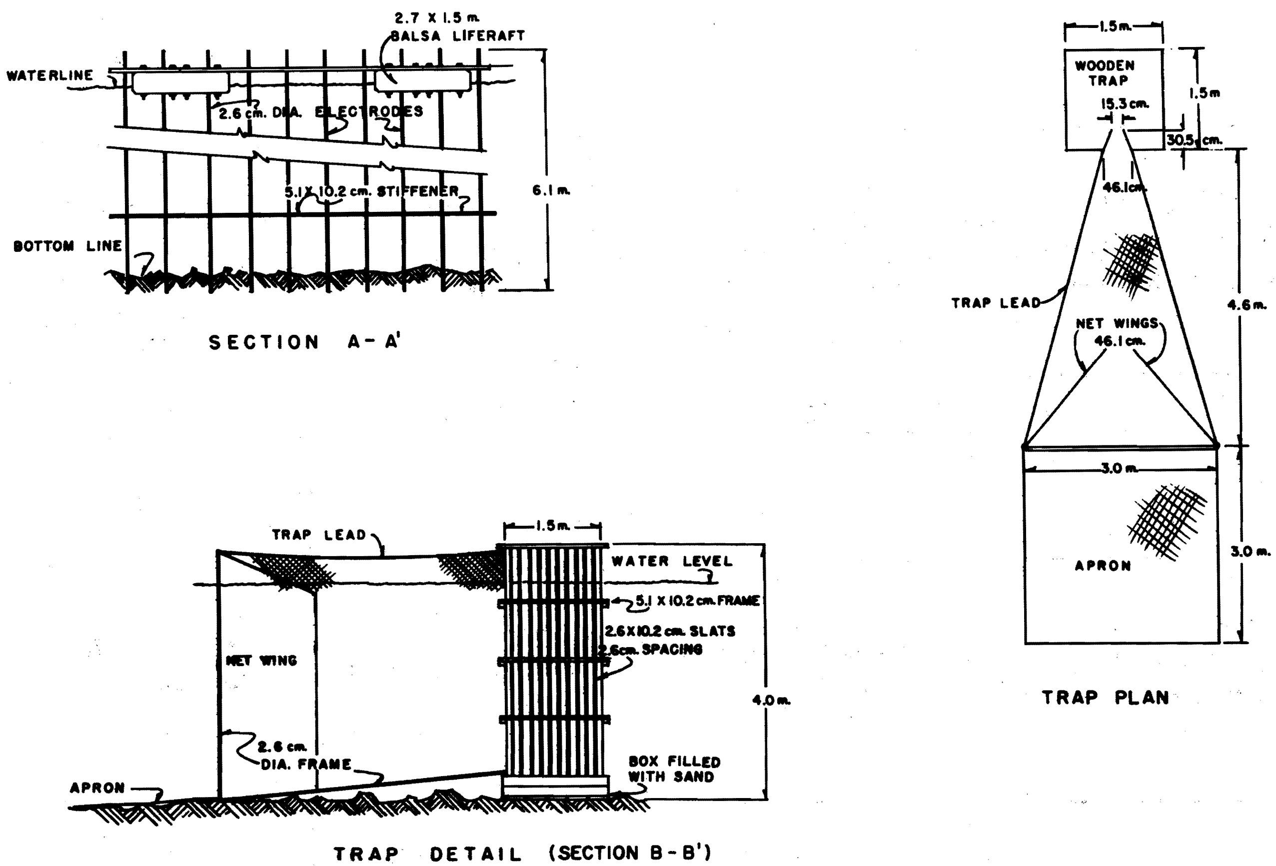

Figure 3.--Plan and detail of trap, including detail on electrode assembly.

Electronic Equipment

The electronic equipment included an ignition pulse generator and a thyratron switching unit, a control unit and sequential switch, and a master control panel (fig. 4). This equipment was similar in principle to that described in detail by Volz (1962).

The master control panel had voltage meters and ammeters for both a.c. and d.c., and a rheostat to regulate the voltage input of the d.c. generator. A calibrated oscilloscope provided monitoring of pulse shape, voltage, frequency, duration, and sequence.

The output of this equipment was pulsating direct current with substantially a square-wave form (2-30 pulses per second). The pulse duration had a range of 2 to 200 milliseconds, depending upon the frequency used. The equipment had a capacity of 80 amperes average current at 250 v., or 20 kw.

Method of Energizing Array

The array was divided into five sections which were energized in a repeating sequence. To accomplish this system of energizing the electrodes, those electrodes in the upstream row were connected to form a single cathode energized by every pulse. Each electrode in the middle row was connected to the corresponding electrode in the downstream row to form a series of five separate groups of anodes (fig. 5). Thus, the groups of anodes

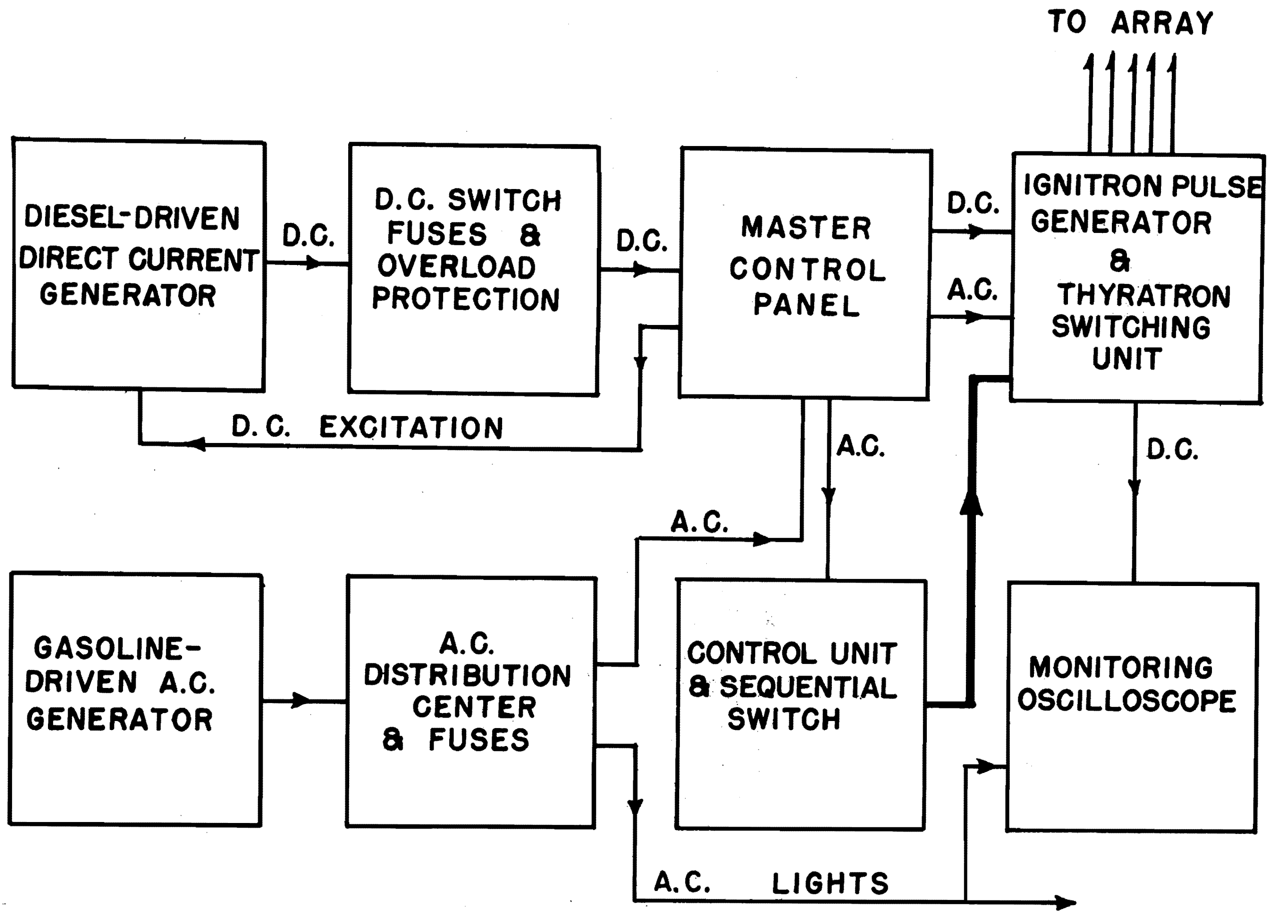

Figure 4.--Block diagram of electrical and electronic equipment.

together with the cathode were energized in a repeating sequence which produced a continuously moving electrical field throughout the array. The peak current was about one-fifth of that which would have been required to energize all of the electrodes at one time; however, the average power consumption was about the same for the sequential pulsing as it would have been for simultaneously energizing the electrodes.

Figure 6 shows the equipotential lines, prepared from analog plotting, created about the electrodes as they were momentarily energized by pulse No. 4. The numbers in the figure represent the percentages of applied voltage from positive to negative electrodes. The pattern of equipotential lines from each of the five pulses is similar to that illustrated for pulse No. 4. The principal differences are near the apex of the array where the convergence of the rows of electrodes causes some distortion.

Electrical Conditions

The electrical conditions of the experiment were: (1) pulse frequencies of 10 and 15 pulses per second (2 and 3 pulses per field per second, respectively, when five fields were pulsed in sequence); (2) pulse durations of 25 and 50 msec.; and (3) applied voltages of 140 and 180 v. at the electrodes.

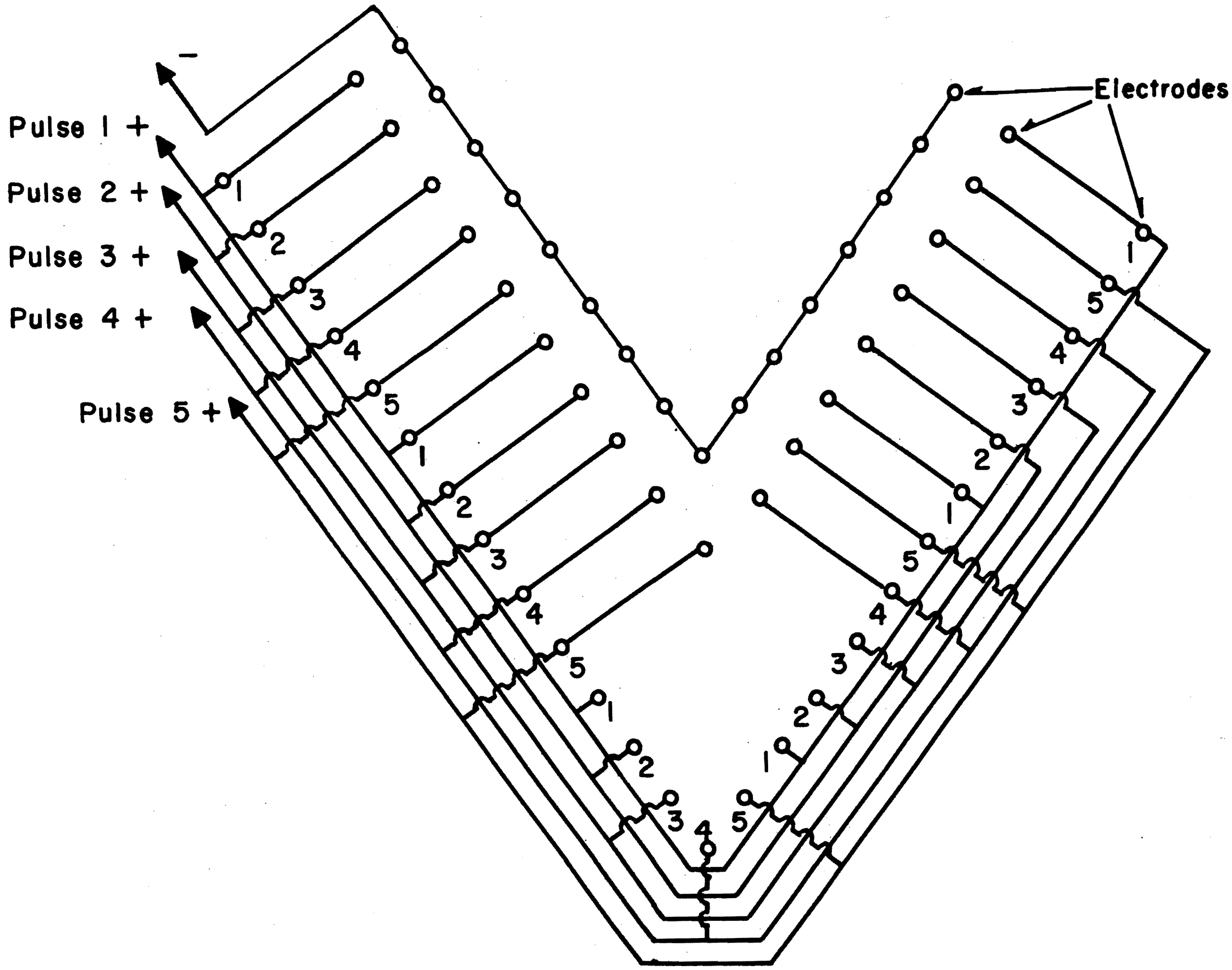

Figure 5.--Wiring diagram of electrode connections of array.

These conditions were selected on the basis of laboratory research to determine the optimum conditions of a sequentially pulsed d.c. electrical field to lead squawfish into enclosures or traps (Maxfield, Liscom, and Lander, 1959). The fish were released in the electrical field. Frequencies of 2, 5, and 8 pulses per second were tested; 2 pulses per second gave the best results. To ensure that fish moving upstream would encounter a frequency of 2 pulses per second in the array at Cascade Reservoir, each of its five electrode sections, or groups, were energized at this rate, or 10 pulses per second for the total array. Because the results in the laboratory with 5 pulses per second were considerably inferior to those with 2, we decided also to test 3 pulses per second per array section, or 15 pulses per second for the total array. As pulse duration and amplitude might cause significant differences under these conditions, two durations, 25 and 50 msec., and two amplitudes, 140 and 180 v., were tested.

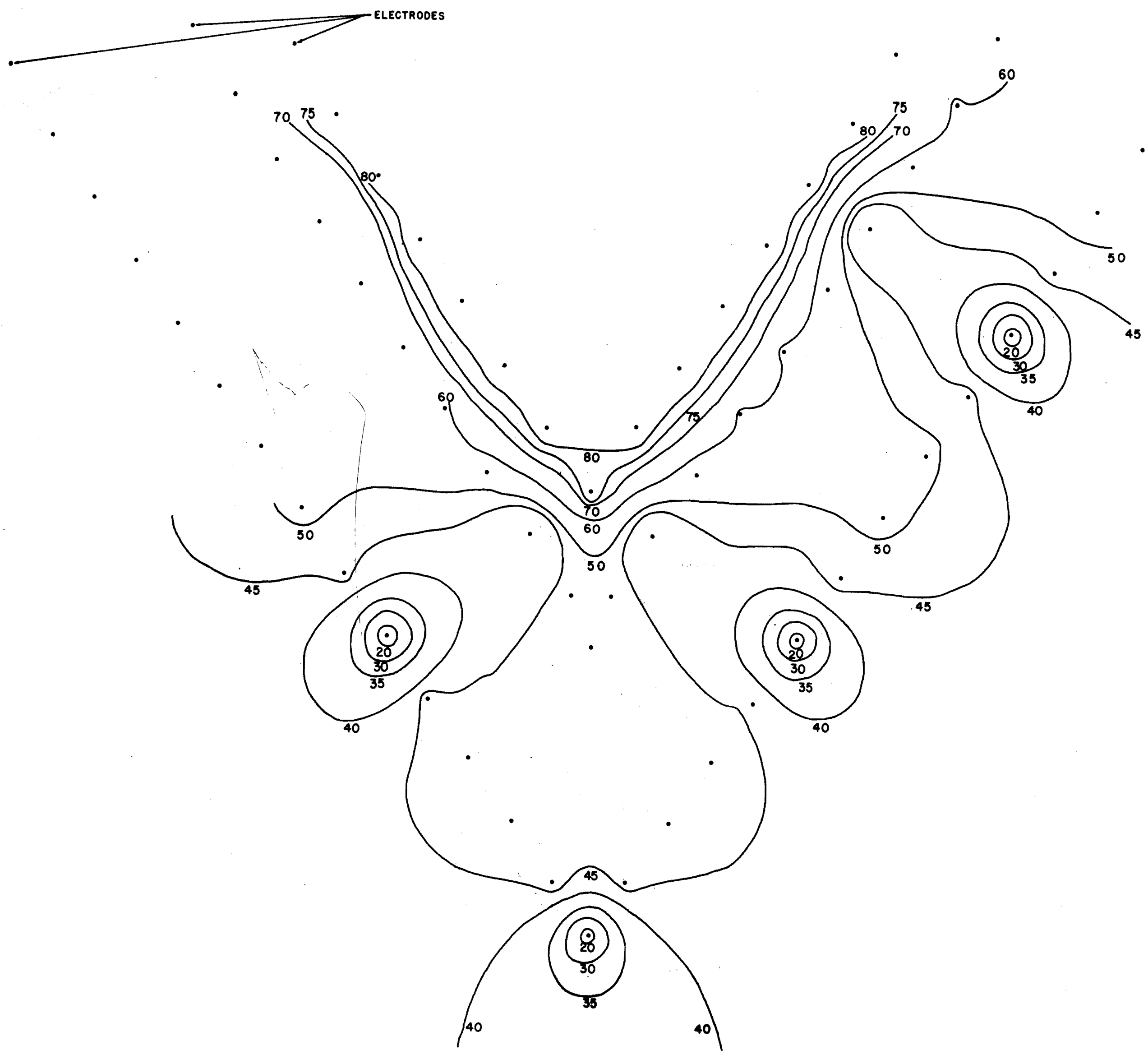

Figure 6.--Plot of equipotential lines for a portion of electrical field, No. 4.

PHYSICAL QUALITY OF WATER

Measurements of water resistivity and temperature were made every 4 hours, with few exceptions, from July 4 to Aug. 1 (table 1). Stream velocities were estimated to be near 0.15 m. per second.

Resistivity

Water resistivity was measured every 4 hours with a conductivity bridge; the sample for each measurement was taken at midchannel upstream from the test site (fig. 2). Resistivity[6] readings ranged from 20,000 to 46,000 ohm cm. (table 1).

[6]Conductivity of the water varied from 21 to 45 micromhos at 18° C.

Temperature

Water temperatures were taken directly from the channel in the same location where the samples for the resistivity measurements were obtained. A standard laboratory thermometer was used. Each measurement was recorded concurrently with resistivity. Water temperatures ranged from 15.6 to 25.6° C. (table 1).

METHOD OF TESTING EFFECTIVENESS OF INSTALLATION

We adopted the hypothesis that a field installation of this type is not effective in diverting adult squawfish into traps. To test

Table 1.--Water temperatures and water resistivities at Tamarack Falls, Cascade Reservoir, Idaho, July 4 to Aug. 1, 1958

	Water temperature						Water resistivity					
	a.m.			p.m.			a.m.			p.m.		
Date	4:00	8:00	12:00	4:00	8:00	12:00	4:00	8:00	12:00	4:00	8:00	12:00
	^{o}C.						Thousands of ohm cm.					
July												
4	--	16.0	15.6	16.6	16.6	--	--	43.0	40.5	37.0	42.0	--
5	--	16.6	17.8	18.9	18.9	--	--	44.0	40.5	40.0	41.7	--
6	--	18.4	18.9	18.9	18.9	18.9	45.0	44.0	41.2	37.0	40.5	41.0
7	18.9	18.4	20.0	20.0	16.6	19.4	43.0	43.5	42.2	41.0	43.0	40.0
8	18.9	18.9	19.4	20.0	19.4	19.4	46.0	42.0	41.0	39.0	43.0	39.0
9	19.4	19.4	20.0	20.0	20.0	20.0	44.0	43.0	42.0	38.0	43.0	39.0
10	20.0	20.0	21.1	21.1	20.0	20.6	44.0	42.0	33.0	38.0	46.0	43.0
11	20.0	21.1	21.1	21.6	21.1	21.1	45.0	40.0	36.0	29.0	36.0	40.0
12	21.1	21.1	22.2	22.8	22.2	21.6	44.0	41.5	33.5	34.0	41.0	42.0
13	21.1	21.1	21.1	21.1	21.1	21.1	43.5	39.5	37.0	35.0	41.0	42.0
14	20.0	20.6	20.0	22.2	21.1	21.1	43.5	39.5	28.0	29.0	38.0	36.0
15	20.6	20.0	21.1	21.1	21.1	20.6	42.5	38.0	35.2	34.0	37.0	39.5
16	20.6	20.0	21.1	23.4	21.1	20.6	41.0	38.2	37.0	33.0	37.5	38.5
17	20.0	20.0	21.1	20.0	21.1	20.0	40.0	39.0	35.5	35.5	40.0	41.0
18	18.9	20.0	20.0	21.1	20.6	20.0	41.0	37.5	34.2	34.0	36.2	38.0
19	19.4	19.4	19.4	21.1	21.1	19.4	39.0	39.0	37.5	33.0	35.0	35.0
20	19.4	19.4	21.1	21.1	22.1	21.1	41.0	36.5	32.0	26.2	29.0	35.0
21	20.0	20.0	21.1	21.1	21.1	20.6	36.0	33.5	29.0	25.0	31.2	33.0
22	20.6	20.6	21.1	23.4	21.1	21.1	33.8	32.0	26.5	20.0	25.0	25.5
23	21.1	21.1	22.8	25.6	22.2	23.4	29.0	27.2	24.0	20.0	23.2	26.8
24	21.6	21.6	21.1	22.2	21.6	21.6	31.0	30.0	24.0	22.0	24.0	27.0
25	21.6	21.6	22.2	22.2	21.1	22.2	38.5	27.5	23.2	20.0	21.2	24.0
26	21.6	22.2	22.8	22.8	22.2	21.6	28.0	25.5	22.2	24.5	26.0	29.0
27	21.1	21.1	21.1	21.1	21.1	21.1	32.5	31.2	27.2	26.5	27.2	28.0
28	20.6	21.1	21.1	21.1	21.1	21.1	30.0	30.0	27.0	23.0	22.0	25.5
29	20.0	21.1	21.1	21.6	21.1	21.1	30.0	30.0	27.0	24.5	26.2	29.5
30	21.1	20.0	20.6	22.2	21.6	21.1	31.0	32.0	29.0	26.0	26.0	29.5
31	21.1	21.1	21.1	22.2	22.2	21.1	30.0	29.5	23.5	22.2	22.2	26.2
Aug.												
1	21.6	21.1	--	--	--	--	27.5	27.5	--	--	--	--

this hypothesis, we required intervals when the power was on and when it was off. We then expected, if the hypothesis were true, to obtain equal catches in the traps under each power condition. A valid test would require, however, that equal numbers of fish be available to the installation when the power was on and when it was off. To satisfy this requirement we designed an experiment in which the power condition ("on" or "off") was alternated for successive 24-hour intervals between July 2 and August 1.

TESTING THE INSTALLATION

The experimental installation at Cascade Reservoir, as used to test the hypothesis, was built in June and tested from July 2 to Aug. 1. The testing began at 10:00 a.m., July 2, and continued through 10:00 a.m., Aug. 1. During this testing, electrical conditions maintained continuously over a 24-hour period were followed by a 24-hour period of "power off." Thus 15 days with "power on" were alternated with 15 days with "power off." Three sets of electrical conditions of varied pulse frequency, pulse duration, and voltage were used as shown in table 2, and one set (pulse frequency, 10 pulses per second; pulse duration, 50 msec.; and voltage, 180 v.) was repeated. Thus four series of tests were made. Several species of fishes besides squawfish were caught in the traps, but only records of squawfish were kept (table 2).

Figure 7, prepared from table 2, shows the catches for each 48-hour test of 24 hours "power on" and 24 hours "power off" expressed as percentages of the total 48-hour catch. In figure 7, each test period started at

Table 2.--Numbers of squawfish in traps 1 and 2 for each 24-hour test with "power on" and for each 24-hour test with "power off," July 2 to Aug. 1, 1958

Test series	Date	Squawfish: Power condition	Fish in trap No. 1	Fish in trap No. 2	Total fish	Electrical conditions: Voltage	Frequency	Duration
			Number	Number	Number	Volts	Pulse/sec.	Msec.
	July							
1	[1] 2	On	0	3	3	180	10	50
Do.	3	Off	2	4	6	--	--	--
Do.	4	On	4	23	27	180	10	50
Do.	5	Off	15	8	23	--	--	--
Do.	6	On	13	33	46	180	10	50
Do.	7	Off	6	7	13	--	--	--
Do.	8	On	15	44	59	180	10	50
Do.	9	Off	4	6	10	--	--	--
Do.	10	On	13	32	45	180	10	50
Do.	11	Off	1	1	2	--	--	--
Do.	12	On	12	17	29	180	10	50
Do.	13	Off	2	0	2	--	--	--
Do.	14	On	13	16	29	180	10	50
Do.	15	Off	6	2	8	--	--	--
2	16	On	1	12	13	180	15	25
Do.	17	Off	3	4	7	--	--	--
Do.	18	On	2	3	5	180	15	25
Do.	19	Off	3	3	6	--	--	--
Do.	20	On	2	9	11	180	15	25
Do.	21	Off	3	4	7	--	--	--
3	22	On	5	9	14	140	10	50
Do.	23	Off	2	2	4	--	--	--
Do.	24	On	8	23	31	140	10	50
Do.	25	Off	6	2	8	--	--	--
Do.	26	On	6	11	17	140	10	50
Do.	27	Off	4	2	6	--	--	--
4	28	On	2	13	15	180	10	50
Do.	29	Off	2	2	4	--	--	--
Do.	30	On	5	5	10	180	10	50
Do.	31	Off	0	4	4	--	--	--
	Total	On	101	253	354	--	--	--
		Off	59	51	110	--	--	--
	Grand Total		160	304	464	--	--	--

[1] The date shown is the date the 24-hour period began; July 2 is actually 10:00 a.m., July 2 to 10:00 a.m., July 3; July 3 is 10:00 a.m., July 3 to 10:00 a.m., July 4;.....

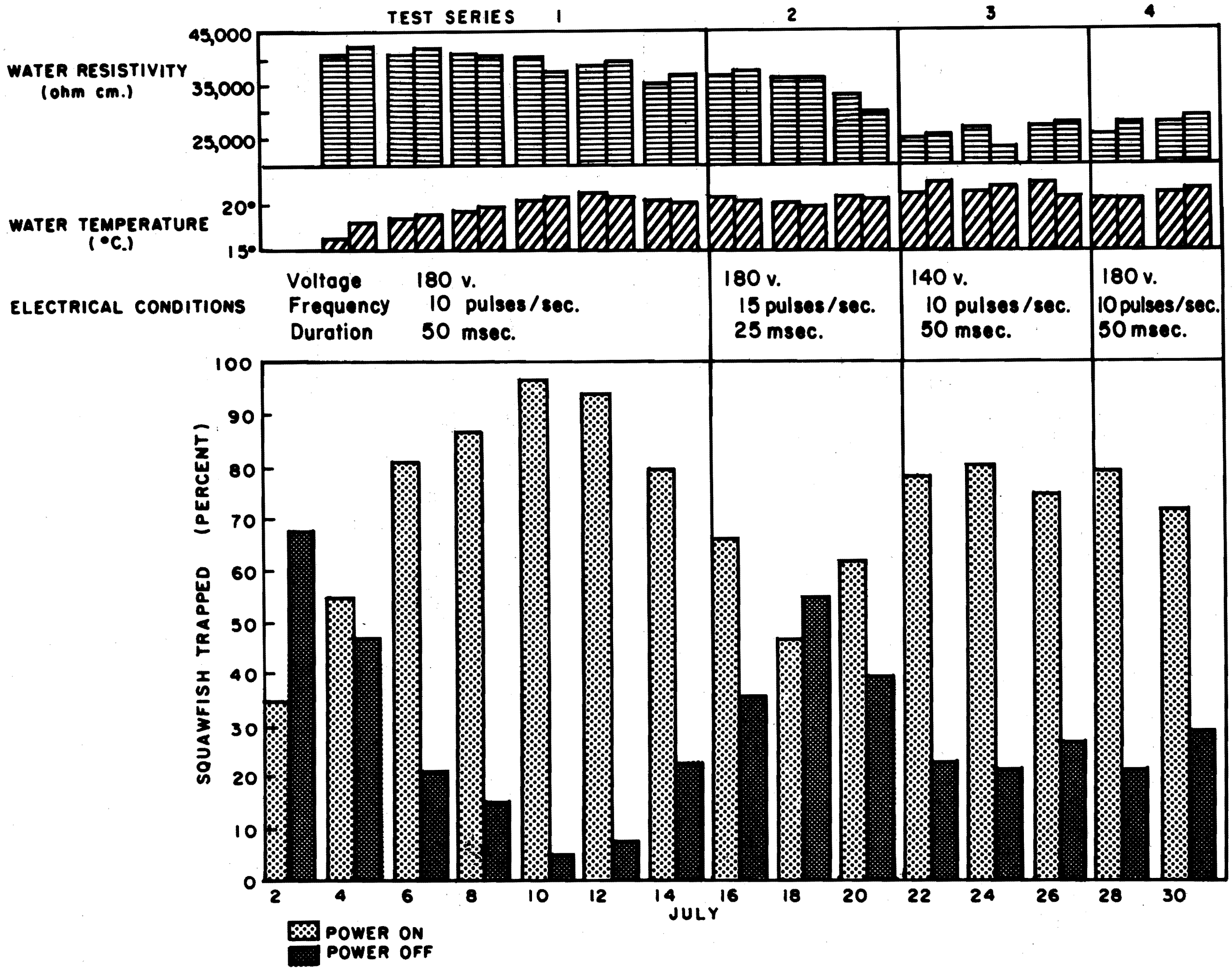

Figure 7.--Percentage of squawfish trapped with "power on" and with "power off" for each 48-hour test, July 2 to Aug. 1, 1958. Data on trapping of squawfish are plotted against average daily water temperature and water resistivity.

10:00 a.m. on the date shown and ended 48 hours later. Also shown in figure 7 are average daily water resistivity and water temperature readings.

Table 3 was prepared to show the numbers and percentages of squawfish taken in each trap for the different conditions. One possible explanation of the consistently greater numbers of fish in trap No. 2 during "power on" lies in the response of the squawfish to the direction of the positive charge of the sequentially pulsed electrical fields. The electrical fields in the electrode array were switched in the direction of the apex away from trap No. 1 (west side of bridge, right bank), and this switching continued in the direction of trap No. 2 (east side of bridge, left bank). It has been demonstrated in the laboratory that adult squawfish move toward the positive charge (Maxfield, Liscom, and Lander, 1959). The larger catches of squawfish in trap No. 2, in comparison with catches in trap No. 1, may have reflected this response.

Table 4 groups the data of table 3 under the different electrical conditions. We assumed that equal numbers of fish were available when the power was "on" and "off" within each test series. The results suggest that the test condition with voltage 180 v., pulse frequency 15 per second, and pulse duration 25 msec. was less effective than the other electrical conditions in diverting the northern squawfish into traps. This result is also shown in figure 8.

Under the hypothesis that the electrical fields did not divert the fish into the traps, we expected half of the total count in all traps to be taken during each power condition. The total catches were as follows (table 4):

Power condition	Total catch of squawfish Number
Power on	354
Power off	110
Expected (in each trap)	232

Table 3.--Numbers and percentages of squawfish in traps 1 and 2 in four series of 48-hour tests, 24 hours "power on" and 24 hours "power off," July 2 to Aug. 1, 1958

Test series	48-hour tests	Date	Squawfish caught						Percentage of total				Electrical conditions		
			Power on			Power off			Power on		Power off		Voltage	Frequency	Duration
			Trap 1	Trap 2	Total	Trap 1	Trap 2	Total	Trap 1	Trap 2	Trap 1	Trap 2			
Number			....	Number	....				....	Percent	....		Volts	Pulses/sec.	Msec.
1	7	July 2-15	70	168	238	36	28	64	29.4	70.6	56.2	43.8	180	10	50
2	3	July 16-21	5	24	29	9	11	20	17.2	82.8	45.0	55.0	180	15	25
3	3	July 22-27	19	43	62	12	6	18	30.6	69.4	66.7	33.3	140	10	50
4	2	July 28-Aug. 1	7	18	25	2	6	8	28.0	72.0	25.0	75.0	180	10	50
Total	--	--	101	253	354	59	51	110	28.5	71.5	53.6	46.4	--	--	--

Table 4.--Numbers and percentages of squawfish trapped in four series of 48-hour tests, 24 hours "power on" and 24 hours "power off," July 2 to Aug. 1, 1958

Test series	48-hour tests	Date	Squawfish caught			Percentage of total		Electrical conditions		
			Power on	Power off	Total	Power on	Power off	Voltage	Frequency	Duration
Number			....	Number	....	.... Percent	....	Volts	Pulses/sec.	Msec.
1	7	July 2-15	238	64	302	78.8	21.2	180	10	50
2	3	July 16-21	29	20	49	59.2	40.8	180	15	25
3	3	July 22-27	62	18	80	77.5	22.5	140	10	50
4	2	July 28 to Aug. 1	25	8	33	75.8	24.2	180	10	50
Total	--	--	354	110	464	76.3	23.7	--	--	--

TEST SERIES	DATE	ELECTRICAL CONDITIONS		
		Voltage	Frequency	Duration
		Volts	Pulse/sec.	Msec.
1	July 2-15	180	10	50
2	July 16-21	180	15	25
3	July 22-27	140	10	50
4	July 28-31	180	10	50

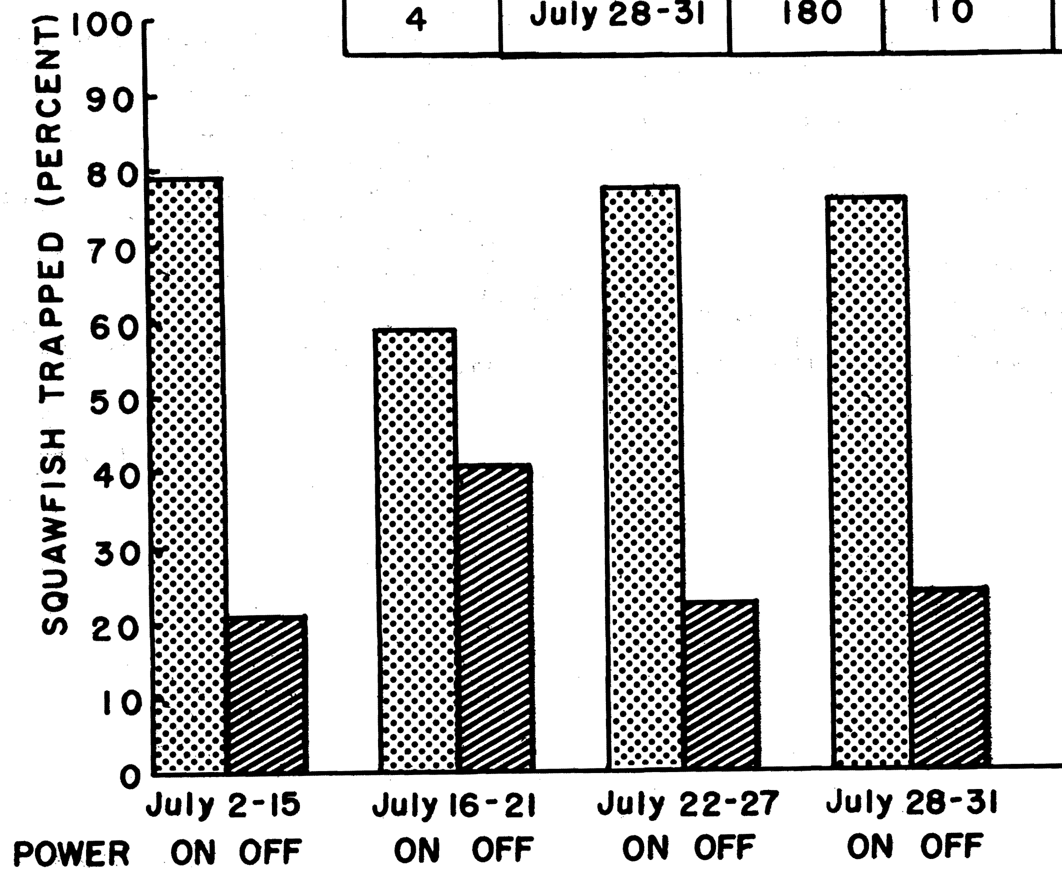

Figure 8.--Percentage of squawfish trapped in four series of 48-hour tests, 24 hours "power on" and 24 hours "power off," July 2 to Aug. 1, 1958.

Chi-square was significant ($p < 0.01$); therefore, we concluded that the squawfish were diverted by the electric fields.

For each of the four test series, we subtracted the "power off" catches from the corresponding "power on" catches (table 4); these figures estimate the numbers trapped under the influence of electricity. To examine the relative effect of electricity during the four series, we then divided these estimates by the "power on" catches and tested the fractions for uniformity. The fraction trapped under the influence of electricity was significantly smaller ($p < 0.01$) for the test series July 16-21. Thus, the data suggest that the effectiveness of the electrical fields in trapping squawfish is decreased when the pulse frequency exceeds some value between 10 and 15 pulses per second (2 and 3 pulses per field per second, respectively, when five fields were pulsed in sequence) or when the pulse duration is shortened below some value between 30 and 50 msec.

CONCLUSIONS AND RECOMMENDATIONS

The operation of the electrical installation at the Tamarack Falls site permits the following conclusions and recommendations: (1) the electrical fields of the electrode array were effective in diverting adult squawfish into traps; (2) the work reported here was an attempt to determine the problems of operation of our equipment and evaluate its effectiveness under field conditions.

For future application of this technique, attention should be given to the following:

1. The velocities and volumes of water to be expected at the site of operation of the installation.
2. Replacement of parts or sections of the electrode array and traps.
3. Power equipment to enable rapid removal of large numbers of fish.
4. Upstream barrier to collect large pieces of debris.
5. Disposal of squawfish and other undesirable fish removed from traps.

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