T H E S I S

on

THE ACTION of DIFFERENT ORGANIC and INORGANIC ACIDS on THE FRY of the CHINOOK SALMON and STEELHEAD TROUT

Submitted to the

O R E G O N A G R I C U L T U R A L C O L L E G E

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for the

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in

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BY

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I.

INTRODUCTION

The effect of Organic and Inorganic Acids upon aquatic life is a very important problem from many standpoints. It is of vast commercial importance in the preservation of our game and food fishes, in Fish Hatchery operations and in the rearing of fishes and aquatic life in private fish ponds; it also has a very important bearing and a general interest in all aquarium operations. Much work has been done along this line already but much is yet to be done. The most valuable work in fish preservation has probably been done by Dr. V. E. Shelford, E. B. Powers, S. A. Forbes and others, of which further mention will be made further on.

The work reported in this paper was undertaken with a view toward clearing up some of the difficulties which attend the practice of aquiculture. It represents but one phase of the general problem of the causes of mortality among fish fry under hatchery conditions. Although the motive was primarily utilitarian, it was interesting to note as the work progressed, how inevitably the various lines of investigation led over in the field of pure science, especially that of physical chemistry and chemical physiology.

The Hatchery at the Oregon Agricultural College consists of two wooden troughs; supplied with water from the city main. Dirt, silt, fungi, algae, and other organic and inorganic matter accumulate in considerable quantities in the troughs. It was noticeable that the greater the quantity of these materials deposited in the troughs, the higher was the death rate to both eggs and fish. The data in Plates II to VI show conclusive evidence of a higher death rate at one time than at another. What might be the cause lying back of this fluctuation in mortality? This is the problem which the author endeavored to solve. The following aspects of this problem are set forth in detail in the subsequent pages.

Four points of attach were suggested, namely:

1. To detect the presence of organic Acids from decaying or macerating organic matter.
2. To detect any harmful inorganic Acids.
3. To determine the presence of injurious minerals or salts or the absence of necessary salts and minerals.
4. To detect gases such as Nitrogen and Carbon dioxide gas. Much work has already been done on this subject and it is a known fact that Nitrogen CO_2, and Oxygen in too highly concen-

trated a form kills fish very quickly.

It is the hope of the author that some light may have been thrown on the problem of the interrelation of aquatic organisms and their environment.

PLATE I

EXPLANATION
of

POLLUTION PLATES

The following plates (II to VI) are the results of careful observations during the past two years of the number of fish which died daily; noting the Temperature of the air and water; sedimentary deposits and growing organic materials. For detailed information consult the column of remarks on each plate. The work which follows was done to determine whether or not the death rate was correlated with local contamination; such as poisons generated by the fish themselves, by dead fish in the troughs, by growing fungi, algae, and other organic matter, or whether it is related to contamination from more remote sources at the head of the water supply.

PLATE II

FALL CHINOOK SALMON EGGS and YOUNG FRY

Taken Oct. 2, 1919, in Sandy River
25,000 eggs

Table data taken by

PROF. G. F. SYKES & J. Ø. FOLEY

TROUGH POLLUTION CHART

Year
1919-20 Temperature of H_2O 1@C (Noted by #1 and Air by 1')
Temperature of Air 1' @ C

Date	A.M. In Trough A and B.	P.M.	A.M.	P. M.	Dead A (eggs) Daily average both tanks				Dead B (fry)			
Nov.	1'	1'	1'	1'	1	2	3	4	1	2	3	4
22	10	13	10	12	8	17	1	6	0	1	3	2
23	11	12.50	11	13	10	30	0	0	0	1	2	15
24	12	14	11	14	12	35	4	0	6	10	20	2
25	13	15	12	15.5	5	0	0	0	35	4	7	1
26	10	12	9.5	10.5	3	2	0	0	9	3	2	0
27	9.50	11	9	10	2	0	0	0	6	4	1	3
28	8.8	10	8	10	4	3	1	2	12	16	4	0
29	11	13	10	12.5	11	1	1	1	0	0	1	0
30	10	12	9.7	11	12	4	3	0	0	0	0	9

REMARKS:

Sedimentary deposits quite thick necessitating cleaning of troughs. Saprolegnia fungi growing freely on dead forms in a very short time. Probability of waste as Organic Acids from sediment fungi and decaying matter.

Date	A.M.	P.M.	A.M.	P.M.	Dead A (eggs) Daily average				Dead B (fry) both tanks			
	In trough A & B											
Dec.	1'	1'	1'	1'	1	2	3	4	1	2	3	4
1	10	11	Same as Nov.		6	0	0	9	0	4	6	9
2	11	12.5	"	"	18	11	10	4	9	10	12	10
3	11.5	13	"	"	10	0	6	3	6	14	10	2
4	10	12	"	"	4	10	4	0	0	0	1	0
5	9.5	10.5	"	"	5	0	2	0	3	2	1	0
6	8.7	9.5	"	"	6	1	4	5	4	1	0	1
7	19	12	"	"	7	8	4	2	6	7	3	1
8	11	13	"	"	4	1	1	2	2	2	4	3
9	12	13.5	"	"	10	6	5	4	11	7	6	5
10	12	15	"	"	20	3	2	1	21	4	12	15
11	18	18	"	"	21	20	20	1	14	12	20	10
12	13.5	13	"	"	25	15	16	10	26	16	15	18
13	14.5	14	"	"	30	10	9	8	32	40	10	11
14	10	10	"	"	50	43	20	30	40	30	18	22
15	11.5	10	"	"	20	50	20	60	24	25	16	18
16	13.5	13	"	"	15	40	30	20	21	36	28	18

REMARKS:

During period of the cold there was an extremely high rate of mortality at least 500-600 fry dying. There was also large numbers killed when freeze was over and sediment commenced to come through the pipes.

PLATE III

Continuation of Chart Experiment on

TROUGH POLLUTION on CHINOOK SALMON

Experimental data discontinued at end of two months & troughs cleaned up.

Data of Table by G. F. Sykes & J. O. Foley

1919-20					Temperature of H_2O noted by #1			Temperature of Air noted by #1		
Date	Time									
Dec.	1'	1'	1'	1'	1	2	3	1	2	3
17	1.45	5	5	8	400	35	10	21	30	40
18	3.5	6	7	9	250	10	5	3	10	15
19	3	5	4	7	55	56	12	4	6	10
20	5	7	6	9	10	25	15	20	21	20
21	7	10	8	13	4	20	21	18	16	14
22	10	13	11	12.5	30	21	20	5	7	6
23	11	12.5	11	14	24	30	20	10	21	20
24	10.5	12	12	15	40	60	80	40	60	0
25	12	14.5	13.5	16	0	0	0	5	7	4
26	13	13	14	12.5	0	0	0	0	0	0
27	12.5	15	11	14	0	0	0	3	2	1
28	13	16	12.5	13.5	5	10	15	0	14	16
29	14	15	10	15	2600	2100	2100	490	3050	2440
30	14.5	16	13.5	15	100	60	50	700	41	14
31	11	12	12	13.5	4	60	20	600	100	350

REMARKS:

As soon as all sediment was cleaned from trough at end of December, noted lessening of death rate was noted. Much foam, sediment, fungi and algae from murky water.

December 17-19 100 fish transferred from A' to B'. Sediment killed thousands of eggs and fish. Many in A' died in hatching. Many in A' froze during the cold spell.

PLATE IV

EXPERIMENT ON TROUGH POLLUTION FOR YEARS 1920-21

1921 Date	Temperature of Air	Temperature of H_2O	Dead in Trough A	Remarks
Jan. 1-31	4 to 13	2 to 12	400 Eggs did not hatch or died.	
Feb. 1	5	3	20	Received shipment of 5000 Chinook eggs from Little Salmon River and commenced hatching on Jan. 1, 1921. From then to 31- No data taken during hatching period except for number of eggs not hatching, which was lower due to milder weather conditions. Temperatures and counts taken at 6:00 PM. *High death rate due to shutting off of water and suffocation of fish in such large numbers in trough. Sediment was let collect in trough now, and was about 1/2 to 1 inch thick all during the month of March, and a higher death rate was noticeable in this case of this year's experiment as in that of last year's in regard to increase of sediment fungi and algae, and hence pollution of trough. Green Algae and Saprolegma Fungi very plentiful and growing on dead fish if left in the trough over 24 hours.
2	6	4	25	
3	8	6	21	
4	10	9.5	31	
5	8	7	30	
6	9.5	8	25	
7	11	9	29	
8	11.5	10	60	
9	12	11	70	
10	10.5	7.8	80*	
11	9.5	6.9	100*	
12	8	5	200*	
13	7	5	40	
14	8.5	6	20	
15	9.5	7	10	
16	10	8	12	
17	11	9	13	
18	12	10	14	
19	11.5	9.5	20	
20	13.5	11.5	21	
21	14	12	21	

PLATE IV -cont'd

1921 Date	Temperature of Air	Temperature of H_2O	Dead in Trough A	Remarks
22	12.5	11	20	
23	11	9	20	
24	12.5	11	18	
25	13	11	19	
26	10.5	8.8	20	
27	12.5	10.3	21	
28	14.5	12.5	21	

PLATE V

1921 Date	Temperature of Air C	Temperature of H_2O C	Dead in A	Remarks
Mar. 1	12.5	10.0	20	
2	13.0	11.0	21	Sediment and Fungi thick
3	9.0	8.0	18	
4	8.7	7.8	16	
5	12.0	10.8	15	
6	15.0	12.0	14	
7	12.0	11.0	5	
8	13.2	11.8	4	Trough cleaned up.
9	16.5	13.8	3	
10	13.3	11.6	2	
11	14.0	12.1	1	
12	12.2	10.0	20	
13	12.2	10.0	21	
14	12.5	9.2	22	
15	11.0	13.6	21	Trough Becoming dirty
16	16.0	13.2	4	
17	16.2	12.1	14	
18	14.3	12.0	16	
19	14.0	12.0	18	
20	14.0	12.0	21	
21	14.0	12.0	20	
22	12.5	10.0	24	
23	13.0	10.8	34	
24	13.5	10.9	50	Much sediment, algae fungi and decomposed matter
25	12.6	10.0	60	

PLATE V-cont'd

1921 Mar.	Temperature of Air C	Temperature of H_2O C	Dead in A	Remarks
26	14.0	10.9	21	
27	14.5	10.8	20	
28	14.0	10.6	10	
29	12.3	10.5	12	
30	13.6	11.0	14	
31	12.7	11.0	16	
April				
1	13.0	11.2	12	
2	12.8	10.6	10	
3	12.0	10.2	9	
4	12.0	10.5	8	Trough cleaned up and death rate con-
5	12.6-	10.4	6	stant and slow.
6	12.3	9.8	5	
7	12.6	9.6	2	
8	12.0	9.0	1	
9	16.2	14.0	0	
10	16.0	14.2	4	
11	15.1	13.8	9	
12	14.3	11.0	6	
13	12.6	10.6	5	

PLATE VI

1921 Apr.	Temperature of Air C	Temperature of H_2O C	Dead in A	Remarks
14	13.6	10.0	21	
15	14.2	10.2	18	Trough very clean
16	13.8	7.8	29	
17	15.6	10.0	21	One fish alive with fungi growing on it
18	14.2	11.0	21	
19	13.6	9.0	20	
20	12.5	11.0	20	Fair amount of sediment and fungi
21	13.5	10.2	16	
22	11.0	7.8	24	
23	12.0	10.0	18	Congestion of belly region of fish
24	13.8	11.0	19	
25	13.0	9.0	21	
26	15.0	11.0	20	Many fish popeyed
27	16.0	14.5	20	
28	16.8	10.5	16	Many fish with head and tail curved backward
29	15.4	11.0	24	
30	14.2	10.2	18	
May 1	15.5	13.1	20	
2	16.6	12.2	21	Mortality is greater with greater change of climatic conditions
3	13.2	10.5	24	
4	15.6	12.0	50	
5	14.7	12.5	24	
6	15.8	13.1	36	Eggs that are dead in trough seem to have a similar toxic effect upon live fish.
7	15.9	13.6	24	
8	16.2	14.6	60	

PLATE VI-cont'd

1921 May	Temperature of Air C	Temperature of H_2O C	Dead in A	Remarks
9	15.8	13.2	20	
10	14.9	12.6	35	

EXPERIMENT DISCONTINUED

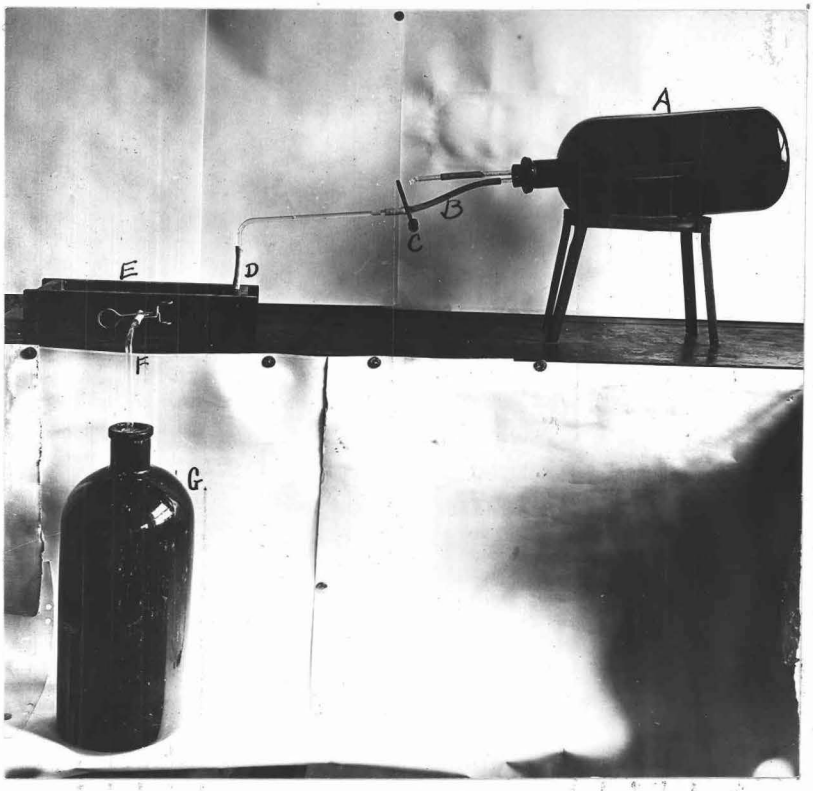
II.

MATERIALS and METHODS of STUDY.

This article will be concerned with the resistance of young fish to certain common acids, organic and inorganic, and their application to the problem at hand, it will be necessary to go somewhat into detail as to materials and methods used in carrying on these experiments. The Fishes used for study were the Fry of the Chinook Salmon (Oncorhyncus Tschawytscha) and of the Steelhead Trout, (Salmo Rivuloris) in its very immature stages. The Acids selected were, Hydrochloric, Sulphuric, Acetic, Tartaric, Oxalic and Citric Acids. A series of preliminary experiments were performed to determine the survival periods of the Fish and then normalities of a representative worth were selected. Each solution differed in concentration approximately 50%. This was deemed accurate enough to suit the case as all showed a very marked susceptibility and very weak solutions had to be used of a necessity. The Fry were first weighed in a tared beaker with a known weight of water and later were immersed in a running solution of known strength of acid to determine the survival time of the fish. The apparatus used (Plate VII.) was a Modification of Dr. V. E. Shelford's Gradient tank. (Jr. of American Pharmaceautical Association, Vol. VIII. No. 7, July 1918.

The apparatus is as follows; 1. A three Liter bottle, (a) with the Stock Solution and equipped with a tube and hosing (B) and air inlet (C) the flow being regulated by means of a stop cock; the solution passes down into a trough 6 inches wide by 12 inches long, thru a T shaped inlet (D) and passed out thru a perforated tube as an outlet (E) this was then caught by a 3 liter bottle (F) the outflow being regulated by a stop cock at G. Experiments were run at different temperatures to note any variation. The survival time of the Fish was noted in minutes and the weight in grams. Both survival time curves and velocity of Fatality curves were plotted. Check solutions of tap water were also run along with these in order to eliminate all error possible. The Acids were standardized against $\frac{N}{20}$ Sodium Hydroxide. The Hydrogen Ion concentration work was done by the colormetric method, (Jr of Bacteriology, Vol. II No. 1; Jr of Washington Academy of Science Vol. VI. P. 483-1916; and from Park and Williams Text on Pathogenic Organisms) by the permission and aid of materials furnished by the Department of Bacteriology.

PLATE VII



III.

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EXPLANATION
of
PLATES VIII to XLIX

The following plates show orginal research done with Citric, Oxalic, Sulphuric, Acetic, Hudrochloric, and Tartaric Acids on the Fry of the Chinook Salmon and Steelhead Trout. Normalities of varying strengths (approximately .1 N to .004 N in each case) were used. The weight of the fish in Grams was taken before and after its death in the Acid; as will be explained in detail under section, "Materials and Methods). The survival time was recorded in minutes and seconds, and any peculiarities of behavior were set down in a Remarks column. The Experiments were performed at different ages, weights and temperatures to note any difference in survival time. Later on survival time and velocity of fatality curves were plotted. (See Experimental Data Plates 51 to 56.)

PLATE VIII

CITRIC ACID

SPECIES-ONCORHYNCUS TSCHAWYTSCHA - Temperature 25-C

Normal	Weight of fish in Grams	May 7-14,'21 Survival time in minutes	Remarks
.0980	.300	9 min.	
	.250	9 "	
.0476	.200	9 " 30 Sec.	
	.250	9 " 40 "	
.0224	.420	15 "	
	.400	15 " 10 "	
.0108	.230	18 " 30 "	
	.250	18 " 45 "	
.0048	.400	37 "	
	.350	36 " 30 "	
.0018	.200	1 hour	
	.250	1 hour	
.0004	.250	3 days	
	.400	Alive at end of 72 hours	

PLATE IX

CITRIC ACID

SPECIE ONCORHYNCUS TSCHAWYTSCHA

Temperature 15.5-C

Normal	Weight of fish in Grams	Apr.4-9, '21. Survival time in Minutes	Normal	Weight of fish in Grams	Apr.11-16, '21. Survival time in Minutes
.0980	.330	12 min.	.0980	.300	11 min.30 sec.
.0476	.350	17 " 15 S..	.0476	.300	16 "
.0224	.400	22 "	.0224	.350	21 " 30 "
.0108	.500	30 " 15 "	.0108	.400	28 " 45 "
.0048	.365	39 "	.0048	.400	36 " 30 "
.0018	.250	22 hrs.	.0018	.200	20 hrs.
.0004	.200	45 "	.0004	.321	43 "

PLATE X

CITRIC ACID

SPECIE-ONCORHYNCUS TSCHAWYTSCHA
(Steelhead $T_r$out)

Temperature 16.5-C & 21.0.

Normal	Weight of Fish in Grams	May 1-7'21 Survival time in minutes.	Normal	Weight of Fish in Grams	May 7-14'21 Survival Time in Minutes
				T.-21.0-C	
.0980	.160	5 min.	.0980	.143	3 min.
.0476	.145	7 "	.0476	.150	6 "
.0224	.150	11 " 20 sec.	.0224	.150	9 " 10 sec.
.0108	.142	13 " 30 "	.0108	.160	11 " 50 "
.0048	.137	15 " 30 "	.0048	.173	14 "
.0018	.129	17 " 30 "	.0018	.149	15 " 58 "
.0004	.130	33 " 40 "	.0004	.150	32 "

PLATE XI

CITRIC ACID

SPECIE-SALMO RIVULORIS

Temperature 18.5-C

Normal	Weight of Fish in Grams	May 7-14'21 Survival Time in Minutes	Normal	Weight of Fish in Grams	May 16-20, '21-Survival time in Minutes
.0980	.130	4 min.30 sec.	.0980	.150	5 min.
.0476	120	6 "	.0476	.160	8 " 10 sec.
.0224	.156	12 "	.0224	.166	13 " 30 "
.0108	.136	14 "	.0108	.173	15 " 40 "
.0048	.125	15 " 40 "	.0048	.129	16 "
.0018	.150	20 "	.0018	.156	22 "
.0004	.130	35 "	.0004	.140	40 "

PLATE XII

CITRIC ACID

COMPARATIVE WEIGHTS

Apr.1-19, 1921.

Weights in Natural o Habitat or Conditions	Normal	Weight after Treatment	Remarks
.445 grams	.0980	.460 grams	.015 grams increase
.376 "	.0476	.400 "	.024 " "
.358 "	.0224	.423 "	.065 " "
.421 "	.0108	.512 "	.081 " "
.323 "	.0048	.423 "	.083 " "
.345 "	.0018	.552 "	.207 " "
.340 "	.0004	.410 "	.080 " "

PLATE XIII

CITRIC ACID

ONCOHYNCUS TSCHAWYTSCHA
(Early Spring Chinook)
Series II

Temperature 17.5-C

Normal	Weight of Fish in Grams	Apr.19, '21-Survival time of fish in minutes	Normal	Weight of fish in grams	Apr.22 '21-Survival time of fish in minutes	Remarks
.0980	.445	10 min.	.0980	.400	10 min.15s.	Die with convulsive jerks and movements. In very dilute solutions shows a whitening around fins of fish just before death. Whole body assumes this appearance.
.0476	.376	15 " 30s	.0476	.395	16 " 15 "	
.0224	.358	20 " 50"	.0224	.426	25 "	
.0108	.421	27 " 20"	.0108	.500	29 " 30 "	
.0048	.323	37 " 20"	.0048	.350	38 " 15 "	
.0018	.345	19 hr.-55 min.-30 sec.	.0018	.342	2 hrs.	
.0004	.340	42 hrs. Lived from 2:00 PM-4-19-21. Alive 5:30-4-20-21. Dead 10:00 AM 4-21-21	.0004	.500	Still living at 45 hrs.-Dead between 45 to 50 hrs.	

Plate LVI

Curves for Citric Acid Experiments.

Temperature 25°C.

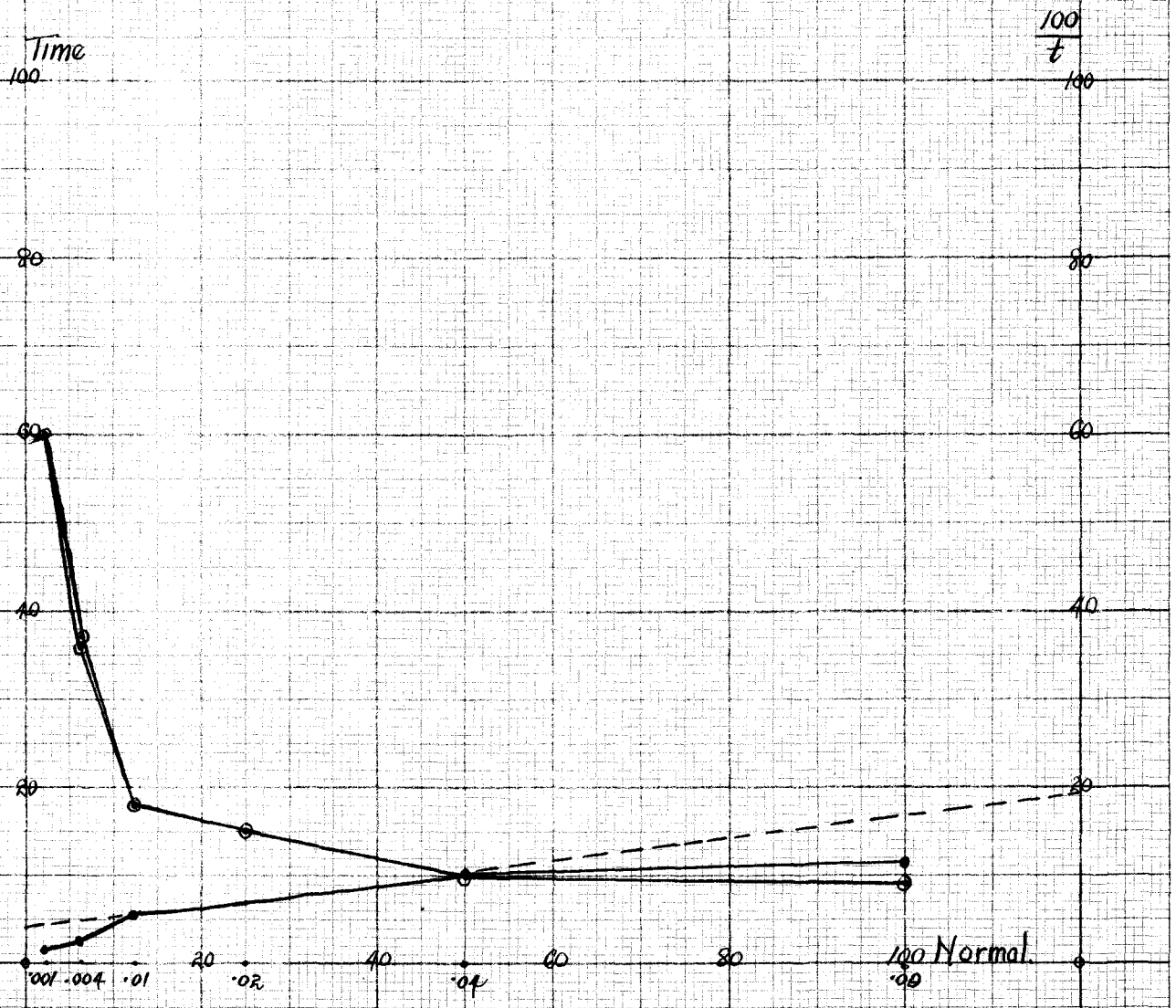

PLATE XIV

CITRIC ACID

SPECIE-ONCOHYNCUS TSCHAWYTSCHA

Temperature 20.5-C

Normal	Weight of Fish in Grams	Apr. 28-30 '21-Survival time of fish in minutes	Normal	Weight of Fish in Grams	May 1-2 '21 Survival time of fish in minutes	Remarks
,0980	.310	10 min.	.0980	.300	10 min.	For remarks see table of Apr. 28-30 1921.
,0476	.210	10 "	.0476	.250	11 " 15 s	
.0224	.450	16 "	.0224	.400	15 " 10 "	
.0108	.250	20 "	.0108	.300	23 " 15 "	
,0048	.450	38 "	.0048	.300	36 " 25 "	
.0018	.262	1 hr.	.0018	.321	1 hr 20 m	
,0004	.296	Alive at end of $3\frac{1}{2}$ days X-is then discontinued.	.0004	.350	Alive at end of $4\frac{1}{2}$ days	

PLATE XV

OXALIC ACID

SPECIE-ONCORHYNCUS TSCHAWYTSCHA

Temperature 15.8-C

Normal	Weight of Fish in Grams.	Apr.4-9-21 Survival Time of Fish in Minutes	Normal	Weight of Fish in Grams	Apr.11-16 '21- Survival Time in MInutes
,0566	.300	6 min.	.0566	.250	4 min. 12 s.
.0315	.250	6 " 45 s.	.0315	.361	5 " 30 "
.0154	.321	12 "	.0154	.350	10 " 15 "
.0076	.365	16 "	.0076	.400	14 " 10 "
.0020	.300	27 " 30 "	.0020	.256	25 "
.0001	.450	2 hrs.	.0006	.435	1 hr.30 min.
.00022	.330	Indefinite	.00022	Indefinite	

PLATE XVI

COMPARATIVE WEIGHTS
OXALIC ACID

Apr.21-21

Natural Weight as per Experiment.	Normal	Weight after Treatment	Remarks
.310	.0566	.350	.040 grams increase
.270	.0315	.287	.017 " "
.330	.0154	.357	.027 " "
.375	.0076	.394	.019 " "
.270	.0020	.290	.020 " "
.465	.0006	.559	.094 " "

PLATE XVII

OXALIC ACID

SPECIE-ONCORHYNCUS TSCHAWYTSCHA

Temperature 15.75-C

Apr.20'21			Apr.21'21			
Normal	Weight of fish in grams	Survival time of fish in Minutes	Normal	Weight of fish in grams	Survival time in minutes	Remarks
.0566	.310	5 min.	.0566	,450	5m 30s	Some of the larger specimens not as natural as the smaller ones, hence the probability of the reason they survive longer.
.0315	.279	6 " 40 s	.0315	.450	6" 15 "	
.0154	.330	11 " 50 "	.0154	.450	9"	
.0076	.375	15 "	.0076	.300	18"	
.0020	.290	25 " 40 "	.0020	.356	25" 30"	
.0006	.465	1 hr 44 m	.0006	.210	1 hr	.559 g after death in the acid
.00022	.329	Put in 2PM 4-19-21 Alive yet at 5PM 4-22-21	.00022	Experiments on this strength discontinued.		

plate-IV

Curves for Oxalic Acid Experiments

Temperature 158° C.

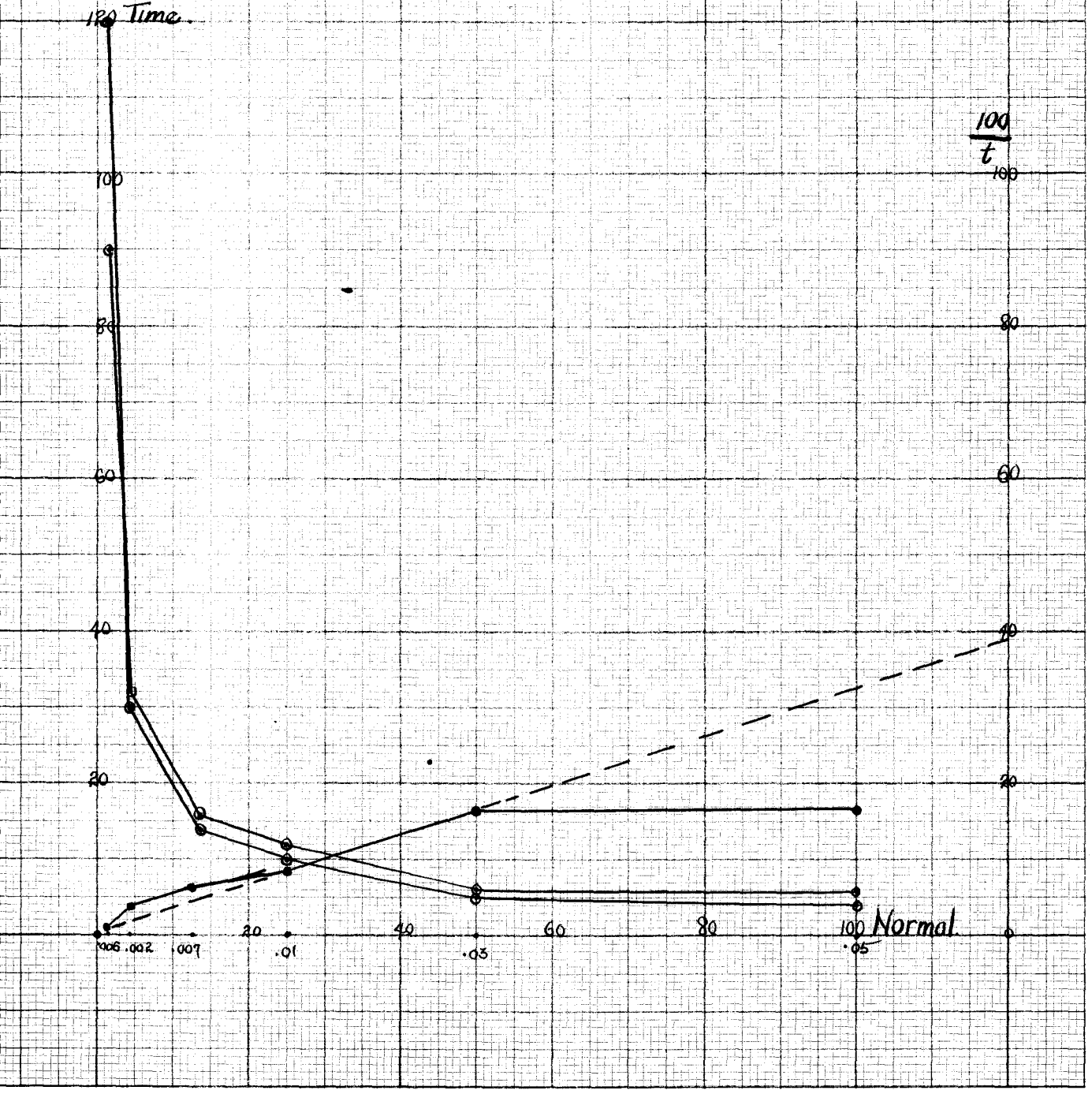

PLATE XVIII

OXALIC ACID

STEELHEAD TROUT
(Salmo Ruvuloris)
Series #5
Temperature 16.5-C

Normal	Weight of Fish in Grams	May 1-7-21 Survival time in minutes	Normal	Weight of fish in Grams	May 7-14-21 Survival time in minutes
				Temp. 21-C	
.0566	.132	1 min 30 sec	.0566	.149	1 min
.0315	.126	2 " 15 "	.0315	.132	2 "
.0154	.145	3 " 15 "	.0154	.125	3 "
.0076	.134	5 " 45 "	.0076	.150	4 " 50 sec
.0020	.118	7 " 30 "	.0020	.160	5 " 15 "
.0006	.147	35 "	.0006	.120	29 "
.00022	.136	Indefinite over three hours	.00022	.119	120 "

PLATE XIX

OXALIC ACID

SPECIES-SALMO RIVULORIS

Temperature 18.5-C

Normal	Weight of Fish in Grams	May 7-14-21 Survival Time in Minutes	Normal	Weight of Fish in Grams	May 16-20-21 Survival Time in Minutes
,0566	.140	1 min 40 sec	.0566	.125	1 min
.0315	.130	2 min 30 sec	.0315	.165	3 min
.0154	.125	3 min	.0154	.156	4 min
.0076	.150	6 min	.0076	.143	6 min
.0020	.126	8 min	.0020	.127	8 min 30 sec
.0006	.136	34 min 30 sec	.0006	.134	35 min
.00022	.147		.00022	.236	240 min

PLATE XX

OXALIC ACID

SPECIE-ONCORHUNCUS TSCHAWYTSCHA

Temperature 25-C

Normal	Weight of Fish in Grams	May-7-14 Survival Time in Minutes	Remarks
.0566	.300	3 min 45 sec	*Lived in acid of higher temperature-is appreciably much shorter; weight taken into consideration. It was noticeable in the more dilute solutions.
	.320	3 " 30 "	
.0315	.260	5 " "	
	.220	4 " 30	
.0154	.430	6 " 30 "	
	.400	6 "	
.0076	.350	10 "	
	.310	9 " 30 "	
.0020	.300	18 "	
	.350	18 " 10 "	
.0006	.400	30 "	
	.430	31 "	
.00022*	.350	Lived over three days	
	.300*	Lived over three days	

PLATE XXI

OXALIC ACID

SPECIES-ONCORHUNCUS TSCHAWYTSCHA

Temperature 20.5-C

Normal	Weight of Fish in Grams	Apr. 28-30 '21-Survival time in Minutes	Normal	Weight of Fish in Grams	May 1-7 '21-Survival time in Minutes	Remarks
.0566	.300	4 min 30 sec	.0566	.300	4 min	For Remarks see table on Tartoric in Apr. 28-30-21
.0315	.286	5 min 10 "	.0315	.300	6 "	
.0154	.400	7 " 20 "	.0154	.286	6 "	
.0076	.356	10 " 15 "	.0076	.452	11 " 30 sec	
.0020	.250	18 " 30 "	.0020	.500	22 "	
.0006	.412	30 " 30 "	.0006	.300	25 " 50 "	
.00022	.300	Alive yet at end of 3½ da. Discontinued	.00022	.398	Lived over 4 days, or alive yet after 96 hours, or 5760 min.	

PLATE XXII

SULPHURIC ACID

SPECIE-ONCORHYNCUS TSCHAWYTSCHA

Temperature 16-C

Normal	Weight of Fish in Grams	Apr.4-9-21 Survival Time in Minutes	Normal	Weight of Fish in Grams	Apr.11-16-21 Survival Time in Minutes
.0926	.300	4 min	.0926	.250	3 min
.0436	.360	4 " 10 sec	.0436	.300	4 "
.0216	.485	10 "	.0216	.198	11 "
.0116	.300	10 " 30 "	.0116	.362	12 "
.0049	.421	25 "	.0049	.300	23 " 45 sec
.0030	.286	1 hr.30 min	.0030	.400	1 hr.45 min
.0012	.290	3 " 20 "	.0012	.500	4 "

Plate-LII

Curves for Sulphuric Acid Experiments

Temperature 16°C.

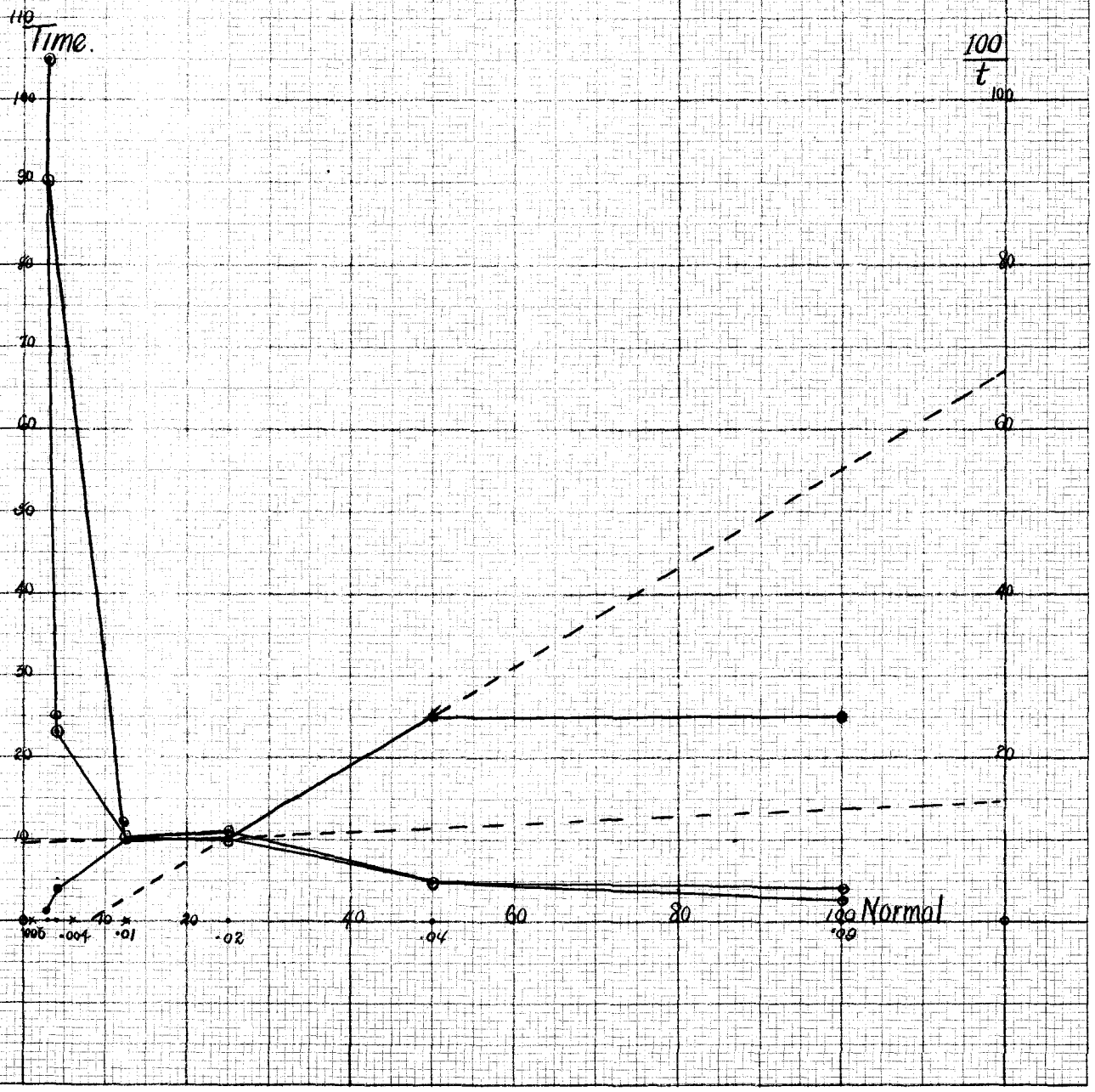

TABLE XXII

SULPHURIC ACID
on
SALMO RIVULORIS

Date Temperature 18.7-C

Normality	Wt.of fish in grams	May 1-7-21 Survival time of fish in minutes	Normality	Wt.of fish in grams	May 7-14-21 Survival time of fish in minutes	REMARKS:
				Temperature 21-C		
.0926	.146	1 min.40 sec.	.0926	.150	1 Min.10 Sec.	
.0436	.150	2 min.40 sec.	.0436	.150	2 Min.	
.0216	.150	9 Min.	.0216	.143	7 Min.30 Sec.	
.0116	.160	10 Min.	.0116	.125	9 Minutes	
.0049	.159	13 min.50sec.	.0049	.160	12 Min.30 Sec.	
.0030	.142	15 Minutes	.0030	.165	13 Min.50 sec.	
.0012	.130	30 Minutes	.0012	.170	35 Minutes	

TABLE XXIV

SULPHURIC ACID

Specie: Salmo Rivuloris

TEMPERATURE 18.3 C

Normality	Wt. of fish in grams	May 7-14-21 Survival time in minutes	Normality	Wt. of fish in grams	May 16-20-21 Survival time in Minutes	REMARKS
.0926	.126	1 Minute	.0926	.132	1 Min.30 Sec.	
.0436	.143	2 Minutes	.0436	.146	2 Minutes	
.0216	.153	9 Minutes	.0216	.152	9 Min.10 Sec.	
.0116	.146	9 Min.40 Sec.	.0016	.136	9 Min.30 Sec	
.0049	.128	12 Minutes	..0049	.140	12 Minutes	
.0030	.137	14 Min.30 Sec	.0030	.159	15 Min 10Sec	
.0012	.146	31 Minutes	.0012	.160	32 Min. 15 sec.	

TABLE XXV

SULPHURIC ACID

Specie: Oncorhyncus Tschawytscha

Temperature 20.5 C

Normality	Wt. of fish in grams	April 21-30 1921 Survival time of fish in minutes	Normality	Wt. of fish in grams	Apr. 1-7 1921 Survival time of fish in minutes	REMARKS:
.0926	.190	2 Min 50 Sec	.0926	.300	3 Minutes	
.0436	.220	3 Min 30 Sec	.0436	.350	4 Min 20 Sec	
.0216	.196	4 Minutes	.0216	.472	5 Minutes	
.0116	.310	6 Minutes	.0116	.500	7 Min 30 Sec	
.0049	.300	11 Minutes	.0049	.300	15 Minutes	
.0030	.300	24 Min 30 Sec	.0030	.300	27 Minutes	
.0012	.300	26 Minutes	.0012	.296	29 Min 30 Sec	

TABLE XXVI

SHOWING GENERAL RESULTS OF ADDITION OF H_2SO_4 to SEA WATER

AND THE EFFECT ON FISHES

Table compiled from - Shelford - Acidity Affecting Fishes.

$\frac{N}{10}$ CC H_2SO_4	Pt. per million	Normality	CC of CO_2 per liter	P.h	Species & Results HERRING Died after	HERRING O.K. after	VIVIPOROUS PERCH Died	VIVIPOROUS PERCH O.K.	FLAT FISH
6.2	30.3	.00062	7.0	7.25		Indefinite			
7.1	31.7	.00071	8.0	7.05		8 hours			
8.0	39.2	.00080	9.0	6.85	480 Minutes				
15.5	65.9	.000155	17.3	6.30	60 Minutes				
6.2	30.3	.00062	7.0	7.25				Indefinite	No effect
				7.6				Indefinite	No effect
				7.45				Indefinite	No effect
7.1	31.7	.00071	8.0	7.05				Indefinite	No effect
8.0	39.2	.00080	9.0	6.85				Aclimatized	
15.5	65.9	.000155	17.3	6.3	300 Min.				No effect 1 day
22.6	110.7	.00226	25.4	5.5	40 Min.				No effect 1 day
59.5	291.5	.00595	66.6	4.35	35 Min.				Died after 127 Min.

TABLE 3

V. E. Shelford

Relative Resistance of Different Species of Fish

Specie	Resistance H_2SO_4 running	Wt. in grams	Resistance H_2SO_4 standing	Wt. in gram	Resistance H_2SO_4 standing	Wt in grams
Surf Smelt			8	4.0		
Herring	10	2.25	10	2.25	10	2.25
Viviporous Perch	50	22.0	25	15.0-20.0	21	22.00
Flat Fish	150	5.0-10.0			11.0	6.00

TABLE XXVII

TABLE OF COMPARATIVE WEIGHTS

SULPHURIC ACID

Natural wt. in Grams	Normality	Weight after experiment is run, in grams.	Remarks:
.356	.0926	.510 Grams	.154 grams Increase
.350	.0436	.410 Grams	.060 Grams Increase
.485	.0216	.610 Grams	.125 Grams Increase
.400	.0116	.550 Grams	.150 Grams Increase
.250	.0049	.300 Grams	.050 Grams Increase
.234	.0030	.342 Grams	.108 Grams Increase
.300	.0012	.380 Grams	.080 Grams Increase

TABLE XXVIII

SULPHURIC ACID

Specie: Oncorhyncus Tschawytscha

				Temperature 16.8 C		
Normality	Wt of fish in grams	Apr. 20, '21. Survival time of fish in Min.	Normality	Wt of fish in grams	Apr. 22, 1921. Survival time in minutes	REMARKS:
.0926	.256	4 Min 30 Sec	.0926	.300	5 Min.	Showing a slight increase in resistance with age and weight
.0436	.400	4 Min 40 sec	.0436	.421	5 Min20Sec	
.0216	.484	11 Minutes	.0216	.400	10 Min.	
.0116	.400	11 Minutes	.0116	.500	12 Min.	
.0049	.35 0	22 Minutes	.0049	.391	25 Min 30Sec	
plus0030	.234	1 Hr 38 Min	.0030	.210	1 Hr.15 Min	plus .342 grams after death
.0012	.300	3 Hr 13 Min	.0012	.300	1 Hr.45 Min	plus .380 grams after death

TABLE XXIX

SULPHURIC ACID

Specia: Oncorhyncus Tschawytscha

May 7-14 1921

Temperature 25 C

Normality	Weight of fish in grams	Survival time of fish in minutes	Remarks:
.0926	.200	2 Minutes	
.0926	.300	2 Minutes	
.0436	.250	3 Minutes	
.0436	.300	3 Min. 30 Sec.	
.0216	.200	3 Minutes	
.0216	.400	3 Min 30 Sec	
.0116	.300	5 Min 10 Sec	
.0116	.550	6 Min 10 Sec	
.0049	.300	10 Minutes	
.0049	.330	10 Min 15 Sec	
.0030	.350	23 Minutes	
.0030	.300	23 Minutes	
.0012	.400	25 Minutes	
.0012	.300	24 Min 30 Sec	

TABLE XXXI

TARTARIC ACID

Specia: Oncorhyncus Tschyawytscha

May 7-14 '21.

Temperature 25 C

Normality	Weight of fish in grams	Survival time in Minutes	REMARKS:
.0958	.350	5 Minutes	
.0958	.400	5 Min 30 Sec	
.0440	.350	6 Minutes	
.0440	.450	6 Min 40 Sec	
.0240	.300	11 Minutes	
.0240	.500	12 Minutes	
.0128	.250	20 Min 10 Sec	
.0128	.300	20 Min 40 Sec	
.0068	.400	16 Min 10 Sec	
.0068	.450	17 Minutes	
.0016	.300	25 Minutes	
.0016	.350	26 Minutes	
.0012	.270	35 Minutes	
.0012	.300	35 Min 45 Sec	

plate LIII

Curves for Tartaric Acid Experiments

Temperature 20°C.

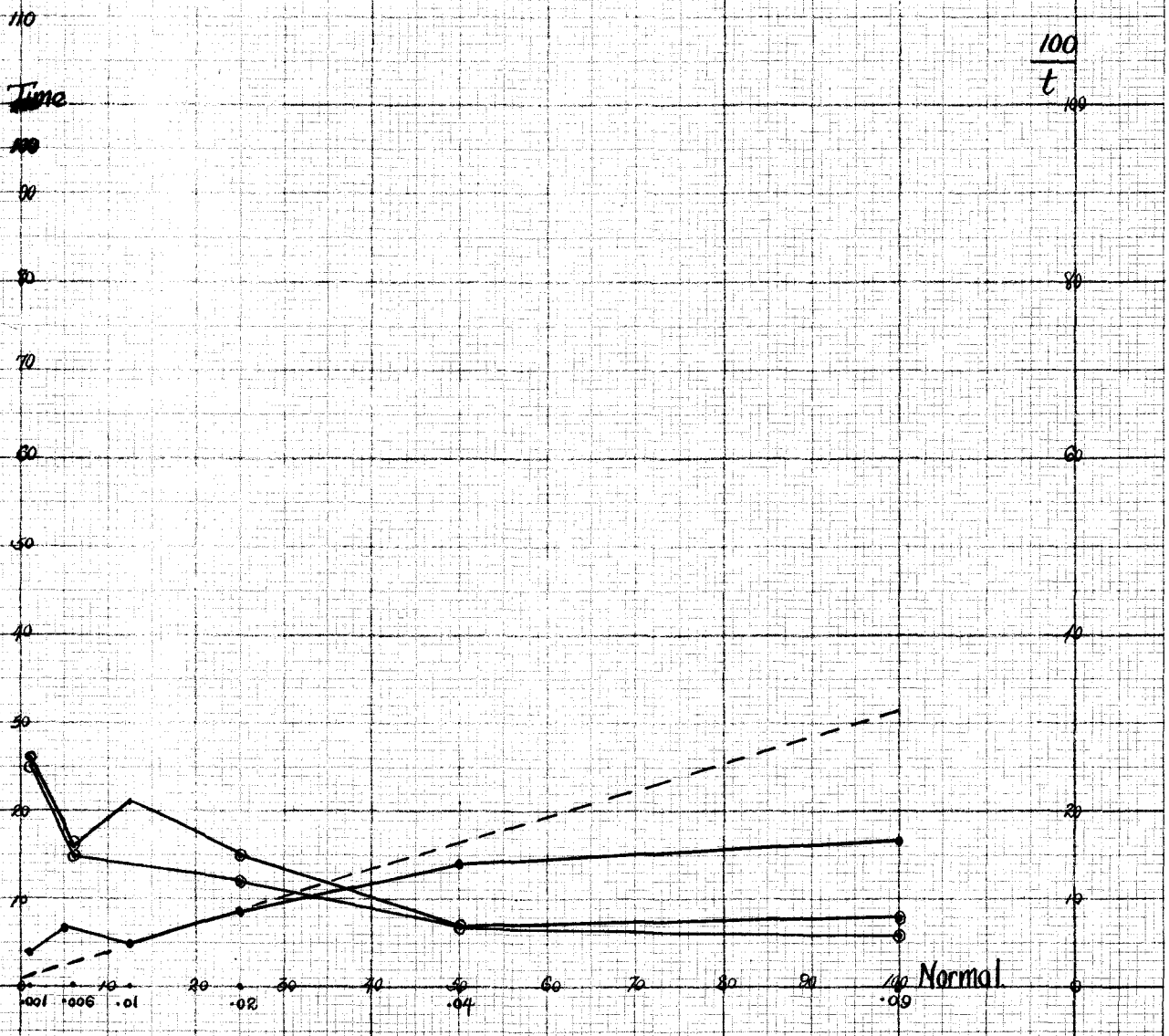

TABLE XXX

TARTARIC ACID

Specie: Oncorhyncus Tschyawytscha

Temperature 20.5 C

Normality	Wt. of fish in grams	Apr.38-30 1921 Survival time of fish in minutes	Normality	Wt of fish in Grams	May 1-7 1921 Survival time of fish in minutes	REMARKS:
.0958	.400	6 Minutes 15 Sec	.0958	.500	8 Min 50 Sec	There is evinced a very noticeable increase, decrease or stability with increase in weight or visa versa-- That is, age does not seem to enter into consideration as much as weight and temperature.
.0440	.300	7 Min 20 Sec	.0440	.421	7 Minutes	
.0240	.250	12 Minutes	.0240	.362	15 Minutes	
.0128	.200	7 Minutes	.0128	.500	21 Min 15 Sec	
.0068	.330	15 Minutes	.0058	..400	16 Min 10 Sec	
.0016	.296	26 Minutes	.0016	.284	25 Minutes	
.0012	.250	36 Min 30 Sec.	.0012	.298	37 Minutes	

TABLE XXXII

TARTARIC ACID

Specie: Oncorhyncus Tschawytscha

Temperature 15.75 C

Normality	Wt. of fish in Grams	Apr. 1-20 1921 Survival Time of fish in Min.	REMARKS:
.0958	.252	10 Minutes	
.0440	.320	12 Minutes	# Fish probably injured and in both specimens the yolk sac was just closed, not quite mature yet.
.0240	.250	13 Min 20 Sec	
.0128	.298	# 10 Minutes	
.0068	.495	35 Min 40 Sec	
# .0016	.478	36 Minutes	# May have been injured. .596 Grams after death
# .0012	.350	3 Hrs. 20 Min	.467 Grams after death

Normality	Weight	Apr. 1-21, 1921	%	REMARKS:
.0958	.452	11 Min 40 Sec		
.0440	.450	14 Min 30 Sec		
.0240	.354	25 Min 12 sec		
	.178	10 Min 50 Sec		
.0128	.447	40 Min 30 Sec		
.0068	.321	39 Min 25 Sec		
.0016	.210	40 Min 30 Sec		
.0012	.320	4 Hr. 30 Min		

TABLE XXXIII

TARTARIC ACID

Specie: Oncorhyncus Tschyawytscha

Temperature 16.0 C

Normality	Wt. of Fish in Grams	April 4-9- 1921 Survival time in minutes	REMARKS:
.0958	.300	11 Minutes	
.0440	.400	14 Minutes	
.0240	.336	15 Min 30 Sec	
.0128	.289	17 Minutes	
.0068	.250	25 Min 45 Sec	
.0016	.260	24 Minutes	
.0012	.300	3 Hours	

Normality	weight	April 11-16 1921	REMARKS:
.0958	.250	10 Min 30 Sec	
.0440	.350	12 Min 15 Sec	
.0240	.400	16 Minutes	
.0128	.326	18 Min 10 Sec	
.0068	.420	38 Min 30 Sec	
.0016	.400	40 Minutes	
.0012	.300	3 Hr. 25 Min	

TABLE XXXIV

TARTARIC ACID

Table of Comparative Weights.

April 21, 1921.

Natural weight as per experiment	Normality	Weight after experiment	REMARKS:
.352 grams	.0958	.500	.148 grams increase
.326 grams	.0440	.434	.114 grams increase
.250 grams	.0240	.350	.100 grams increase
.398 grams	.0128	.510	.112 grams increase
.395 grams	.0068	.520	.125 grams increase
.478 grams	.0016	.596	.118 grams increase
.350 grams	.0012	.467	.117 grams increase

TABLE XXXVII

ACETIC ACID

Specie: Oncorhyncus Tschawytscha

May 7-14, 1921

Temperature 25-C

Normality	Weight of fish in Grams	Survival time in minutes	REMARKS:
.0802	.300	4 Minutes	Difference in
.0802	.250	3 Min 30 Sec	death rate is
.0425	.200	5 Minutes	not so noticeable
.0425	.220	5 Min. 10 Sec	where weight is
.0218	.350	8 Minutes	increased very
.0218	..330	7 Min 30 Sec	noticeably.
.0107	.200	15 Min	
.0107	.250	15 Min 40 Sec	
.0045	.426	30 Min 40 Sec	
.0045	.450	31 Minutes	
.0010	.253	1 hr 10 Min	
.0016	.500	2 hours	
.0004	.280	30 hours	
.0004	.260	30 hours	

TABLE XXXVIII

ACETIC ACID

Specie: Oncorhyncus Tschawytscha

Temperature 16-C

Normality	Weight of fish in grams.	Apr. 4-9, 1921 Survival time in minutes	REMARKS:
.0802	.300	7 Min 10 Sec	
.0425	.200	9 Minutes	
.0218	.360	11 Min 30 Sec	
.0107	.350	25 Minutes	
.0045	.250	40 Minutes	
.0010	.450	6 hours	
.0004	.500	30 hours	

Normality	Weight	April 11-16, 1921	REMARKS:
.0802	.350	6 Minutes	
.0425	.300	8 Min 15 Sec	
.0218	.400	10 Minutes	
.0107	.436	22 Min 45 Sec	
.0045	.440	36 Minutes	
.0010	.360	5 hours 30 min.	
.0004	.350	27 hours	

TABLE XXXV

TARTARIC ACID

Specie: Salmo Rivuloris

Temperature 18.5 C

Normality	Weight of fish in grams	May 7-14 '21 Survival time in minutes	REMARKS:
.0958	.132	7 Minutes	
.0440	.128	8 Min 15 Sec	
.0240	.150	12 Minutes	
.0128	.160	14 Min 30 Sec	
.0068	.150	14 Min 50 Sec	
.0016	.130	54 Minutes	
.0012	.127	60 Minutes	

Normality	Weight	May 16-20, '21	REMARKS:
.0958	.125	6 Min 30 Sec	
.0440	.155	8 Min 50 Sec	
.0240	.163	13 Minutes	
.0128	.147	13 Min 30 Sec	
.0068	.136	14 Minutes	
.0016	.145	55 Minutes	
.0012	.150	65 Minutes	

TABLE XXXVI

TARTARIC ACID

Specie: Salmo Rivuloris

Temperature 18.7 C

Normality	Weight of fish in grams	May 1-7, 1921 Survival time in Minutes	REMARKS:
.0958	.136	7 Min. 30 Sec	
.0440	.146	9 Min 30 Sec	
.0240	.150	12 Min 50 Sec	
.0128	.134	13 Min 40 Sec	
.0068	.172	14 Minutes	
.0016	.150	56 Minutes	
.0012	.150	61 Minutes	

Temperature 21.0 C

Normality	Weight	May 7-15, 1921	REMARKS:
.0958	.160	5 Minutes	
.0440	.152	8 Minutes	
.0240	.156	11 Min 30 Sec	
.0128	.165	12 Minutes	
.0068	.125	13 Minutes	
.0016	.150	50 Minutes	
.0012	.150	58 Minutes	

plate-LI.

Curves for Acetic Acid Experiments

Temperature - 16° C.

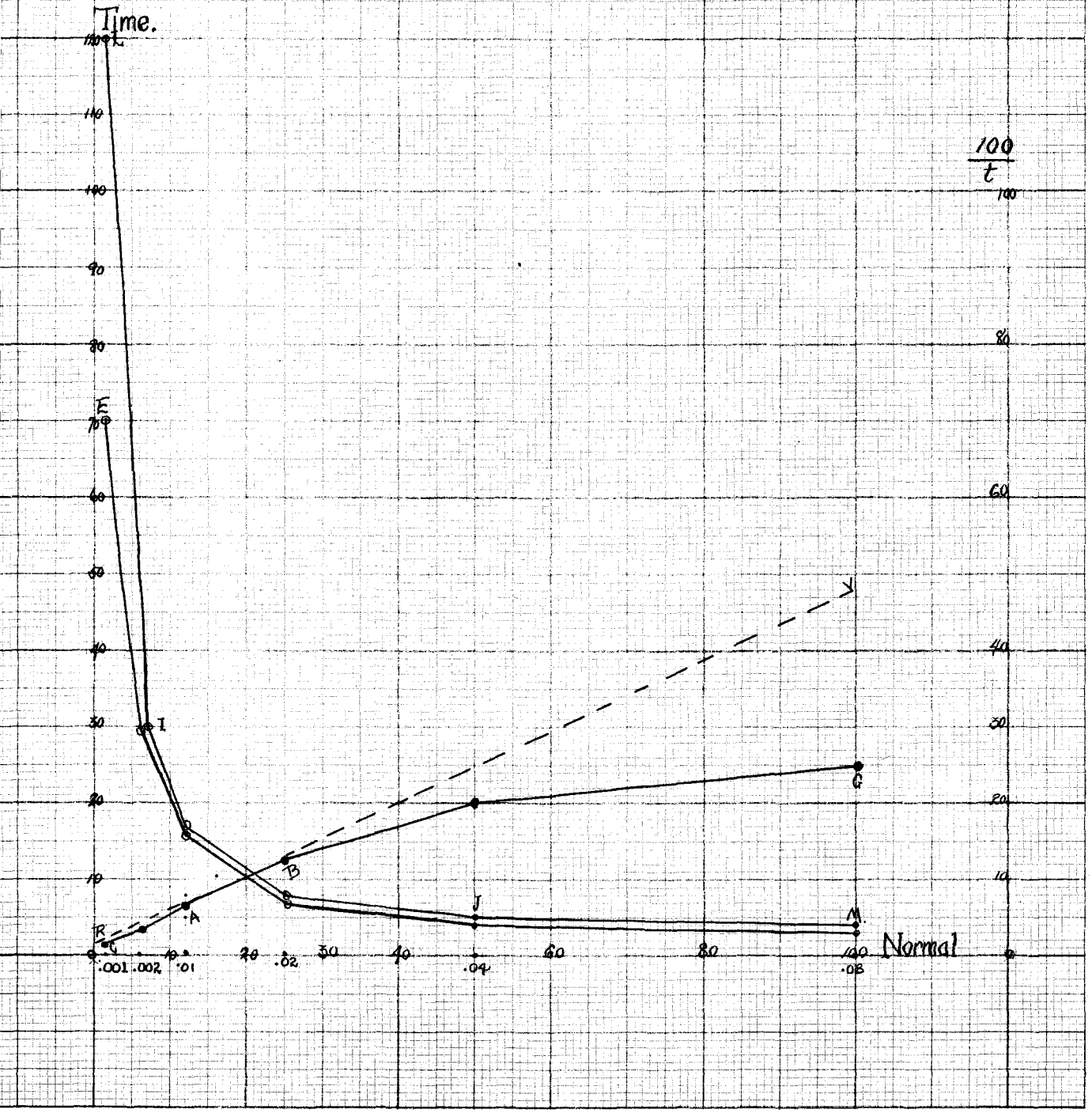

TABLE XXXIX

ACETIC ACID

Specie: Oncorhyncus Tschawytscha.

Temperature 20 C

Normality	Weight of fish in Grams	April 18, 1921 Survival time of fish in Minutes	REMARKS:
.0802	.401	3 Min 6 Sec	Skin assumes a very whitish appearance in Acetic Acid and fish die with labored breathing and gill movements.
.0425	.257	5 Min 30 Sec	
.0218	.312	6 Min 50 Sec	
.0107	.257	21 Min 30 Sec	
.0045	.258	36 Min 4 Sec	
# .0010	.315	4 hours 30 min	# Blood showed around gills upon death. Fins and gills first become whitish and finallly the whole body just before death of fish.
.0004	.372	25 hours 45 Min	

Normality	Weight	April 22, 1921	REMARKS:
.0802	.362	3 Minutes	Shows the shrivelled appearance and same Osmotic effects as in HCl only it is much more pronounced than in the former.
.0425	.485	7 Min 20 Sec	
.0218	.500	10 Minutes	
.0107	.320	25 Min 30 Sec	
.0045	.250	35 Min 20 Sec	
.0010	.264	2 hours	
.0004	.296	23 hours 44 min	

TABLE XL

ACETIC ACID

Specie: Oncorhyncus Tschawytscha

Temperature 20.5 C

Normality	Weight of fish in grams	April 28-30, 1921 Survival time in Minutes	REMARKS:
.0802	.396	4 Min 30 Sec	For remarks refer to table on Tartaric Acid. Table of Apr. 28, 30, 1921.
.0425	.120	5 Min 30 Sec	
.0218	.400	9 Minutes	
.0107	.118	15 Minutes	
.0045	.437	31 Min 50 Sec	
.0010	.250	1 hour 30 min	
.0004	.200	26 hours 30 min	

Normality	Weight	May 1-7, 1921	REMARKS:
.0802	.362	5 Minutes	
.0425	.410	7 Minutes	
.0218	.500	10 Min 15 Sec	
.0107	.298	18 Min 50 Sec	
.0045	.200	32 Min 10 Sec	
.0010	.250	1 hour 45 Min	
.0004	.260	30 hours	

TABLE XLI

ACETIC ACID

Specie: Salmo Rivuloris

Normality	Date May-1-7, 1921 Weight of fish in grams	Survival time in minutes	REMARKS:
		Temperature 18.7-C	
.0802	.150	3 Minutes	Become very white in each case before death and this is most evident right at death with a greater degree of white sticky mucous like substance on the outside than in the results with any of the other acids altho all cause this to some degree.
.0425	.148	7 Minutes	
.0218	.147	15 minutes	
.0107	.150	22 Minutes	
.0045	.156	85 Minutes	
.0010	.132	Indefinite over 4 hours	
.0004	.124	Indefinite over 4 hrs. and as long as 12 hrs. Experiment discontin.	

Normality	Date Weight May 7-14, 1921	Survival time in minutes	REMARKS:
		Temperature 21.0 C	
.0802	.149	2 Minutes	
.0425	.140	5 Min 30 Sec	
.0218	.130	14 Minutes	
.0107	.129	20 Min 30 Sec	
.0045	.150	80 Minutes	
.0010	.150	Indefinitely and as long as 4 hours	
.0004.	.162	Over 4 hours and as long as 11 hrs. Expt. discontinued.	

TABLE XLII

ACETIC ACID

Specie: Salmo Rivuloris

Normality	Weight of fish in Grams	May 7-14, 1921 Survival Time in minutes	REMARKS:
.0802	.130	3 Minutes	
.0425	.125	6 Min 30 Sec	
.0218	.150	14 Min 10 Sec	
.0107	.136	20 Minutes	
.0045	.140	80 Minutes	
.0010	.156	over 5 hrs.	
.0004	.130	lived 6 hrs.	

Normality	Weight in grams	May 16-20, 1921 Survival Time	REMARKS:
.0802	.120	3 Min 10 Sec	
.0425	.160	7 Minutes	
.0218	.160	15 Minutes	
.0107	.150	21 Minutes	
.0045	.136	80 Min 30 Sec	
.0010	.143	lived 5 hrs 30 minutes	
.0004	.150	lived 7 hrs.	

TABLE XLIII

Tables taken from Powers work on the Goldfish to show differences in time survival between the acids used by the writer and salts of one of the acids, namely Hydrochloric Acid. (HCl)

SODIUM CHLORIDE

Nov. 19, 20, 1916 Temperature 21.5 C

Normality	Wt. of fish in grams	Survival time of fish in minutes	Normality.	Wt. of fish in grams	Survival time in minutes
0.600	2.5	28 Minutes	0.277	2.7	178 Min.
0.500	2.7	30 Minutes	0.266	2.6	260 Min.
0.417	2.7	33 Minutes	0.266	2.6	270 Min.
0.417	2.85	61 Minutes	0.253	2.7	296 Min.
0.417	2.9	55 Minutes	0.253	2.7	451 Min .
0.347	2.6	97 Minutes	0.241	2.65	304 Min.
0.347	2.7	93 Minutes	0.241	2.7	478 Min.
0.289	2.75	114 Min.	0.201	2.	1290 Min.
0.289	2.8	155 Min.	0.201	3.0	2040 Min.

plate - LV.

Curves for Hydrochloric Acid Experiments

Temperature 21°C

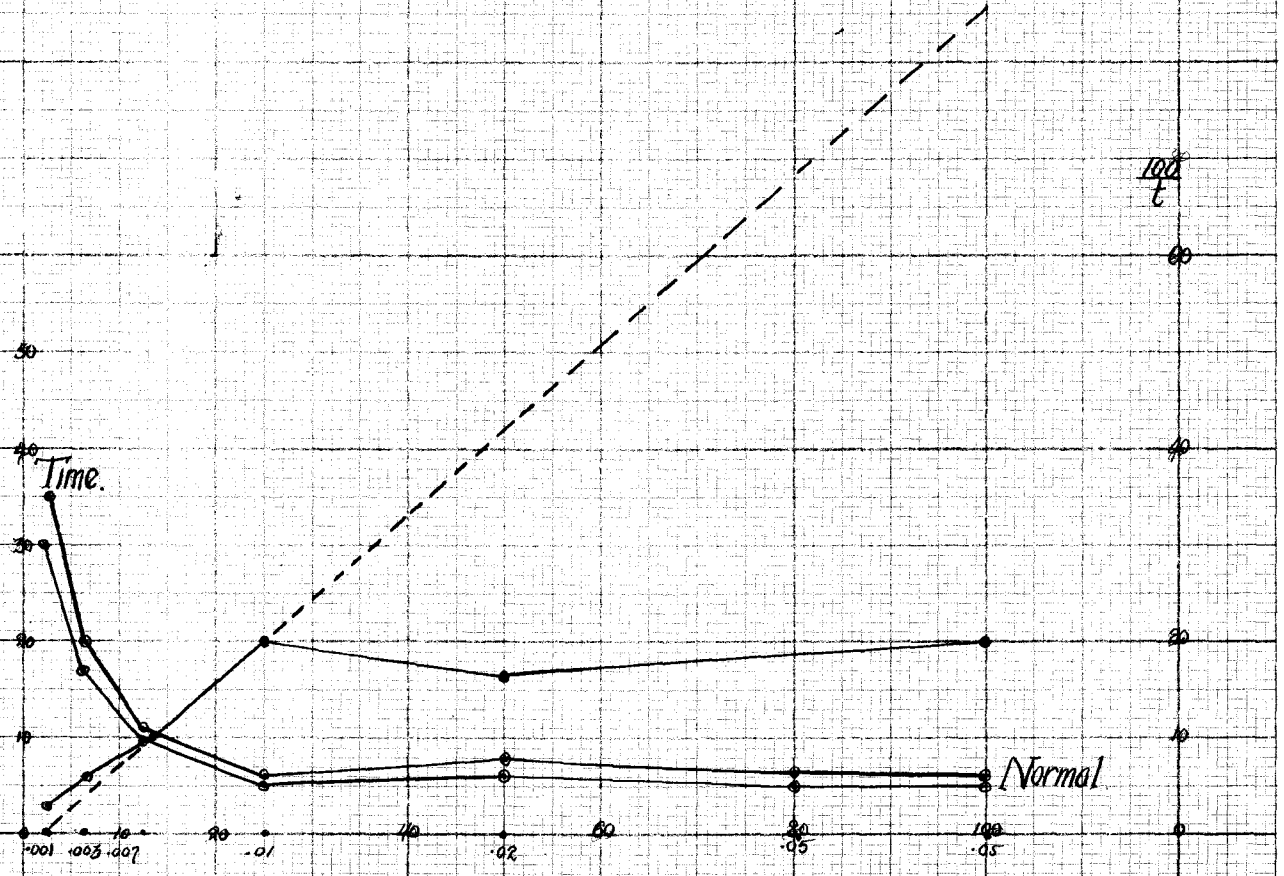

TABLE XLIV

HYDROCHLORIC ACID

Specie: Oncohyncus Tschawytscha

Temperature 21 C

Normality	Wt. of Fish in grams	April 18, 1921 Survival time of fish in minutes	REMARKS:
.0500	.395	5 Min 5 Sec	Seems to paralize respiration almost immediately, especially in the stronger solution. Do not assume such a whitish appearance.
.0270	.332	6 Min 25 Sec	
.0126	.286	5 Min 57 Sec	
.0070	.375	10 Min 45 Sec	
.0034	.312	17 Min 50 Sec	
.0010	.389	35 Minutes	
.0006 #	.556	8 hrs. 15 min.	# Gills show up unusually red as if inflamed.

Normality	Weight	April 21, 1921	REMARKS:
.0500	.400	6 min 20 Sec	Shows very shrivilled up or constricted condition if not left two long and then opposite effect takes place, namely swelling up and bursting of fish. This is especially noticeable in the strong solutions first.
.0270	.376	8 Minutes	
.0126	.300	6 Minutes	
.0070	.376	11 Minutes	
.0034	.397	20 Minutes	
.0010	.300	30 Minutes	
.0006	.300	1 hr. 30 Min.	

PLATE XLV

HYDROCHLORIC ACID

Specie: Oncorhyncus Tschawytscha

Normality	Weight of fish in grams	May 7-14, 1921 Survival Time in minutes	REMARKS:
.0500	.300	2 Minutes	Shows a shorten-
.0500	.330	2 Min. 10 Sec	ing of the killing
.0270	.200	2 Min 40 Sec	time with the rise
.0270	.250	3 Minutes	in temperature.
.0126	.465	4 Minutes	
.0126	.400	4 Minutes	
.0070	.500	7 Min 10 Sec	
.0070	.500	7 Minutes	
.0034	.400	14 Min. 30 Sec	
.0034	.330	14 Minutes	
.0010	.350	23 Minutes	
.0010	.265	22 Minutes	
.0006	.300	40 Minutes	
.0006	.250	38 Min 30 Sec	

PLATE XLVI

HYDROCHLORIC ACID

Specie: Oncorhyncus Tschawytscha

Temperature 20.5 C

Normality	Wt. of fish in grams	Apr. 28, 30, 1921 Survival of Time of fish in Minutes	REMARKS:
.0500	.296	3 Minutes	For remarks
.0270	.200	3 Min 40 Sec	refer to Table
.0126	.320	4 Min 15 Sec	on Tartaric.
.0070	.350	8 Minutes	Table of April
.0034	.400	16 Minutes	28, 30, 1921.
.0010	.330	24 Min 35 Sec	
.0006	.310	45 Minutes	

Normality	Weight of fish	May 1,7, 1921 Survival Time	REMARKS:
.0500	.300	3 Min 15 Sec	
.0270	.400	5 Minutes	
.0126	.500	6 Min 50 Sec	
.0070	.456	10 Minutes	
.0034	.510	18 Min 10 Sec	
.0010	.396	25 Minutes	
.0006	.521	1 Hour	

AMMONIUM CHLORIDE

Nov. 24, 25, 1916. Temperature 21 C

Normality	Wt of fish in grams	Survival time of fish in minutes	Normality	Wt of fish in grams	Survival time in minutes
0.352	3.5	29 Minutes	0.160	2.8	166 Min.
0.352	3.7	20 Minutes	0.160	3.7	261 Min.
0.319	3.6	30 Minutes	0.141	2.3	111 Min.
0.319	3.8	31 Minutes	0.141	?	
0.268	3.45	38 Minutes	0.115	3.0	376 Min.
0.268	4.0	37 Minutes	0.115	3.5	106 Min.
0.249	2.8	48 Minutes	0.096	2.7	123 Min.
0.249	3.2	64 Minutes	0.096	2.7	663 Min.
0.224	2.5	99 Minutes	0.064	2.5	1080 Min.
0.224	3.7	90 Minutes	0.064	2.8	1080 Min.
0.166	2.9	283 Minutes	0.041	2.5	1080 Min.
0.166	3.2	285 Minutes	0.041	?	

POTASSIUM CHLORIDE

Nov. 17, 1916 Temperature 20.5 C

Normal-ity	Wt. of fish in grams	Survival time of fish in minutes	Normal-ity	Wt of fish in grams	Survival Time in Minutes
0.434	2.9	14 Minutes	0.192	2.85	151 Min.
0.434	3.2	17 Minutes	0.192	2.9	282 Min.
0.378	2.9	11 Minutes	0.172	3.0	207 Min
0.378	2.0	16 Minutes	0.172	3.1	396 Min.
0.328	2.8	22 Minutes	0.134	2.9	286 Min.
0.328	3.0	26 Minutes	0.134	2.9	900 Min.
0.286	3.2	25 Minutes	0.122	2.8	347 Min.
0.286	3.3	44 Minutes	0.122	3.1	527 Min
0.243	2.9	55 Minutes	0.112	3.1	318 Min
0.243	2.8	57 Minutes	0.112	3.2	292 Min.
0.214	2.9	69 Minutes	0.102	3.55	279 Min.
0.214	2.8	150 Minutes	0.102	2.8	900 Min.

PLATE XLVII

HYDROCHLORIC ACID

Series: Oncorhyncus Tschawytscha

Temperature 16.0 C

Normality	Wt. of fish in grams	Apr. 4, 9, 1921. Survival Time of fish in Minutes	REMARKS:
.0500	.400	6 Minutes	
.0270	.300	7 Minutes	
.0126	.286	11 Minutes	
.0070	.350	18 Minutes	
.0034	.300	36 Min 30 Sec	
.0010	.400	36 Minutes	
.0006	.500	8 hrs. 30 min	

Normality .6	Weight in grams	Aprl. 11, 16, 1921 Survival Time	REMARKS:
.0500	.400	6 Minutes	
.0270	.300	6 Min 40 Sec	
.0126	.350	10 Min 30 Sec	
.0070	.430	16 Minutes	
.0034	.460 #	34 Min 40 Sec	# Temperature here was 19 C
.0010	.500	35 Minutes	
.0006	.500	7 hrs. 10 Min.	

PLATE XLVIII

HYDROCHLORIC ACID

Series: Salmo Rivuloris

Temperature 18.7 C

Normality	Weight of fish in grams	May 1, 7, 1921 Survival Time in Minutes	REMARKS:
.0500	.145	1 Min 40 Sec	
.0270	.150	6 Minutes	
.0126	.153	8 Min 50 Sec	
.0070	.146	# 4 Min. 10 Sec	# Probably an injured speciman. Did not seem very lively.
.0034	.149	10 Min. 50 Sec	
.0010	.159	25 Minutes	
.0006	.150	40 Minutes	

Temperature 21 C

Normality	Weight of fish in Grams	May 7,14, 1921 Survival in Min.	REMARKS:
.0500	.150	1 Minute	
.0270	.150	5 Minutes	
.0126	.125	6 Min. 50 Sec	
.0070	.130	9 Minutes	
.0034	.143	10 Minutes	
.0010	.145	20 Minutes	
.0006	.150	33 Minutes	

PLATE XLIX

HYDROCHLORIC ACID

Specie: Salmo Rivuloris

Temperature 18,5 C

Normality	Weight of fish in grams	May 7, 14, 21 Survival time in minutes.	REMARKS:
.0500	.130	1 Minute	
.0270	.120	5 Minutes	Noticeable whitening of fish before death.
.0126	.150	8 Minutes	
.0070	.146	10 Minutes	
.0034	.135	10 Minutes	
.0010	.180	27 Minutes	
.0006	.170	45 Minutes	

Normality	Weight of fish in grams	May 16, 20, 1921 Survival Time	REMARKS:
.0500	.150	1 Min. 20 Sec	
.0270	.130	5 Min. 40 Sec	
.0126	.140	7 Min. 40 Sec	
.0070	.150	10 Minutes	
.0034	.140	10 Minutes	
.0010	.143	25 Minutes	
.0006	.156	33 Min. 30 Sec	

PLATE L

Experiment with Distilled H_2O @ 65.6 F

Experiment with Tap H_2O @ 66.8 F -- used as check

1919 Apr.21,'19. Wt.of fish	Time of Survival in distilled water	Time of survival in Tap water	Wt.in tap water on death	Wt. in distilled water on death
Normal wt.				
1. .462	Put in at 10:50 AM No change 11:00 " " " 11:10 "	Survival Time was unlimited	1. .462	1..500
2. .380	1 Weakening at	except for	2. .381	2. .400
3. .296	11:40 A.M.	death of one fish--probably	3..298	3..320
4. .472	2 fish almost dead in dist.H_2O	already devit-	4..473	4. .500
5. .500	at 12:00 A.M. 1 dead 12:10 PM	alized. It lived 4 hrs and	5..500	5. .532
	3 dead 12:30 " 5 dead 1:00 " 5 dead 1:30 "	50 Min. Died at 3:00 P.M.		
	Temperature of distilled water on death of fish was 72.2 F.	Temperature of tap water on the death of single fish dying, was 72.5 F.		
	Two hrs. 20 Min all fish dead in distilled H_2O. Noticeable swelling of fish upon death	Temperature of both solutions runs fairly constant as can be seen.		

REMARKS:

(1) Increase of .038 grams

(2) Increase of .019 grams

(3) Increase of .022 grams

(4) Increase of .027 grams

(5) Increase of .032 grams

The weight of fish upon death in distilled water shows a distinct increase in weight while those in Tap water or natural solution, was just about constant. Shows distinct Osmotic effect of diminished absence of inorganic constituents.

IV.

EXPERIMENTAL DATA

In the study of the Resistance of the Fry to the different acids used, we will consider first a study of each acid and then make a comparison of them. Before taking up each one however let us first consider the pharmacological action of Organic acids and Inorganic acids upon Proteplosm. Inorganic acids in concentrated solutions are very severe caustics precipitating the protein of the cell, but in dilute solution tend to liquify it. Thus we have a colloidal relation here of Hydrogels and Hydrosols.* (Paton) Colloids & living phenomena, Vol.7,p.p 465-473. Scientific Monthly.

Organic acids however such as acetic, citric and tartoric, are broken down by the body into CO_2 and H_2O. This brings into play the increase in the Hydrogen ion concentration due to the formation of H_2CO_3 from the CO_2 formed increasing the output of carbonates and CO_2 from the body. Oxalic acid does not break down in this manner and thus is accumulative and acts as a very severe poison in very small amounts as shown by Tables on these acids. The Experiments with acetic acid will now be considered. (Tables on this acid.)

In the Acetic acid experiments the resistance of the Fry to concentrations of .08 to .001 (refer to tables for further particulars) was tested. In these we find that Fry varying from .1 grams to .6 grams had a resistance varying from 3 minutes up as high as 180 minutes in the weaker concentrations. By a close examination of the Data it is found that in neither this nor any of the acids used does the survival time increase proportionally with the concentration. At high concentrations the decrease in survival (.08, .04, .02 N) was less rapid than the decrease in concentration of the solutions (Tables VIII to L.) The increase in time in the weaker solutions however is more proportionate until it approaches a concentration of .001 to .0004 N when there is another rapid jump in Time survival . This perhaps can be shown clearly by referring to the graphs characteristic of the different acids. (Plates 51 to 56 inclusive.)

The Curve for Acetic acid when explained will be explanatory for the curves on the other acids. The curve L.I.J.M. represents the time survival in Acetic acid also a parallel curve E.I.J.M. for comparison. From L. To I. we have the greatest uniformity of time survival and from

there on the Curve drops in a more or less abrupt manner. In the velocity of fatality curve CABG we observe that there is a gentle curve from E to A in the weak solutions and then from A to B it tends to approach a straight line. After passing the point B there is an immediate and decided drop in the higher concentrations from B to G. B to A is the theoretical straight line in which it should move. For comparison of velocity of Fatality and time survival curves, see Plates 52 to 56 inclusive. The Fish in this solution show a very whitened appearance just before death. Citric and Tartoric show similar signs, but not to such a marked degree.

SULPHURIC ACID.

In this experiment we note a shorter survival time and more abrupt breaks in both the time survival curve and the velocity of fatality curves (Plate 52) An examination of plates on this acid will also show how the fish die in identically the same time in two solutions of different strength; then there is a sudden drop and they may be identical for another solution when there is a last abrupt drop to the high concentrations and death in a very short time, 1 minute to 2 minutes. There is of course in all of these experiments a slight variation with temperature, weight and age, which will be

discussed later on. The Heart beat is very rapid in Sulphuric acid. Fishes all show an increase in weight after death. In plotting the curve for Plates 51 to 56 inclusive, a scale of 10 was used for both time survival and velocity of fatality on the vertical axes. In the normalities the higher concentration was given an equality of 100 and each succeeding normality in proportion to 100 as it was in strength to the highest normality. I divided by the time gives us the reciprocal of the time survival and is represented by $\frac{100}{t}$.

TARTARIC ACID.

Under Tartaric acid we observe a more marked killing rate, except probably with the exception of Oxalic acid in all solutions even the very weak ones. (Plates on Oxalic Acid, also Graph on Plate 53.)

OXALIC ACID.

In this experiment we have a very high Toxicity and a uniform rise of survival time with decrease in concentration up to a certain dilution, when it begins to fluctuate. The velocity of fatality curve after approaching a straight line has a very continuous drop in this acid with no abrupt breaks. Fluctuations only occur in the straight solutions.(Plate 54)

HYDROCHLORIC ACID

In this as in the other acids we have a uniform increase in survival time in accordance with graph on Plate and Tables on this acid. Here we have a very abrupt break in the fatality after it has passed the theoretical straight line. The normalities here correspond with those of Oxalic; namely that the highest concentrations in both of these strong acids is only .05 while in the others it is twice that strength, or .09 to .08.

CITRIC ACID

In this acid which is a very weak one,(showing the weakest reactions of the series) we have a fairly uniform increase in survival time with the decrease in concentration of the solutions. The fatality curve here nearly approaches the Time survival curve.

SUMMARY and ADDITIONAL REMARKS
on

ACID DATA

It will be seen from the brief discussion of each acid that the following is evident:

1. That there was an instantaneous reaction of concentrations from .09 N to .004 N after which the survival time was (stretched out) or indefinite.

2. This point (.004 N) denotes the threshold of Toxicity point for all of the acids except Tartaric and Hydrochloric, which differs from this rule in the vicinity of such concentrations.

3. That above the threshold of Toxicity the rate of time survival increased very slowly with the increase of concentration. (Plates 51 to 56) There was a great deal of variation between different acids.

4. At concentrations between A and B, Plate 51, the survival time increased rapidly.

5. Below this C to A the concentrations did not affect the survival time to such a marked degree.

6. We see the acids Tartaric, Hydrochloric, and Sulphuric are most destructive to fish life. While Citric, Acetic and Oxalic have a Threshold of Toxicity for above the former.

7. It is evident that there is not as great a variation in survival time with the increase in concentration as with the dissociation of the Hydrogen Ion in the solution.

V.

DISCUSSION
of

EXPERIMENTAL DATA.

The experimental Data just discussed gives definite proofs from which it is possible to draw some concrete conclusions in regard to the problem under consideration. I will now take up and discuss the following; namely,

1. Hydrogen Ion concentrations.
2. Osmatic relations and colloidal conditions together.
3. Temperature-weight conclusions.
4. Mineral composition of water of the vicinity.

It will be readily noticed that there is a close correlation between the time survival of the fish in the various concentrations and the P_h value of each acid.

Tabulation of P_h values of the different acids used:

1. Tartaric Acid

Normality	P_h Value
.0958	2.2
.0440	2.4
.0240	2.6
.0128	2.6 plus
.0068	2.6 plus
.0016	3.2 plus
.0012	3.4 plus

This is a fairly strong acid not dissociating very rapidly and should kill very uniformly which is in fact the case.

2. Hydrochloric Acid

Normality	P_h Value
.0500	1.0
.0270	1.6
.0126	1.8
.0070	2.0
.0034	2.4
.0010	2.6 plus
.0006	3.2

As can be readily seen from this table this acid is very dissociable and should be very toxic in all concentrations with a fairly wide range of survival time.

3. Sulphuric Acid

Normality.	P_h Value
.0926	1.0
.0436	1.4
.0216	1.6
.0116	2.0
.0049	2.2
.0030	2.6
.0012	3.0

This acid as regards its ionization should follow Hydrochloric in Toxicity, which it really does.

4. Acetic Acid

Normality	P_h Value
.0802	3.0
.0425	3.0 plus
.0218	3.4
.0107	3.4 plus
.0045	3.6
.0010	3.7
.0004	3.8

This we expect to be a weak acid from its P_h values and to have a fairly constant killing time in various concentrations.

5. Oxalic Acid

Normality	P_h Value
.0566	1.6
.0315	1.8
.0154	2.2
.0076	2.6
.0029	2.8
.0006	3.6
.00022	3.8

This we can see is a very strong acid approaching HCl and H_2SO_4 in Toxicity as it is fairly highly ionized. It approaches more nearly the neutral point than some of the weakest solutions in the rest of the acids, hence the long survival in the last solution which is

greater than in some of the less dissociated acids. The Normalities are also halved.

6. Citric Acid

Normality	P_h Value
.0980	2.4
.0476	2.6
.0224	3.0
.0108	3.0
.0048	3.2
.0018	3.6
.0004	4.0

As we can easily see this is the weakest one of the series and should have the longest survival time in its concentrated solutions which it in reality has.

Therefore does it not seem very evident that the death rate of the fish is proportional to the P_h of the acid. In support of this the author is making a resume of articles by other writers.

Table shows that with the raising of the P_h or Hydrogen Ion concentration below 6.85 (neutrality between acid and Basic reaction) the Acid was more Toxic while above that on more infinite dilution or lowering of the Hydrogen Ion concentration the results were indefinite. (Towards Basic that is above 6.85) Tables also show a slight difference to P_h in the different species.

Water containing Carbonates must be kept running in order to prevent precipitation of Sulphates.

It was found that at times the movements of these fish were governed largely by differences in the Hydrogen Ion concentration, slight increased in the Hydrogen Ion concentration being avoided by both Herring and Salmon. This keeps important fish from our shores and destroys many beneficial animals already here. Hence, the reasons for finding a method as was the authors purpose of combating this pollution of shore and stream water by sewage pollution, acid manufacture and like industrial evils necessitated by our factories near streams and places where such animals are living. Also an increase danger of mosquito infection. There has been besides the miles acid process of sewage, that of neutralizing or eliminating of these acids, some discussion of using lime as a bed precipitating the acids as $CaSO_4$ as it comes over. A discussion of Miles Acid process is not discussed here as it is of no importance in the Conclusion to be reached by the writer of this Thesis. (It may be found in work done by Weston 1916, Oil, Paint and Drug Reporter.)

OSMOTIC and COLLOIDAL PRESSURES.

Osmotic relations evinced in the problem and Colloidal Chemistry of the problem. Do the acids organic and inorganic acids have an Osmotic effect upon fish life

in a similar manner to salts. The general concensus of opinion is to the contrary. We know that acids such as HCl are not in proportion to their moleculor weights. Now on the other hand altho there may be no Osmotic pressure exerted there is a Colloidal interchange caused by acid which changes proteins from Hydrogels to Hydrosols (solid to liquid proteins) and hence there is a high probability of an Osmotic interchange after this takes place. Tables on these acids show some indication of this as they show a very decided increase in weight.

Effect of Temperature and Weight

The survival time of the fish is lowered in a solution of a constant concentration with a rise in Temperature. This agrees with other workers. An increase in weight, however, increases the survival time.

General Remarks on Acidity and Mineral Composition of the Vacinity

It was found that fish died very rapidly in distilled water, and as the conductivity of distilled water and its Hydrogen ion concentration is just neutral, led us to make an analysis of our city water, which shows a neutral or very nearly reaction.(within range of indicators available.) It is even used by the Chemistry department of this institution in chemistry as the mineral content is not high enough to seriously interfere with their tests. Does it not seem that probably this is one

of the causes of our fish hatchery troubles. This is further supported by the following article by V. C. Shelford on the Effect of Gas Wastes on Fishes, in the Bulletin of the Illinois State Laboratory of natural History, Vol. XI. Mar. 1917.

Dr. Wells ('15 and 15a) found out the following, that water slightly alkaline lessens the activity of fishes and renders the mortality relatively high $\frac{N}{100}$ KOH (56 cc per Liter) kills them in a few hours. Neutral water seems to be more or less Toxic to fishes and they become more and more inactive until death occurs, supported by Authors experiments with Distilled water. Therefore we can see that an optimum acidity is obvious. This acidity is rendered so by the CO_2 generated by the fish themselves and also present to a quite considerable extent in all waters. Higher concentrations prove fatal soon. Will live for some time in10-20 cc per liter of CO_2 and 2040 cc per liter of Carbon Dioxide. $\frac{N}{10,000}$ $H2SO_4$ (4.9 pts per M) is fatal in a day or so, but $\frac{N}{20,000}$ H_2SO_4 2.4 pts per M) seems to be near their optimum as they seem to live in this for a long time. Fishes react very definitely to exceedingly small concentrations of Hydrogen and Hydroxyl ions, prefer acid to neutral or alkali but prefer alkali to neutral medium.

They usually turn back when inserted in a gradient tank when the acid concentration falls below

$\frac{N}{12,000}$ H_2CO_3. This probably gives us a key to the difference in death rate in a polluted and clean trough. Shelford in the same paper also showed that altho fishes did not recognize such gas waste as coal tar by products, they very readily turned away from organic waste or pollution. This probably is because they are not near to them, but something previously experienced as harmful to them but the opposite effect is noted when something new or strange is thrown into the water.

VI.

CONCLUSIONS

1. Such Acids as HCl, H_2SO_4, Tartaric, Acetic, Citric and Oxalic are all very fatal to young fry in concentrations around .1400 gm. to .0340 gms. of the acid per liter.

2. Water too low in acidity is avoided by fishes and is fatal to them. They prefer water with a very slight trace of acidity and plenty of mineral content present. From the author's observations it has been noticed that altho fish are plenty in most streams in the vacinity they avoid the water of the stream from which our hatchery water comes, due to its neutrality and lack of mineral matter.

3. That acids such as HCl, Tartaric, and like acids cause a changing of the composition of the body, liquifying its protein content and causing a leeching out of its contents. Distilled water has a similar effect.

4. That the death rate of the animal in acid polluted water depends upon a number of factors; namely, age, weight and temperature of the solution.

5. These generalizations and conclusions of the author may throw some useful light on the difficulties of the problem at hand in regard to Hatchery trough contamination.

6. It is very vital that troughs be kept scrupulously clean (Plates II to VI.) and free from all organic matter.

7. Now in regard to some definite conclusions on the acid experiments we may say that:

a. There is a concentration of each substance which will cause death and below which will not cause death. This point has been designed as the threshold of Toxicity.

b. The velocity of Fatality is increased very slowly above this threshold of Toxicity with increase of concentration.

c. With a further increase we get a very decided drop in survival time.

d. It was also found that in concentrations higher than this, there tended to be a drop, that is at certain concentrations especially those above which the author has used in this experiment but which were used as preliminary testers of range of survival that in solutions over $\frac{N}{10}$ there was no appreciable difference in Survival Time, death being almost instantaneous.

8. The curve denoted as the velocity of Fatality Curve approaches a straight line when the survival time has reached its maximums, namely in the last two weakest normalities, ranging from .01 to .0006 in concentration.

9. Rise in temperature causes a lowering of the survival time.

10. Age and weight cause a wide variation in survival time. Compare experiments run on Salmo Rivuloris (Tables 8 to 50 and those of Oncorynchus Tschawytscha.

BIBLIOGRAPHY

Title	Author	Publication
1. The goldfish as a Test animal in the study of Toxicity.	E. B. Powers	Illinois Biological Monograms Vol.IV. Oct. 1917
2. Relation of marine fishes to acid with particular reference to the Miles Acid process of sewage treatment.	V. E. Shelford	Publication of the Puget Sound Biological Station, Dec. 26, 1918.
3. The Reactions of Goldfish to certain habit forming drugs.	V. E. Shelford	Jr. of the American Pharmaceutical Association. Vol. VII No.7 July 1918.
4. Osmotic and surface Tension phenomena of living elements and their physiological significance.	J.F.McClendon	Beal Bulletin Vol. 22, Feb. 1912. No. 3.
5. Ecological Succession.	V. E. Shelford	Beal Bulletin, Vol. 22, Dec.1911. No.1.

6. An experimental study of the effects of gas waste upon fishes with especial reference to stream pollution.	S.A. Forbes	Bulletin of the Illinois State Laboratory of Natural History, Vol.XI. Mar. 1917.
7. An experimental study of the movements of Herring and other Marine fishes.	V.E. Shelford and E.B. Powers	Beal Bulletin Vol.XXVIII No. 5 May, 1915.
8. Colormetric Determination of P_h (Hydrogen Ion concentration.)	A.M. Clark and H.A. Lubs	Jr. of Bacteriology. Vol II. No.1
9. Colormetric Determination of Hydrogen Ion concentration.		Jr. of Washington Academy of Science. Vol.VI. p. 483-1916.
10. Hydrogen Ion Concentration.	Park & Williams	Text Book on Patheogenic Organisms.