APPLICATIONS OF SALT IN ELECTROFISHING

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United States Department of the Interior, Fred A. Seaton, Secretary
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APPLICATIONS OF SALT IN ELECTROFISHING

By

Robert E. Lennon and Phillip S. Parker
Fishery Research Biologists
Leetown (P.O. Kearneysville), W. Va.
Bureau of Sport Fisheries and Wildlife

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ABSTRACT

The use of cattle blocks of salt is an effective and economical means of reducing high resistivities and improving electrofishing in large and small, high and low, cold and warm streams in the southern Appalachian Mountains. Electrofishing trials were conducted in salted and salt-free sections of high resistivity streams. Using salt improved the effective range of the electrode system. A greater percentage of available fish was taken on initial passes through test sections; larger numbers of fish were taken per section due to the extended effective range of the electrodes; and the fish were more thoroughly stunned and easier to net. The rate of mortality among trout taken in salted section was less than 1 percent greater than among fish collected in salt-free sections. The high yield of fish obtained provides more accurate population estimates.

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APPLICATIONS OF SALT IN ELECTROFISHING

Success in electrofishing is largely dependent upon the electrical resistivity of the water. Resistivity, or specific resistance, is defined as the electrical resistance of a cubic centimeter of any material and is measured in ohms. Measurements can be expressed in ohms resistivity or in its reciprocal ohms conductivity. In water, resistivity varies inversely to a great extent with the quantity and quality of dissolved solids and to a lesser but important degree with temperature. It, in turn, influences the strength and range of an electrical field in water and it must therefore be overcome in electrofishing to reach and narcotize fish. Failure to take the factor of resistivity into account often predisposes the application of electrogear in certain waters to mediocre or poor results.

The wide variety of AC and DC electrode systems in use today with power inputs of 115 to 500 volts, represents more or less successful means for collecting fishes in waters of various resistivities. Research and development continue to result in improvements on electrode systems, power sources, and methods of application to increase the efficiency of electrofishing in very high and very low resistivity waters. Little has been done, however, to alter resistivities to improve electrofishing. Such alteration would be unnecessary on most waters and impractical or impossible on some. However, it has proven practical to reduce the extremely high resistivities of trout streams in the southern Appalachian Mountains to levels at which all-season electrofishing can be done efficiently.

Resistivities measured in 50 streams in Great Smoky Mountains National Park in North Carolina and Tennessee, and in Shenandoah National Park in Virginia, ranged from 28,500 to 207,000 ohms with the majority exceeding 50,000 ohms. These are among the highest readings obtained in natural waters in North America. Measurements made recently on 15 trout streams in the northern Appalachian Mountains in New Hampshire ranged from 22,000 to 122,000 ohms and indicate that the high resistivity condition is perhaps typical of streams draining the entire Appalachian chain of mountains. In contrast, spring water in production pools at the Leetown, W.Va., fish-cultural station has resistivities of 2,460 to 2,600 ohms at 54° to 62° F. Samples of single-distilled water at the same station ranged from 90,000 to 110,000 ohms at 80° F.

The use of an alternate-polarity electrode system enabled successful electrofishing in streams with resistivities up to 100,000 ohms but efficiency declined sharply above that level. The necessity of sampling fish populations in as many of the streams of the parks as possible, often during cold seasons when low temperatures increased the electrical resistance of waters, led to experiments with blocks of cattle salt to reduce resistivities and increase the efficiency of the shocker equipment.

METHODS

A portable, battery-powered, 1,000-cycle conductivity bridge (Model RC-7, Industrial Instruments, Inc.), with K-0.1 probe was used to determine the resistivities of waters in the laboratory and field. Readings are obtained quickly and directly over a wide range in ohms resistivity.

The salt used in laboratory and field trials was 50-pound blocks of white cattle salt, commonly available at about one dollar each. No appreciable differences were noted in trials made with plain and mineralized blocks of salt that would justify the slight additional cost for the latter. In field tests, one to several blocks of salt were placed 25 to 50 yards upstream from seine-blocked sections 100 yards long in streams of 5 to 50 cfs flow.

The portable, gasoline-powered generators used for electrofishing were of 230-volt, AC, 600- and 2500-watt capacities. The electrode systems employed were Petty-type, alternate-polarity units (Petty 1955). Improvements incorporated into this electrode system for park work included trailers to expand the electrical field in high-resistivity waters and the substitution of No.8, 440-wire, electric welding cable for the braided copper shielding-wood dowel electrodes (Lennon & Parker 1955). The welding cable has proven easier to use on rough streams and is much more durable than shielding.

The welding cable electrodes were made as follows: two equal lengths of cable were clamped together. The insulation was removed from the first 30-inch portion of one cable, then a 6-inch gap left, and a 30-inch portion of the other cable was bared. Thus the insulation was removed from alternate 30-inch portions of the cables, always leaving 6-inch gaps of insulated cable between the bared portions, until the desired number of electrodes was obtained. Electrode systems of 12, 18, and 24 feet in length are used most frequently, depending upon the size of the stream to be shocked. Longer systems could be used effectively on larger streams.

Solderless terminal lugs are fastened to cable tips on one side of an electrode system. Terminals of this type can be easily and quickly bolted to alternate-polarity terminals on the bottom of the switch-brail. The cable tips at the opposite end of the system are insulated from one another with electrical tape. Dog-chain clasps are used to fasten electrode systems to the brails and thereby systems of different lengths can be readily substituted on the brails.

THE EFFECTS OF SALT UPON RESISTIVITY

The effects of cattle salt applied in 1 ppm amounts to 1 liter samples of water were observed in the laboratory. The resistivities of the samples ranged from 48,000 to 1,000,000 ohms. With the exception of the latter sample, the resistivities were considered typical of those encountered in southern Appalachian trout streams. Measurements of resistivity were made successively following 1 or 2 ppm applications of salt until the accumulated salt in a water sample amounted to 30 ppm (table 1).

The samples were held in water baths throughout the trials to preserve near-constant temperatures in the test solutions. The influence of water temperature on resistivity was exhibited during preliminary trials wherein the resistivity of one sample increased from 53,000 to 57,000 ohms when the temperature changed from 61 to 59° F. In another, the resistivity increased from 48,000 to 56,000 when the temperature dropped from 64 to 56° F. In a third sample the resistivity increased from 104,000 to 148,000 ohms when the temperature was reduced from 64 to 40° F.

The results of applying salt to selected samples showed that relatively few ppm of the salt are required to reduce resistivities by 50 percent, particularly among the higher resistivity waters. For example, the resistivity of a sample at 52,000 ohms was reduced 50 percent by 11 ppm of salt; at 76,000 ohms by 8 ppm; at 110,000 ohms by 5 ppm; at 220,000 ohms by 3 ppm; and at 1,000,000 ohms by less than 1 ppm of salt. The progressive reduction in resistivity was slower in water samples at 40° than at 60° F.

These trials demonstrated that decreasing advantage is gained by the addition of more salt beyond 12 ppm (figure 1). Regardless of initial resistivities and temperatures of the samples, the application of 30 ppm of salt put final resistivities within a range of 8,000 ohms (14,000 to 22,000 ohms).

The effects of salt on resistivities in large and small streams were observed in both parks during the winter of 1956-57. This season of the year was chosen since water levels and temperatures were relatively stable. The more elaborate trials were made on Indian Creek in the Great Smokies since it is a small and rapid trout stream with a closely parallel truck road which facilitated movements from one trial station to another. Salt points and stations were located at convenient sites and immediately preceding a trial, the volume of stream flow, the normal resistivity, and water temperature were measured at each station.

Typical of the results obtained in Indian Creek and other streams were those observed when a 50-pound block of salt was placed in the water for 15 minutes (table 2). The stream at this point was flowing at 34.4 cfs, the resistivity was 207,000 ohms, and the water temperature was 44° F. Sixteen pounds of salt were dissolved from the block in the 15-minute period. At Station I, 100 yards downstream, the resistivity dropped in 11 minutes to a low of 54,500 ohms or 26 percent of the original level. It increased abruptly to 150,000 ohms 5 minutes after the salt was removed from the stream but did not return to the original level until 27 minutes later.

Table 1. — The resistivities of water samples to which various concentrations of cattle salt were added

Salt concentration (ppm)	Resistivities in thousands of ohms										
	Sample L (60° F.)	Sample K (59° F.)	Sample I (62° F.)	Sample J (60° F.)	Sample F (60° F.)	Sample G (61° F.)	Sample H (56° F.)	Sample M (40° F.)	Sample C (65° F.)	Sample E (63° F.)	N (deionized) (60° F.)
0	52.0	57.0	76.0	76.0	104.0	110.0	112.0	148.0	220.0	222.5	1,000.0
1	47.5	51.0	68.0	69.0	82.0	90.5	90.0	123.0	155.0	155.0	330.0
2	44.0	47.0	60.0	61.0	75.0	78.0	78.0	105.0	117.0	120.0	205.0
3	41.0	43.5	55.0	55.0	66.0	68.0	69.0	92.0	94.0	96.0	150.0
4	38.0	40.0	50.0	50.0	58.0	61.0	62.0	82.0	80.0	82.0	115.0
5	35.0	38.0	45.0	47.5	54.0	54.0	55.0	73.0	68.0	70.0	95.0
6	33.5	36.0	42.0	42.5	48.0	50.0	50.0	66.0	59.0	62.0	83.0
7	32.0	33.0	39.0	39.5	45.0	46.0	46.5	61.0	54.0	55.0	72.0
8	30.0	31.5	36.5	37.0	43.0	42.0	43.0	56.0	48.5	50.0	63.0
9	28.5	30.0	34.0	35.0	39.0	38.0	40.0	53.0	44.0	45.0	57.0
10	27.5	28.5	32.0	33.0	36.0	36.5	37.5	49.0	40.5	41.5	51.0
11	26.0	27.0	30.5	31.0	34.0	31.5	35.0	46.0	38.0	39.0	47.0
12	25.0	26.0	29.0	29.5	31.5	30.0	33.0	44.0	34.5	37.0	43.0
13	24.0	24.5	27.5	28.0	30.0	29.0	31.5	41.0	33.0	34.5	40.5
14	23.0	23.5	26.0	26.5	28.5	27.5	29.5	39.5	31.0	32.5	37.0
15	22.0	22.5	25.0	25.5	27.0	26.0	28.5	38.0	29.5	31.0	35.0
16	21.5	22.0	24.0	24.5	26.0	25.0	27.0	36.0	27.5	29.5	33.0
17	20.5	21.0	23.0	23.5	25.0	24.0	26.0	34.0	26.0	28.0	31.0
18	20.0	20.5	22.0	22.5	23.5	23.0	24.5	33.0	25.0	26.5	29.0
19	19.5	19.5	21.2	22.0	22.5	22.0	23.5	31.5	24.0	25.0	28.0
20	18.5	19.0	20.5	21.0	22.0	21.2	23.0	30.0	23.0	24.5	27.0
21	....	....	20.0	20.5	21.0	20.5	22.0	29.5	22.2	23.5	26.0
22	17.5	17.5	19.0	20.0	20.0	20.0	21.5	28.5	21.2	22.5	25.0
23	....	....	....	....	....	....	20.5	27.0	20.5	22.0	23.5
24	16.5	17.0	18.0	18.5	19.0	19.0	20.0	26.5	20.0	20.8	22.5
25	....	....	....	....	....	....	....	25.5	....	20.0	22.0
26	15.5	16.0	17.0	17.5	18.0	17.5	18.5	25.0	....	....	21.0
27	....	....	....	....	....	....	....	24.0	18.0	19.0	20.5
28	15.0	15.0	16.0	16.5	16.5	17.0	17.5	23.5	....	....	19.5
29	....	....	....	....	....	....	....	22.5	17.0	17.5	....
30	14.0	14.5	15.0	15.5	16.0	15.5	16.5	22.0	16.2	17.0	18.5

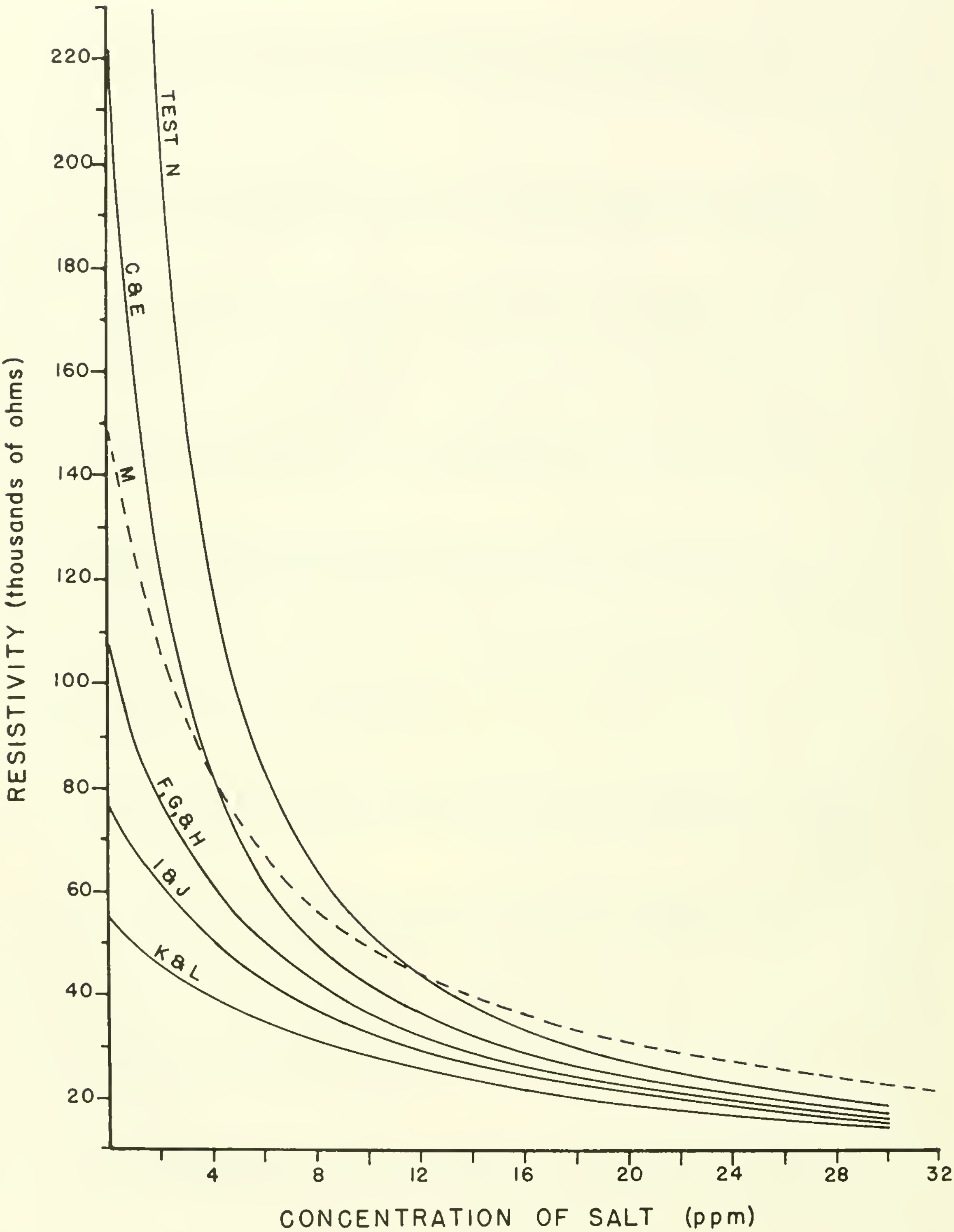

Figure 1.--The effects of cattle salt on the resistivities of various water samples. The results in Samples K and L; I and J; F, G, and H; and C and E listed in table 1 were averaged. Test N was made with a sample of deionized water for comparison

Table 2:- Resistivities measured at 3 stations below point where 50-pound block of cattle salt was placed in stream for 15 minutes. A total of 16 pounds of salt was dissolved from the block. Elapsed time is listed from introduction of salt block into stream to the last measurement of resistivity at Station III. Stations were located downstream from salt point as follows: Station I, 100 yards; Station II, 2 miles; and Station III, 3.5 miles.

Elapsed time (minutes)	Station I		Elapsed time (minutes)	Station II		Elapsed time (minutes)	Station III	
	Resistivity (in thousands)	Salt (ppm)[1]		Resistivity (in thousands)	Salt (ppm)[1]		Resistivity (in thousands)	Salt (ppm)[1]
1	207.0	0.0	69	180.0	0.1	128	148.0	0.5
2	207.0	0.0	70	175.0	0.2	129	140.0	0.7
3	150.0	1.0	71	171.0	0.3	130	136.0	0.9
4	70.0	5.0	72	165.0	0.5	131	132.0	1.0
5	62.0	6.0	73	158.0	0.6	132	129.0	1.1
6	58.0	7.0	74	150.0	0.8	133	125.0	1.2
7	56.0	7.3	75	142.0	1.0	134	123.0	1.3
8	56.0	7.3	76	134.0	1.2	135	119.0	1.4
9	55.0	7.5	77	127.0	1.4	136	117.0	1.5
10	55.0	7.5	78	120.0	1.6	137	115.0	1.5
11	54.5	7.6	79	114.0	1.8	138	113.0	1.6
12	54.5	7.6	80	108.0	2.0	139	112.0	1.6
13	54.5	7.6	81	104.0	2.2	140	111.0	1.7
14	54.5	7.6	82	100.0	2.4	141	110.0	1.7
15	55.0	7.5	83	97.0	2.6	142	110.0	1.7
16	58.0	7.0	84	95.0	2.7	143	111.0	1.7
17	58.0	7.0	85	93.0	2.8	144	111.5	1.6
18	66.0	6.0	86	92.0	2.8	145	112.0	1.6
20	150.0	1.0	88	93.0	2.8	146	112.5	1.6
22	180.0	0.4	90	96.0	2.6	147	114.0	1.6
24	190.0	0.2	92	102.0	2.3	148	116.0	1.5
26	195.0	0.1	94	110.0	1.9	149	118.0	1.4
28	200.0	0.1	96	120.0	1.6	150	120.0	1.4
30	205.0	0.1	98	129.0	1.4	151	122.0	1.3
35	205.0	0.1	100	138.0	1.1	152	125.0	1.2
40	205.0	0.1	102	146.0	0.9	153	127.0	1.2
45	205.0	0.1	104	154.0	0.7	154	129.0	1.1
47	207.0	0.0	106	159.0	0.6	155	131.0	1.0
			108	162.0	0.5	156	134.0	0.9
			110	165.0	0.4	157	136.0	0.9
			112	168.0	0.4	158	138.0	0.8
			114	171.0	0.3	159	140.0	0.8
			116	172.0	0.3	160	142.0	0.7
			118[2]	173.0	0.3	165	152.0	0.4
						175	161.0	0.2
						185	165.0	0.1
						187	165.0	0.1
						226	170.0	0.0

1/ Concentrations of salt in ppm estimated from curves in figure 1

2/ Observations at Station II terminated in order to intercept bolt of salt at Station III

Station II was located 2 miles downstream from the salt point. The volume of flow was 43.4 cfs, the resistivity 188,000 ohms, and water temperature 44° F. The salt reached this point in 69 minutes and the resistivity dropped to 92,000 ohms or 49 percent of the original level. After 50 minutes of observation at this station, the resistivity had increased to 173,000 ohms and readings were discontinued in order to intercept the salt at the next station.

At Station III, 3.5 miles downstream from the salt point, the volume of flow was 51.6 cfs, resistivity 170,000 ohms, and water temperature 44° F. The salt reached this station approximately 10 minutes before the observer did or about 118 minutes after the block was introduced into the stream at the salt point. The 10-minute error was closely estimated from back-calculations and from results of other trials when only Stations I and III were observed. The salt was in the area of Station III for 110 minutes and the resistivity dropped to a low of 110,000 ohms or 65 percent of the original.

The data obtained at the salt point and at Stations I and III were related to the concentration of salt in ppm by two methods. First, the concentration of salt added to the stream at the salt point and the average concentrations of salt as it passed Stations I and III during the periods of observation were calculated on the basis of the 16 pounds of salt dissolved from the block during the 15-minute period, the stream flow rates measured in cfs at Stations I and III, and the lengths of time in minutes that the salt was in the station areas. Accordingly, the salt dissolved into the stream at the salt point at an average rate of 8.3 ppm for the 15-minute period. Its average concentration at Station I during the 44 minutes it influenced resistivity was 2.8 ppm. The average concentration at Station III for 110 minutes was 0.8 ppm. In the second method, the concentrations of salt at the various levels of resistivity measured at Stations I and III were estimated from the curves shown in figure 1. The concentrations of salt at Station I ranged from 0.1 to 7.6 ppm as the resistivity dropped from 207,000 to 54,500 ohms but the average concentration for the 44-minute period was 2.6 ppm. The concentrations at Station III ranged from 0.1 to 1.7 ppm as the resistivity dropped from 170,000 to 110,000 ohms and the average concentration was 0.6 ppm. Despite the dilution of the salt and the stretchout of the bolt over the 3.5 miles between the salt point and Station III, the resistivity was appreciably lowered.

The close agreement at Stations I and III between the calculated average concentrations of salt (2.8 and 0.8 ppm respectively) and the estimated average concentrations (2.6 and 0.6 ppm respectively) derived from curves in figure 1 supports the validity of the curves and indicated that they can be used in the interpretation of data on resistivity collected in streams.

Additional, detailed observations were made on Indian Creek and 8 other streams (table 3). One or two blocks of salt were placed in them for varying periods of time and resistivities were greatly reduced. The degree to which the resistivity was reduced in a trial area was roughly controlled by placing the salt block in either fast, slow, shallow, or deep spots in the stream. In Roaring Fork (Stream G, table 3), 31 pounds of salt were dissolved at Station I during a 2-hour period to reduce the resistivity from 106,000 to a range of 37,000 - 66,000 ohms. The stream flow was 12.5 cfs and water temperature 49° F. At Station III, 32 pounds of salt were used in 1.75 hours to reduce the resistivity from 103,000 to a range of 40,000 - 52,000 ohms when the flow was 11.9 cfs and temperature 50° F. At Station IV, 50 pounds of salt were used in 2.5 hours by placing the block in fast water. The resistivity was reduced from 106,000 to 20,000 ohms, the flow was 12.5 cfs, and water temperature was 50° F. The salt used at the rate of 20 pounds per hour at Station IV had greater effect in reducing resistivity than did the rate of 15.5 pounds per hour at Station I. It was found, too, that a block of salt would last from 1 to 4 hours, depending on the size of the stream and the location of a block placed in it.

The effects of salt on an electric field in water were tested at one of the stations on Roaring Fork. The stream at this point was 33 feet wide, its flow was 25.8 cfs, and its temperature was 50° F. A 6-electrode, alternate-polarity system was stretched across the stream and the relative strengths of the electric fields in the water were measured at input voltages of 230 and 330 volts AC

Table 3:- The results of preliminary tests of electrofishing with 230-volt, alternate-polarity gear in adjacent, 50-yard sections of salted and salt-free waters. Four or more passes were made through each seine-blocked section on 9 small streams which contain rainbow trout, eastern brook trout, or both.

Stream	Water temp. (°F.)	Salt used (lbs.)	Resistivity (thousands of ohms)		Salted section						Salt-free section					
					Pass and number of trout					Total trout	Pass and number of trout					Total trout
			Normal	With salt	I	II	III	IV	V		I	II	III	IV	V	
A	50	64	80.0	26.0	45	7	9	1	0	62	19	5	2	3	0	29
B	46	44	155.0	35.0	9	0	2	0	..	11	9	1	3	0	..	13
C	49	20	110.0	20.0	13	1	0	0	..	14	11	3	1	3	..	18
D	48	30	142.0	38.0	27	4	1	1	..	33	10	3	5	2	..	20
"	48	50	136.0	17.0	27	2	3	0	..	32	7	6	1	0	..	14
E	42	28	119.0	56.0	14	3	0	0	..	17	15	2	1	2	0	20
F	50	47	159.0	26.0	11	2	0	1	..	14	7	3	0	0	..	10
G	49	31	106.0	37.0	13	1	0	0	0	14	7	0	1	0	0	8
"	49	40	101.0	....	9	2	1	0	..	12	8	2	1	0	..	11
"	50	32	103.0	40.0	17	3	0	1	..	21	11	2	4	0	..	17
"	49	50	106.0	20.0	15	4	1	0	..	20	5	2	1	2	1	11
H	44	40	116.0	30.0	18	3	3	2	0	26	14	2	4	3	1	24
"	47	32	115.0	30.0	9	4	1	0	0	14	13	5	0	3	0	21
I	45	31	176.0	25.0	5	1	0	1	..	7	9	0	1	0	..	10
Totals					232	37	21	7	0	297	145	36	25	18	2	226
Percentage of total					78.1	12.5	7.1	2.3	0	56.8	64.2	15.9	11.0	8.0	0.9	43.2

and at resistivities of 50,000 ohms in salted water and 100,000 ohms in salt-free water. Voltage readings were made in the water at measured distances from the electrode system by means of a probe with 5-inch gap and a voltmeter. The readings indicated that the electric field was extended as well as stronger in the salted water, particularly in a lateral direction from the electrodes. For example, at 330 volts input, the 1-volt isovolt line extended 4 feet off the end of the electrode system and 4.3 feet downstream as compared with 2.4 feet off the end and 4 feet downstream in salt-free water. The extension of the field laterally in salted water has proven a great advantage in rough and brush lined streams.

The alternate-polarity electrofishing gear operated well and was found to be safe to use in salted water. The risk of shocks is minimized by wearing rubber boots and rubber-coated work gloves.

THE EFFECTS OF SALT IN ELECTROFISHING

A series of trials to determine the effects of salt and reduced resistivities on electrofishing were run on 9 small streams which contained rainbow trout, eastern brook trout, or both (table 3). The persistently high water levels which prevailed in both parks through the late winter and spring of 1957 restricted the choice of streams to those which were small, accessible, and which consequently had relatively few fish per station.

Fourteen, 100-yard survey sites were selected and divided into 50-yard test sections which were as nearly alike in every respect as possible. It was likely, however, that some sections contained more fish than adjacent ones. The test sections were blocked upstream and downstream with 3/4-inch stretch mesh, nylon seines to prevent movements of fish into or out of the sections.

The salt blocks for salted test sections were placed in the stream 25 to 50 yards upstream, usually in or above a series of falls or cascades so that thorough mixing and even distribution of the salt would occur before it reached the test section. The blocks were weighed before and after each trial to determine the total amount used. The original resistivities ranged from 80,000 to 176,000 ohms and were reduced in salted sections to a range of 17,000 to 56,000 ohms. Water temperatures at the 14 stations ranged from 42° to 50° F.

Four to five passes were made through each of the salted and salt-free test sections with 230-volt gear during the electrofishing trials. The brail-handlers and scap-netters started at the upstream end of a section and worked downstream to the check seine. This downstream technique was superior to the upstream approach on rough waters in respect to numbers of fish caught and ease of operation. The trout captured during each pass were maintained separately in livecars until fishing in a test section was completed.

There were immediately apparent differences observed in salted and salt-free sections. A larger proportion of the fish available were taken on the first pass through salted sections (78.1 percent) than in salt-free sections (64.2 percent). In two passes, 90.6 percent of the available fish were removed from salted sections in contrast with 80.1 percent from salt-free sections. The combined take in fourth and fifth passes in salted sections amounted to only 2.3 percent of the total fish whereas those captured in salt-free sections amounted to 8.9 percent.

The term available fish used in respect to totals listed refers to those specimens which are in such location, position, condition, and size that they are collectable by the shocker method. This qualification is applied since it is seldom possible to remove all fish from a section of stream by any collecting mechanisms or methods despite sincere attempts to do so.

More trout were taken in salted sections than in salt-free sections in 9 of the 14 stations. This was due in part to the very high resistivities of salt-free waters and to the fact that the lateral field of the electrode system was greater in salted water. Fish were therefore shocked and taken from under banks and boulders where they otherwise would be unobtainable.

The disparity in numbers of trout taken in salted and salt-free sections would have been greater had not the test sites been blocked off with check seines. Many trout in the high resistivity, salt-free sections could not be captured until driven or frightened downstream to the check seine and then surrounded and stunned there. On the other hand, most trout in the salted sections were taken throughout the sections and before the check seines were reached.

One important advantage conferred by salt is that the trout and other species were much easier to capture than in salt-free waters. The reduced resistivities were reflected in more thorough and prolonged stunning of the fish. Escapement from the electric field, particularly in swift cascades, occurred less frequently in salted sections since most specimens were immobilized rather than addled as was typical in salt-free waters. The use of salt therefore made the job of scap netters much easier.

There was doubt that these data obtained on 9 small streams could be considered representative since water conditions were poor and the numbers of fish available were small. The trials were therefore extended through the summer and fall of 1957 to include a total of 100 salted sections on 28 streams and 40 salt-free sections on 16 streams (table 4). A wide variety of conditions relative to weather, water, resistivity, and crew skill was included.

As many as 6 passes were made with electrofishing gear through seine-blocked sections of 50 to 100 yards in length. Up to 189 trout were taken in individual salted sections and 122 trout in salt-free sections. The percentages of trout taken per pass differed, however, by less than 1.5 percent from the preliminary data obtained on the 9 streams (table 3). The first passes through salted sections yielded 77.5 percent of 6,421 trout in 28 streams as compared with 78.1 percent of 297 trout in 9 streams. In contrast, the first passes through salt-free sections yielded 64.7 percent of 2,247 trout on 16 streams and 64.2 percent of 226 trout on the 9 streams.

The same advantages noted in electrofishing in salted sections on the first 9 streams held throughout the expanded trials. Again there were consistently more trout taken in salted than salt-free waters. The trout were more thoroughly stunned in salted waters which improved the pickup rate in very swift, high, and/or turbid waters.

It was presumed that the reduction of resistivities might result in an increased rate of mortality of fish but it proved only slight. The total mortality of trout in salted sections from the combined effects of shocking, holding in livecars, anesthetizing, measuring, and weighing amounted to 4 percent in comparison with 3 percent in salt-free sections. Under optimum shocking conditions when resistivities are reduced by salt to a range of 30,000 to 40,000 ohms, many stations have been worked with electrofishing gear with no losses among trout. The rate of mortality of fish tends to increase, however, when resistivities are reduced to 20,000 ohms or lower.

The shocker was more effective in salted than salt-free, high resistivity waters on all sizes of eastern brook, brown, and rainbow trout, including newly hatched, young-of-the-year specimens 0.9 to 1.5 inches long. Of the 3 species, brook trout and brown trout were more easily captured than rainbow trout in open waters. Of the other species encountered in test sections, the majority of daces, shiners, stonerollers, sculpins, darters, American eels, basses, and sunfishes, were removed in 1 or 2 passes when resistivities ranged between 25,000 and 50,000 ohms. Hogsuckers appeared to be more resistant to shock and capture at all resistivities than the other species.

The close agreement in the percentage of trout collected per pass through salted sections on the 9 streams and on the 28 streams demonstrates not only the consistent advantage of using salt but permits the use of the percentages as escapement factors when but 1 or 2 passes are made through a test section. It is seldom possible to make 4 or 5 passes through a large number of stream survey sites in order to obtain accurate estimates of fish populations. It has proven practical to make but 1 or 2 passes through a good number of representative stations and apply the percentages listed for omitted passes when computing population estimates. The validity of this

Table 4:--The total numbers and percentages of rainbow trout and eastern brook trout captured per pass in 100 salted stations on 28 streams and 40 salt-free stations on 16 streams in Great Smoky Mountains and Shenandoah National Parks with 230-volt, alternate-polarity electrofishing gear

Passes	Salted section Number of trout	Salted section Percentage	Salt-free section Number of trout	Salt-free section Percentage
I	4,975	77.5	1,453	64.7
II	794	12.4	384	17.0
III	442	6.9	233	10.4
IV	210	3.2	158	7.0
V	0	0.0	19	0.9
VI	0	0.0	0	0.0
Totals	6,421	100.0	2,247	100.0

approach to population estimates has been checked and confirmed on a number of the 28 test streams with cresol and with rotenone.

CONCLUSIONS

1. The use of cattle blocks of salt is an effective and economical means of reducing high resistivities and improving electrofishing in large and small, high and low, cold and warm streams in the southern Appalachian Mountains.

2. One or two 50-pound salt blocks were usually sufficient in 28 test streams with flows up to 50 cfs to reduce resistivities from a maximum of 207,000 ohms to a range of 25,000 to 50,000 ohms. Increases in the concentration of salt had proportionately smaller effects in reducing the resistivities below 25,000 ohms.

3. A block of salt lasts up to 4 hours in the water. Substantial reductions in resistivities were measured 3.5 miles downstream. The placement of a block in fast or slow, shallow or deep water influenced its rate of dissolution and thereby roughly controlled the degree to which resistivities were reduced.

4. Electrofishing trials were conducted in salted and salt-free sections of high resistivity streams. The following advantages of using salt were determined: the 230-volt, alternate-polarity electrofishing gear performed best within a range of 30,000 to 40,000 ohms; the effective range of the electrode system was greater, particularly in a lateral direction; a greater percentage of available fish was taken on initial passes through test sections; larger numbers of fish were taken per section due to the extended effective range of the electrodes; and the fish were more thoroughly stunned and therefore easier to scap net.

5. The rate of mortality among trout taken in salted sections was less than 1 percent greater than among fish collected in salt-free sections. Mortalities tended to increase sharply, however, in waters in which resistivities were reduced to 20,000 ohms or lower. On the basis of both mortality and gear performance, the lower limit of desirable resistivity was considered to be 25,000 ohms.

6. Extensive trials have shown that the use of cattle salt in conjunction with alternate-polarity electrofishing gear provides the best means for all-season sampling of fish populations in the extremely high resistivity streams of the southern Appalachian region. The high yield of fish obtained by these means facilitates the computation of more accurate estimates of populations.

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