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SURVIVAL RATES OF THE INDIAN CARP (*CATLA CATLA*, *LABEO ROHITA*, *CIRRHINA MRIGALA*) FROM FIRST TO FOURTH WEEK OF LIFE UNDER DIFFERENT EXPERIMENTAL TREATMENTS

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SUMMARY. Two experiments were carried out on Indian carp (*Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) to determine whether the survival rate could be enhanced by certain experimental treatments. In the first experiment, treatments with antibiotics and vitamin B complex, including B_{12}, were compared with the untreated control; in the second experiment, treatments with vitamin B complex, including B_{12}, and organic manure were compared with the untreated control. Differences in the distributions of survival values obtained for different treatments were compared by the Kolmogorov-Smirnov test. Survival during the first month of life was found to be enhanced significantly by treatments with antibiotics and vitamin B complex, including B_{12}. Using Kendall's coefficient of concordance it was demonstrated that survival was inversely related to initial number in the majority of treatments during the first two weeks of life. Regression of final proportion surviving on initial number accounted for over 70 percent of the within treatment variation.

INTRODUCTION

During the past decade the number of scientific investigations on fish culture has been steadily increasing, with growing awareness of the role of fish protein in improving human diet in India. Development of scientific methods of fish culture promises to be of economic value, particularly in such areas as West Bengal, Orissa and Assam, with their abundance of small tanks, large pools (*jheel*) and impounded waters. These water sources can permit increased protein production through fish culture without heavy expenditure in land or capital.

Culture of fresh water carp under commercial conditions has been receiving consideration. Among investigations in this line, the work of Hora (1947, 1949, 1950a, 1950b) has made contributions to the methods of pond culture, specifying requirements, manuring practices, etc. The potential value of such work may be realised if the market position of the carp is reviewed. According to the Report on the Marketing of Fish in India (Government of India, 1946),* the carp make up 34 percent of the marketable surplus of fresh water fish, or about eighteen million pounds, and are the single largest group of marketable fresh water fishes.

* *Report on the Marketing of Fish in India*, Marketing Series No. 52, Government of India, (1946).

Review of the literature shows that most work has been devoted to the culture of fry and fingerlings in field conditions, with emphasis on nursery management. Investigations of spawn have been concerned with spawning practices of the carp, particularly the factors inducing carp to spawn. A survey of the available literature has not so far revealed investigations on the survival rate of carp during the early period of life, and treatments which may increase survival. The potential importance of such investigations lies not only in the potential market of the adult carp as part of human diet, but also in the necessity of transporting carp during the early period of life. The carp are caught at the spawning grounds, and are transported to Calcutta, where the commercial spawn growers purchase them. During this period, mortality is high, hence reducing ultimate production of carp. Methods developed to increase survival during this period should also, therefore, be of economic value.

To investigate the survival rate of carp during the early period of life, and to determine if certain treatments would increase survival, a series of laboratory experiments were conducted in the Indian Statistical Institute in the months of July and August in 1956 and 1957 on Indian fresh water carp (*Catla catla, Labeo rohita, Cirrhina mrigala*).

EXPERIMENTAL DESIGNS

Experiment 1 (1956). In Experiment 1 three experimental treatments were utilized with five replications of each treatment. The fifteen experimental units so defined were randomly distributed in the laboratory in three rows with five units in each row. Measurements were taken for 21 days. Fluorescent tube lights were used to ensure equal lighting throughout the laboratory. Fans were arranged to maintain constant temperature and distribution of air in the laboratory.

Experiment 2 (1957). In Experiment 2 three treatment groups were utilized, arranged according to a randomized block design. With the three treatments represented in each block, the design adopted five blocks, and the entire design was replicated twice. There were, therefore, a total of thirty experimental units, ten for each treatment. Measurements were taken for 22 days. Lighting and fans were arranged to satisfy the same conditions as in Experiment 1.

MATERIALS AND METHODS

For Experiment 1, one day old carp (*Catla catla, Labeo rohita, Cirrhina mrigala*) were procured from the same source. Upon receipt in the laboratory, it was intended to assign an equal number of the carp to each experimental unit. Exact enumeration of the carp was not feasible due to their minute size, and a sampling procedure of allocation was adopted instead. Equal quantities of pond water, each containing one teaspoon of spawn, were assigned randomly to the experimental units. Subsequent enumerations of the spawn would check the accuracy of this sampling procedure.

Each experimental unit consisted of an earthen bowl or *gamla* of 16" diameter containing 9 litres of water. All *gamlas* used were of the same size, containing the same quantity of pond water from the same source. The water was changed every 24 hours to prevent accumulation of waste products which might injure the carp and affect their survival. Water temperature and pH were recorded daily.

Experimental data were collected by completely enumerating the dead carp each day and enumerating the surviving live carp at the conclusion of the experiment. These counts were taken first by, inducing a water current in the *gamla* by an artificial centrifugal force, and second, withdrawing the dead carp with a glass pipette. Separate fresh pipettes were used for each experimental unit to prevent contamination of one treatment by another. The dead carp were then placed on a flat paper surface for enumeration. Daily counts were taken for the 21 days of the experiment, and the final total of dead and live spawn reconstructed the number of spawn initially introduced.

The spawn were fed live Daphnia, given 10cc by volume each day to each experimental unit. To determine whether this ration was sufficient, a check was made each day to see if any live Daphnia remained. It was found that there were always some Daphnia remaining.

The three experimental treatments were as follows: *A* (control); *B* (antibiotics); and *C* (vitamin B complex with vitamin B_{12}).

In treatment *A*, the water of each experimental unit was left untreated. In treatment *B*, the water of each experimental unit received 270cc of the following antibiotic mixture daily : ½ gram crystalline dehydro-streptomycin sulphate; ½ gram crystalline streptomycin sulphate; 300,000 units procaine penicillin G; 100,000 units soluble penicillin G; added to 100cc distilled water. Sufficient quantities of this dosage were made to permit treatment of 30cc per litre of water containing the spawn. As each experimental unit contained 9 litres of water, 270cc were given. In treatment *C*, the water of each experimental unit received the following dosage of vitamin B complex daily: 5μg crystalline vitamin B_{12}; 3 mg vitamin B_1 (Aneurine Hydrochloride); 30 mg nicotinamide; 1 mg riboflavin; 1 mg calcium pantothenate; 0.5 mg pyridoxine hydrochloride.

For Experiment 2, the carp, allocation procedure, experimental units, food, lighting and fans were identical in principle with those described for Experiment 1. The three experimental treatments were as follows : *A* (control), *B* (manure) and *C* (vitamin B complex with vitamin B_{12}). Treatments *A* and *C* were identical with those of Experiment 1. The water of each experimental unit in treatment *B* received ½ gram of cowdung per day.

Results

Tabular summaries of the data are presented in Tables 1 to 3, and statistical tests of significance in Tables 4 to 11. Figures 1 to 4 represent graphically the survival rates given in Tables 1 and 3.

The daily survival rate and cumulative survival rate were computed for each experimental treatment, summing over the within treatment replications, from the number alive and number dead on each day of the experimental period. The daily survival rate was obtained by dividing the number alive on each day by the number alive on the preceding day. The daily survival rates are presented graphically in Figures 1 and 3 for Experiments 1 and 2 respectively. The cumulative survival rate was computed by dividing the number alive on each day by the initial number.

The cumulative survival rates are represented graphically in Figures 2 and 4, for Experiments 1 and 2 respectively.

Statistical significance of the experimental treatments was tested by means of a homogeneity chi-square, with results given in Table 4, and the Kolmogorov-Smirnov test of significance for two distributions, with obtained values reported in Table 5. These statistical tests are based on proportions obtained for each replication, given in Table 3.

For Experiments 1 and 2, Table 3 presents the final proportion surviving in terms of the initial number introduced, for each replication. Statistical analysis of this data included computation of Kendall's coefficient of concordance, S, for the rank orders of final proportion surviving and of initial number, given in Table 6. To determine the significance of the regression of final proportion surviving on initial number, variance ratios were computed which are given in Table 8. In Table 9, the estimated values of α and β, and the estimated variances of α and β are presented.

To examine the proportion surviving in relation to initial number for successive periods through the experiment, for an initial, middle, and final period the proportions surviving were computed, taking the initial number of the particular period as a base. The data and proportions are presented in Tables 10 and 11 for Experiments 1 and 2. Values for the coefficients of concordance for these data are given in Table 7.

DISCUSSION

At least three general features of the data in both experiments merit discussion: (1) survival rates in the control groups; (2) differences between treatments in survival rates; and (3) survival rate as influenced by the initial number of carp per experimental unit.

The survival rates in the control groups of Experiments 1 and 2 not only provide the basis for comparison for the experimental treatments, but also suggest the nature of survival rates under commercial conditions. Considering first the daily survival rate, Figures 1 and 3 may be examined. In both experiments, there is a drop in survival rate lasting from 3 to 5 days, reaching its lowest point at the midpoint of the interval. The rate then gradually increases, levelling off to a plateau. While this drop in survival is common to both experiments, the time at which it occurs is different in the two experiments. The reason for this lack of agreement is not suggested by the data. It may be noted, however, that with respect to water temperature and pH, the low survival interval did not differ from the remaining period in either experiment. In Experiment 1, the range for the water temperature was 26.5°C to 27.5°C in both the low survival and remaining periods; in Experiment 2, the range was 26°C to 28°C in both periods. The pH in Experiment 1 ranged from 6.9 to 7.2 in both periods, and from 7.2 to 7.7 in both periods of Experiment 2. The cumulative survival rates are shown in Figures 2 and 4. In Figure 4, the fall in cumulative survival is more rapid than in Figure 2, due to the earlier onset of the interval showing a drop in the survival rate.

Differences between treatments in survival rates are also illustrated by Figures 1-4, with the supporting data given in Tables 1 and 2. The results of each experiment will be discussed separately, after which comparisons between the two will be made.

In Experiment 1, the effect on survival of antibiotic and vitamin B complex with B_{12} treatments was investigated. For both experimental treatments, the fall in survival is less marked than in the control group (see Figure 1) resulting in a higher final survival rate (see Figure 2). Before determining whether these differences were statistically significant, the equality of the survival values within treatments was tested. Using a chi-square test of homogeneity, the hypothesis of equality was rejected (see Table 4). Noting that the initial number is a random variable having the same distribution in all the cases, the survival rates under each experimental treatment can be considered as observations on the same random variable. Therefore, to test the significance of the difference between treatments, the distributions of the survival values obtained for the different treatments were compared by the Kolmogorov-Smirnov test. Comparing the two treatments at a time, it was found that both the antibiotic and vitamin B complex treatments differed significantly from the control, but not from each other (see Table 5).

Considering first the effect of the antibiotic treatment on survival of Indian carp during the first three weeks of life, the relevant literature may be reviewed. Previous workers have investigated the effect of antibiotics on survival in the fry and fingerling of trout (*Salmo trutta*). There has been no work reported dealing with the early period following hatching, nor with Indian carp. Wolf (1952) reported slightly higher survival using chlortetracycline with vitamin B_{12} and terramycin. In the work of Phillips *et al* (1952), who used chlortetracycline, oxytetracycline, penicillin, bacitracin, and vitamin B_{12}, the antibiotics did not produce any beneficial effect on survival. Snieszko's (1957) review of the literature shows further conflicting results in this area. While the present data are in agreement with Wolf's, it may be noted that in his work, the antibiotics were combined with vitamin B_{12}. Which factor was effective was not, therefore, shown. The effect of vitamins on survival has been examined for trout by Phillips and Brockway (1957). They report some increase in survival with a vitamin B complex treatment, which is in agreement with the results of this experiment.

Experiment 2 was designed to confirm the effect of vitamin B complex with B_{12} and to examine the effect of manuring treatment on survival. It may be noted that manuring has been a practice recommended to commercial spawn culturists in India (e.g. Hora, 1943). For the data of Experiment 2, the final proportions surviving for each treatment, and replication thereof, were analysed in the same manner as for the preceding experiment. As the within treatment survival values could not be interpreted as equal (see Table 4), the differences between treatments were again examined using the Kolmogorov-Smirnov test (see Table 5). As in the previous experiment, treatment with vitamin B complex produced results significantly different from those of the control. However, the use of cowdung in the manuring treatment did not show results differing significantly from the control. Previous research in this laboratory showed that increasing the dosage of cowdung has a detrimental effect on survival (unpublished data).

Treatment with vitamin B complex with B_{12}, in both experiments and with antibiotics in the first experiment, resulted in a survival rate significantly higher than that of the control (see Figures 2 and 4, and Table 5). This was apparently due to protection afforded by the treatment during the interval showing a sharp drop in survival rate. After that interval had passed, the treatment did not show any further advantage, as is shown by the daily survival rates (see Figures 1 and 3). A hypothesis suggested by these results is that age of the carp may be a significant factor affecting the probability of survival. This hypothesis is also suggested by further analysis of the data described below.

A third feature of the data is the effect of the initial number of carp in a replication on the final proportion surviving. While the present experiments were not designed to test this effect, its possible presence in the data warranted statistical analysis. Table 3 shows, in general, that as initial number decreases, proportion surviving increases, which is in agreement with data reported by Andrewartha and Birch (1954). If the replications within a treatment are ranked in order of initial number, and rank orders are also assigned in terms of final proportion surviving, Kendall's coefficient of concordance can be applied to determine the degree of agreement between the two sets of ranks. The values of these coefficients for the present data are given in Table 6. As these results indicated that, in the majority of treatments, survival is not independent of the initial number, an attempt was made to fit a curve for final proportion surviving (r) in relation to initial number (n). For the replications under the same treatment, the following model was able to explain most of the variation:

$$E(r/n\,|\,n) = \alpha+\beta/n; \quad V(r/n\,|\,n) = k/n$$

where E stands for expectation, r and n are as defined above, α and β for the point of origin and regression coefficient as usually defined, V for variance and k as a constant. To determine whether the regression coefficients account for a significant proportion of the variation, the hypothesis $\beta = 0$ was tested by analysis of variance for each experimental treatment. The variance ratios, reported in Table 8, were significant for all treatments in both experiments, with the exception of the antiobiotic treatment. This analysis showed that for all treatments, excepting the antibiotic treatment of Experiment 1, regression accounts for over 70 percent of the variation. The estimated values of α and β, and their variance, are given in Table 9.

While the above analysis shows that in the majority of treatments proportion surviving is inversely related to initial number, it does not indicate whether this occurs consistently throughout the experiment, or only during a limited period. In order to obtain information on this point, the experimental period was divided up into three parts. The proportion surviving was computed for each period, with the initial number of that period as the base. Tables 10 and 11 give this data for Experiments 1 and 2 respectively. Rank orders were assigned as described previously to obtain coefficients of concordance for the different experimental periods. This analysis (see Table 7) showed that, in the first experiment, proportion surviving was independent of initial number for the first five days and the last nine days of the experiment, but was not independent of initial number during the intervening seven days. In the second experiment, independence was found for all treatments during the last eight days, with lack of independence for the first seven days. During the intervening seven days, this independence was found only for the vitamin B complex treatment. If these results are examined in relation to Figures 1 and 3, it can be seen that the periods showing a significant coefficient of concordance correspond to the interval of low survival. In both of the experiments there is no demonstrable relationship between initial number and proportion surviving after two weeks of life. This result suggests first, that there is an initial period of high mortality which corresponds to the initial period of rapid growth, and second, it is only during this period that the initial number bears an inverse relationship to survival rate. While the mechanism for such results is not revealed by these data, it may be noted that the period of most rapid rate of growth has been shown in other species to be one of susceptibility to various adverse factors and low survival (e.g. in chickens, as discussed by Heuser, 1946). Thus, the higher rate of survival after the second week of life noted in these experiments may be due to the passing of the high initial spurt of growth, during which the probability of survival decreases as number increases. Some suggestions may be advanced to account for these results in terms of the experimental treatments. As was noted earlier in this discussion, the vitamin B complex and antibiotic treatments maintained a higher survival rate than the control and manuring treatments only during this period of high mortality. It was suggested there that these treatments afforded some protection. It would be expected that the mechanisms of such a protection would be different for the two treatments. The antibiotics may check the growth of bacteria, hence reducing such factors as infections, while the vitamin B complex may have advantageous effects with respect to growth and metabolic processes. These mechanisms have also been alluded to by Phillips and Brockway (1957), though not specifically in reference to this particular period of high growth. It should be noted that these suggestions are only advanced as hypotheses, which require experimental corroboration.

Conclusions

During the initial period of life of Indian carp (*Catla catla*, *Labeo rohita*, *Cirrhina mrigala*) the survival rate of the untreated controls showed a sharp drop during a three to five day interval, following which it gradually increased, levelling off within four days after the point of lowest survival.

Experimental treatments with antibiotics and vitamin B complex with vitamin B_{12} significantly enhanced survival rate in comparison with the untreated controls. These treatments were effective only during the period of low survival.

A manuring treatment, which is a recommended practice for commercial spawn culture in India, did not demonstrate any appreciable difference from the untreated controls in survival rate.

Analysis showed that survival rate is inversely related to initial number; however, this relationship did not seem to be valid after the first two weeks of life.

TABLE 1. DAILY AND CUMULATIVE SURVIVAL RATES FOR EXPERIMENT 1

	treatment											
	A control				B antibiotic				C vitamin B complex with vitamin B_{12}			
day	number of live fish	number of deaths	cumulative survival rate	daily survival rate	number of live fish	number of deaths	cumulative survival rate	daily survival rate	number of live fish	number of deaths	cumulative survival rate	daily survival rate
(1i)	(2_i)	(3_i)	$(4_i)=\frac{(2_i)}{11604}$	$(5_i)=\frac{(2_i)}{(2_{i-1})}$	(6_i)	(7_i)	$(8_i)=\frac{(6_i)}{10190}$	$(9_i)=\frac{(6_i)}{(6_{i-1})}$	(10_i)	(11_i)	$(12_i)=\frac{(10_i)}{10960}$	$(13_i)=\frac{(10_i)}{(10_{i-1})}$
0	11604	169	1.0000		10190	80	1.0000		10960	86	1.0000	—
1	11435	846	0.9855	0.9854	10119	8	.9922	.9922	10865	24	.9922	.9922
2	10589	892	0.9039	0.9173	10111	129	.9914	.9992	10841	177	.9900	.9978
3	9697	656	0.8248	0.9238	9982	58	.9797	.9882	10666	60	.9743	.9841
4	9041	657	0.7926	0.9374	9929	76	.9785	.9937	10610	161	.9696	.9965
5	8384	953	0.7608	0.9444	9853	288	.9661	.9928	10606	292	.9597	.9906
6	7461	2019	0.6563	0.8891	9596	595	.9607	.9787	10217	776	.9396	.9722
7	5422	589	0.4665	0.7268	9099	566	.9023	.9390	9447	1196	.8623	.9241
8	5033	1294	0.4337	0.9052	8433	2056	.8268	.9371	8243	3076	.7520	.8720
9	3739	1514	0.3222	0.7429	6377	1701	.6252	.7562	5173	1788	.4726	.6276
10	2225	1372	0.1917	0.5951	4676	1981	.4585	.7333	3418	642	.3121	.6607
11	853	259	0.0735	0.3834	2795	344	.2740	.5977	2776	246	.2535	.8122
12	833	72	0.0659	0.8768	2451	307	.2403	.8769	2466	171	.2254	.8890
13	461	29	0.0397	0.9649	2144	149	.2102	.8747	2297	97	.2098	.9307
14	432	15	0.0372	0.9371	1995	40	.1956	.9305	2200	62	.2009	.9579
15	417	0	0.0359	0.9652	1955	61	.1917	.9799	2137	41	.1952	.9714
16	417	3	0.0359	1.0000	1894	54	.1857	.9688	2096	33	.1913	.9808
17	414	0	0.0357	0.9928	1840	82	.1804	.9715	2063	14	.1875	.9842
18	414	1	0.0357	1.0000	1758	43	.1723	.9826	2049	22	.1862	.9932
19	413	5	0.0356	0.9976	1715	42	.1730	.9752	2027	9	.1842	.9897
20	408	2	0.0352	0.9879	1723	26	.1689	.9762	2018	4	.1835	.9960

TABLE 2. DAILY AND CUMULATIVE SURVIVAL RATES FOR EXPERIMENT 2

	treatment											
	A: control				*B*: manure				*C*: vitamin B complex with vitamin B_{12}			
day	number of live fish	number of deaths	cumulative survival rate	daily survival rate	number of live fish	number of deaths	cumulative survival rate	daily survival rate	number of live fish	number of deaths	cumulative survival rate	daily survival rate
(1_i)	(2_i)	(3_i)	$(4_i)=\frac{(2_i)}{5953}$	$(5_i)=\frac{(2_i)}{(2_{i-1})}$	(6_i)	(7_i)	$(8_i)=\frac{(6_i)}{5762}$	$(9_i)=\frac{(6_i)}{(6_{i-1})}$	(10_i)	(11_i)	$(12_i)=\frac{(10_i)}{7381}$	$(13_i)=\frac{(10_i)}{(10_{i-1})}$
0	5953	310	1.0000	—	5762	316	1.0000	—	7381	495	1.0000	—
1	5643	929	.9479	.9479	5446	844	.9452	.9452	6886	749	.9329	.9329
2	4714	1345	.7919	.8354	4602	1432	.7987	.8450	6137	801	.8315	.8912
3	3369	1130	.5659	.7147	3170	918	.5502	.6888	5336	601	.7229	.8695
4	2239	567	.3761	.6646	2252	527	.3908	.7104	4735	498	.6415	.8874
5	1672	253	.2842	.7468	1725	192	.2994	.7659	4237	312	.5740	.8952
6	1419	149	.2384	.8488	1533	109	.2661	.8886	3927	216	.5320	.9264
7	1270	76	.2133	.8950	1424	64	.2471	.9289	3711	238	.5028	.9450
8	1194	85	.2006	.9402	1360	94	.2361	.9551	3473	192	.4705	.9359
9	1109	57	.1863	.9288	1266	61	.2197	.9308	3281	135	.4445	.9447
10	1052	74	.1767	.9486	1205	62	.2091	.9518	3146	145	.4262	.9589
11	978	53	.1643	.9297	1143	72	.1984	.9485	3001	116	.4066	.9539
12	925	76	.1554	.9458	1071	77	.1859	.9370	2885	67	.3909	.9613
13	849	77	.1426	.9178	994	81	.1725	.9281	2818	92	.3818	.9768
14	772	50	.1297	.9093	913	42	.1585	.9185	2786	60	.3693	.9674
15	722	31	.1213	.9352	871	30	.1512	.9540	2666	35	.3612	.9780
16	691	20	.1161	.9571	841	22	.1459	.9655	2635	44	.3570	.9884
17	671	17	.1127	.9711	819	29	.1421	.9738	2591	31	.3510	.9833
18	654	13	.1099	.9747	790	21	.1371	.9645	2560	33	.3468	.9880
19	641	4	.1077	.9804	769	20	.1335	.9734	2527	35	.3424	.9871
20	637	9	.1070	.9938	749	11	.1300	.9740	2492	26	.3376	.9861
21	628	5	.1055	.9859	738	13	.1281	.9853	2466	21	.3341	.9896
22	623		.1047	.9920	725		.1258	.9824	2445		.3313	.9915

TABLE 3. FINAL PROPORTION SURVIVING IN RELATION TO INITIAL NUMBER INTRODUCED

	treatment								
	A : control			*B* : antibiotic			*C* : vitamin B complex & B_{12}		
	initial number X_1	number surviving Y_1	proportion surviving Y_1/X_1	initial number X_2	number surviving Y_2	proportion surviving Y_2/X_2	initial number X_3	number surviving Y_3	proportion surviving Y_3/X_3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
				experiment 1					
1	3776	8	.0021	2689	358	.1331	3079	387	.1257
2	2456	0	0	2230	432	.1937	2806	402	.1433
3	2034	105	.0516	2105	308	.1463	1862	342	.1837
4	1747	156	.0893	1696	403	.2376	1668	349	.2092
5	1584	137	.0865	1411	196	.1389	1532	525	.3427
				experiment 2					
1	779	72	.092	757	72	.095	1540	421	.273
2	767	62	.081	703	62	.088	985	245	.249
3	752	53	.060	651	62	.095	943	202	.214
4	723	58	.070	641	80	.125	785	247	.315
5	702	63	.090	615	85	.138	737	286	.388
6	597	59	.099	542	80	.148	714	296	.415
7	515	75	.146	530	62	.117	553	221	.400
8	432	58	.134	460	80	.174	439	164	.374
9	353	62	.176	460	70	.152	404	215	.532
10	333	61	.183	403	72	.179	281	148	.527

TABLE 4. CHI-SQUARE VALUES : TESTING WITHIN TREATMENT HOMOGENEITY

experiment	treatment	degrees of freedom	chi-square observed	chi-square 5% level
(1)	(2)	(3)	(4)	(5)
1	control	4	504.7	9.49
	antibiotic	4	108.5	9.49
	B complex with B_{12}	4	322.8	9.49
2	control	9	74.7	16.90
	manure	9	54.4	16.90
	B complex with B_{12}	9	315.8	16.90

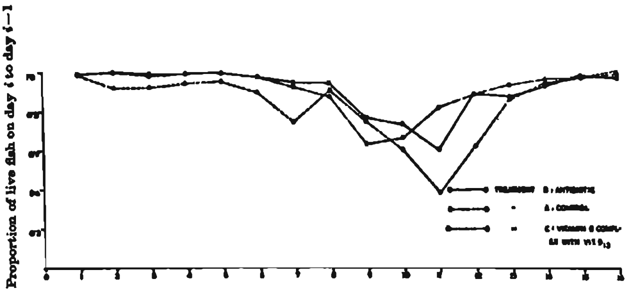

Figure 1. Daily Survival Rate of Spawn for Experiment 1.

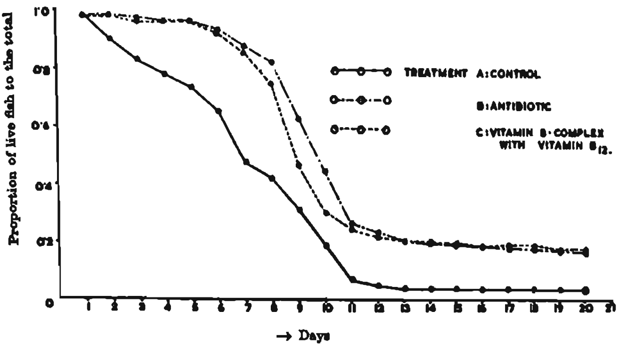

Figure 2. Cumulative Survival Rate of Spawn for Experiment 1.

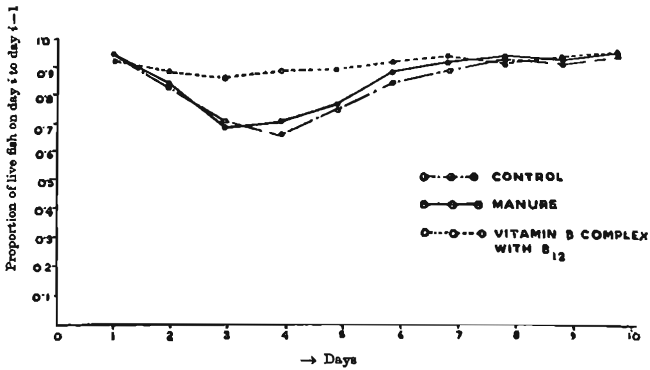

Figure 3. Daily Survival Rate of Spawn for Experiment 2

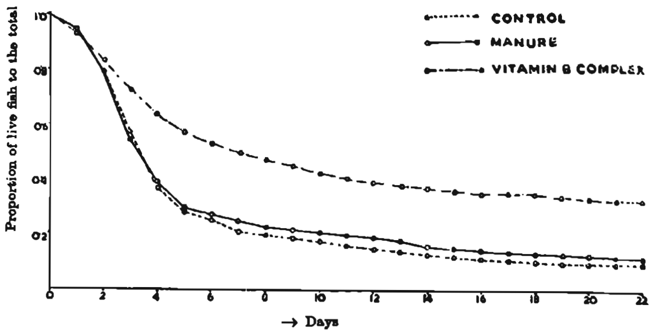

Figure 4. Cumulative Survival Rate of Spawn for Experiment 2

TABLE 5. $D_{m,n}$ VALUES FOR KOLMOGOROV-SMIRNOV TEST OF SIGNIFICANCE FOR TWO DISTRIBUTIONS

experiment	treatment	m	n	$D_{m,n}$ observed	$D_{m,n}$ 5% level
(1)	(2)	(3)	(4)	(5)	(6)
1	control and antibiotic	5	5	1.0	.86,033
	control and vitamin B complex and B_{12}	5	5	1.0	.86,033
	vitamin B complex and B_{12} and antibiotic	5	5	0.1	.86,033
2	control and manure	10	10	0.3	.56,328
	control and vitamin B complex and B_{12}	10	10	1.0	.56,328
	vitamin B complex and B_{12} and manure	10	10	1.0	.56,328

TABLE 6. COEFFICIENT OF CONCORDANCE, S, FOR INITIAL NUMBER AND FINAL PROPORTION SURVIVING

experiment	treatment	S observed
(1)	(2)	(3)
1	control	−6
	antibiotic	−2
	vitamin B complex with B_{12}	−10*
2	control	−31**
	manure	−37**
	vitamin B complex with B_{12}	−33**

*$P = .0083$, **$P = .0023$

TABLE 7. COEFFICIENT OF CONCORDANCE, S, FOR INITIAL NUMBER AND PROPORTION SURVIVING FOR SUCCESSIVE EXPERIMENTAL PERIODS

experiment	treatment	observed S for period in days		
(1)	(2)	(3)	(4)	(5)
1		1–5	6–12	13–21
	control	−6	−8*	−2
	antibiotic	−4	−8*	−4
	vitamin B complex with B_{12}	−4	−8*	−2
2		1–7	8–14	15–22
	control	−27**	−29**	−7
	manure	−25**	−39**	−5
	vitamin B complex with B_{12}	−29**	−11	−1

*$P < .042$, **$P < .036$.

TABLE 8. ANALYSIS OF VARIANCE SUMMARY TABLES TO TEST SIGNIFICANCE OF REGRESSION

	treatment									
	control				antibiotic			vitamin B complex with B_{12}		
source of variation	*d.f.*	*s.s.*	*m.s.*	*f*	*s.s.*	*m.s.*	*f*	*s.s.*	*m.s.*	*f*
					experiment 1					
regression	1	14.0206	14.0206	14.103*	.4820	.48200	.099	42.4836	42.48360	10.254*
residual	3	2.9824	.9941		14.6040	4.86800		12.4288	4.14293	
total	4	17.0030			15.0860			54.9124		
					experiment 2					
regression	1	5.2126	5.21260	73.303**	4.1696	4.16960	30.357**	41.6037	41.6037	15.494**
residual	8	.5689	.07111		1.0988	.13735		21.4814	2.6852	
total	9	5.7715			5.2684			63.0851		

*$P < .05$, **$P < .01$.

TABLE 9. ESTIMATED VALUES OF α AND β FOR REGRESSION OF PROPORTION SURVIVING ON INITIAL NUMBER

experiment	treatment	$\hat{\alpha}$	$\hat{\beta}$	$\hat{V}\hat{\alpha}$	$\hat{V}\hat{\beta}$
(1)	(2)	(3)	(4)	(5)	(6)
1	control	−.07596	257.387	.000959	4698.25
	B complex with B_{12}	−.03465	476.879	.017340	48559.43
2	control	−.00032	62.490	.0003656	116.89
	manure	−.01064	78.630	.000255	82.16
	B complex with B_{12}	.17941	112.080	.001839	803.79

TABLE 10. EXPERIMENT 1: PROPORTION SURVIVING IN RELATION TO INITIAL NUMBER FOR SUCCESSIVE PERIODS IN THE EXPERIMENT

treatment	initial no.	no. surviving on 5th day	survival rate in this period 1–5	no. surviving on 12th day	survival rate in this period (5–12)	no. surviving on 21st day	survival rate in this period 12–21
(1)	(2)	(3)	(4)=(3)/(2)	(5)	(6)=(5)/(3)	(7)	(8)=(7)/(5)
	2456	1401	.5704	0	0	0	—
	3776	2255	.5972	10	.0017	8	.8
control	2034	1789	.8795	148	.0827	105	.7095
	1584	1510	.9533	208	.1516	137	.6587
	1747	1632	.9342	160	.0980	156	.9750
	2689	2570	.9215	410	.1595	358	.8732
	2230	2168	.9722	572	.2638	432	.7552
antibiotic	2105	2030	.9644	370	.1823	308	.8324
	1696	1646	.9705	604	.3670	403	.6672
	1411	1371	.9717	427	.3115	196	.4590
	1862	1787	.9597	383	.2143	342	.8930
	3079	2922	.9490	480	.1966	387	.8063
vitamin B complex	2806	2716	.9679	492	.1811	402	.8171
	1668	1591	.9538	444	.3871	349	.7860
	1532	1488	.9713	664	.4462	525	.7907

TABLE 11. EXPERIMENT 2: PROPORTION SURVIVING IN RELATION TO INITIAL NUMBER FOR SUCCESSIVE PERIODS IN THE EXPERIMENT

treatment	initial no.	no. surviving on 7th day	survival rate during first week	no. surviving on 14th day	survival rate during second week	no. surviving on 22nd day	survival rate during last week
(1)	(2)	(3)	(4) = (3)/(2)	(5)	(6) = (5)/(3)	(7)	(8) = (7)/(5)
control	752	156	.2074	74	.4744	53	.7162
	702	121	.1724	74	.6116	63	.8513
	432	99	.2292	68	.6869	58	.8529
	515	126	.2447	88	.6984	75	.8523
	597	136	.2278	78	.5735	59	.7564
	353	130	.3683	80	.6154	62	.7750
	779	137	.1759	87	.6350	72	.8276
	723	126	.1743	73	.5794	58	.7945
	333	96	.2883	80	.8333	61	.7625
	767	143	.1864	70	.4895	62	.8857
manure	757	170	.2246	81	.4765	72	.8889
	460	112	.2435	92	.8214	70	.7609
	641	158	.2465	102	.6456	80	.7843
	651	145	.2227	79	.5448	62	.7848
	460	138	.3000	111	.8043	80	.7207
	530	167	.3151	86	.5150	62	.7209
	703	140	.1991	82	.5857	62	.7561
	615	137	.2228	100	.7299	85	.8500
	403	108	.2680	91	.8426	72	.7912
	542	139	.2565	99	.7122	80	.8081
vitamin B complex	985	437	.4436	274	.6270	245	.8942
	1540	576	.3740	446	.7743	421	.9439
	553	341	.6166	262	.7683	221	.8435
	281	201	.7153	175	.8706	148	.8457
	714	375	.5252	330	.8801	296	.8970
	430	257	.5854	175	.6809	164	.9371
	737	407	.5522	310	.7617	286	.9226
	404	267	.6609	227	.8502	215	.9471
	943	349	.3701	224	.4183	202	.9018
	785	501	.6382	303	.6048	247	.8152

REFERENCES

ANDREWARTHA, H. G. and BIRCH, L. C. (1954): *The Distribution and Abundance of Animals*, University of Chicago Press, Chicago.

HEUSER, G. F. (1940): *Feeding Poultry*, John Wiley, New York.

HORA, S. L. (1943): Manuring of ponds and artificial feeding of fishes. *Indian Farming*, **4**, 559–562.

——— (1947): Role of fisheries in the improvement of the nutrition of the Indian people. *Indian Farming*, **8**, 280–281.

——— (1949): Fishery resources of Western Bengal and their utilisation. *Science and Culture*, Calcutta, **15**(5), 176–180.

——— (1950a): Development of fisheries. *Industry*, 168–171.

——— (1950b): Food and people—Development of fisheries. *Journal of Scientific and Industrial Research*, **5**,(5), 143–145.

KENDALL, M. G. (1948): *Rank Correlation Methods*, Griffin, London.

MASSEY, F. J. JR. (1951): The Kolmogorov–Smirnov test for goodness of fit. *J. Amer. Stat. Ass.*, **46**, 68–78.

PHILLIPS, A. M. JR., LOVELACE, F. E., BROCKWAY, D. R. and BALZA, G. C. JR. (1952): *The Nutrition of Trout*. Cortland Hatchery Report 21. New York. Conservation Department, Fishery Research Bulletin 16.

PHILLIPS, A. M. JR. and BROCKWAY, D. R. (1957): The nutrition of trout. IV. Vitamin requirements. *Progressive Fish-Culturist*, **19**(3), 119-123.

SHIMENKO, S. F. (1957): Use of antibiotics in the diet of salmonid fishes. *Progressive Fish-Culturist*, **19**(2), 81-84.

WOLF, L. E. (1952): Experiments with antibiotics and vitamin B_{12} in the diet of brown trout fingerlings. *Progressive Fish-Culturist*, **14**(4), 148–153.

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