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Brook Trout Populations in High Lakes

Populations of brook trout, *Salvelinus fontinalis,* inhabiting two adjacent alpine lakes were studied over an eight-year period. In one lake few large fish were captured compared with earlier years. This lack of fish cannot be attributed to harvest since fishing pressure is slight in this remote area. The brook trout in the other lake were consistently larger and in better condition. I was interested in the following objectives: (1) To compare condition and survival of the brook trout populations in both lakes; (2) To apply rotenone to one lake in order to learn more about the structure of the fish population and to note the effect of the toxin in the very soft water; (3) To determine the effectiveness of angling as a means of representing length distribution.

The limnology of the waters is described by Rabe and Gaufin (1964) and Rabe (1965). Previous estimations of population size, scale analyses, and stomach sampling data were made of the brook trout (Rabe and Dyer, 1964). Rainbow trout, *Salmo gairdnerii,* were also present but in lesser numbers (Rabe, 1966).

Physical and Limnological Data

The lakes are located at an elevation of 10,600 to 11,000 feet in the Swift Creek drainage of the Green River system on the south slope of the Uinta Mountains, Utah. Extensive shoal areas in lake X-25 together with a permanent inlet stream provide adequate spawning conditions. Lake X-26 is about one-half mile away and 400 feet higher. The steep slope of the basin, large boulders comprising most of the substrate, and intermittent seepage inlets provide little or no spawning area. Summer water temperatures of both lakes are below 60 degrees F. Total dissolved solids are less than 10 mg/1. Ice and snow cover the area from seven to nine months of the year. Species diversity is slight at all trophic levels. Standing crop of plankton is low as compared to eutrophic waters (Table 1). X-26 trout consume more benthos than X-25 fish, indicating a greater invertebrate biomass in the lake (Rabe and Dyer, 1963).

TABLE 1. Average Plankton Counts over Six Sampling Periods from July-September.[1]

Lake	Date	Net Zooplankton	Rotifers	Net Phytoplankton	Nannoplankton
X-25	1960	77	176	417	8,330
	1961	48	66	2,250	6,330
	1962	18	25	154	21,971
X-26	1960	33	161	2,480	1,920
	1961	20	60	3,183	8,167
	1962	30	12	1,583	4,596

[1] Expressed as number per liter (Rabe and Gaufin, 1963).

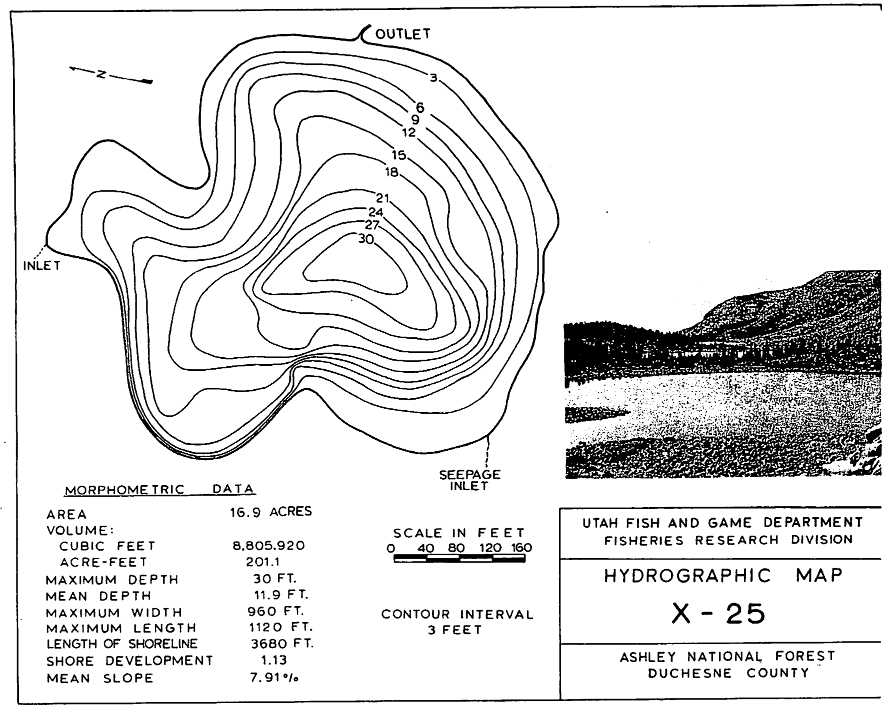

Figure 1.

Conditions Prior to Poisoning

Utah Fish and Game records show that X-25 was planted with 1500 brook trout fry ir 1958 and that X-26 received 2100 fish that year. No stocking policy was in effec before this time, and it was done largely on field recommendations (personal com munication). Fish collections from the two lakes were made in 1957 by Fish anc Game personnel (Hales, 1958). From 1959 to 1964 samples were collected by rod and reel and gill nets. Fish population estimates by Rabe and Dyer (1963) indicated about 600 fish per acre in X-26 and 1000 per acre in X-25. Brook trou from X-25 exhibited smaller growth increments than did X-26 fish. Young of th year trout were consistently observed in the shoals in X-25 but were rarely seen ir X-26.

Average lengths, weights, and condition of the fish were presented in Tables 2 anc 3 over a period of eight years. A decrease in length size of brook trout samples fron X-25 was very apparent during this time. Larger fish were consistently present ir X-26. Trout collected in 1957, 1959, and 1960 from X-25 reached lengths of 300 mn as compared with 1963 and 1964 when samples seldom attained a length of 225 mm Trout from X-26 showed relatively little change in maximum length. Fish sample exceeding 225 mm in X-25 were in much poorer shape than smaller trout in th same lake. Many possessed large heads and snakelike bodies. Such extremes in condi tion did not exist in X-26.

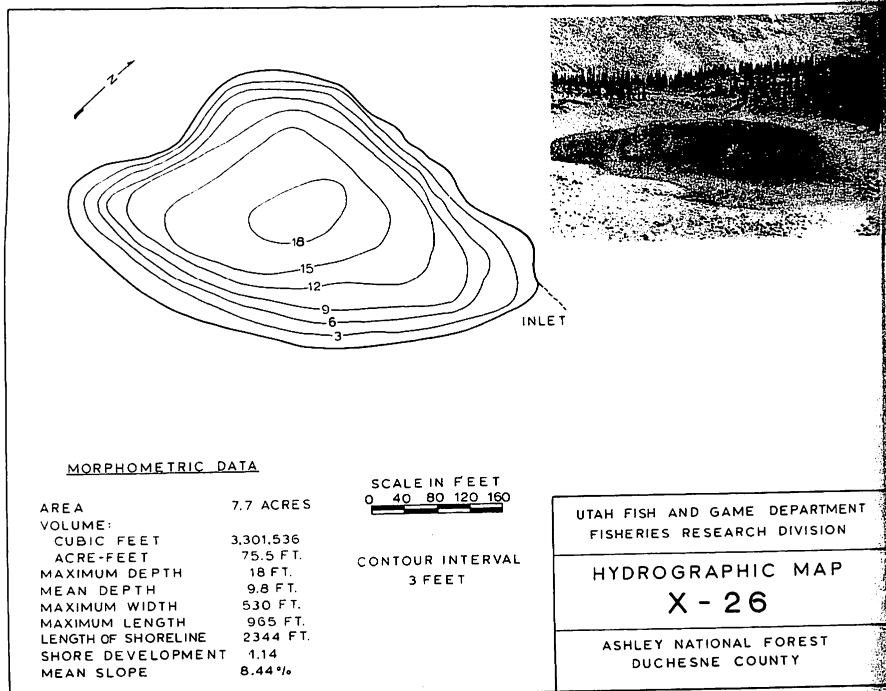

Figure 2.

The null hypothesis that conditions changed little over the years for fish 176-200 and 201-225 mm lengths in X-25 was not rejected at the 5 per cent level of significance when the F test was used with a least square analysis of variance for unequal subclass numbers for years 1960-1964 (Table 4). Lake X-26 trout were found to be in much better condition for comparable length groups sampled in August than samples from X-25. Fish 201-225 mm for both lakes were included in a least square AOV. Lakes and year effects and the lake and year interaction were all found to be significant at the 1 per cent level. The X-26 mean of 1.051 exceeded the X-25 mean of 0.854. However, examination of the lake and year subclasses clearly shows an upward trend for condition in X-26 while X-25 remained essentially the same for 1960-1962.

When the 200-250 subclasses were combined over a five-year period, 1960-1964, essentially the same results were found as for the 201-225 mm length classes. The X-26 mean condition, 1.011, exceeded the 0.815 of X-25. However, years 1962, 1963, and 1964 show quite higher condition for X-26 than in 1960 and 1961, even though small numbers were included in 1963 and 1964. Condition factors of X-25 fish remained surprisingly constant throughout the entire period, ranging from 0.776 to 0.834.

TABLE 2. Comparison of Length, Weight, and Condition K(T.L.)[1] of Brook Trout in Lake X-25. (Experimentals)

Year	Length Class 101-125	126-150	151-175	176-200	201-225	226-250	251-275	276-300
1957—July Av. length								278 (38)[2]
1959—Sept. Av. length		142	167	188	214	244	261	278
Av. weight		29	47	68	100	120	139	169
K(T.L.)		1.004(7)	1.003(10)	1.023(23)	1.019(8)	0.836(13)	0.778(26)	0.782(4)
1960—July	110	132	166	190	213	247	261	279
	13	24	44	65	86	85	115	132
	0.960(11)	1.064(4)	0.962(11)	0.948(15)	0.890(13)	0.564(1)	0.646(7)	0.608(3)
August	122	134		190	214	239	260	
	16	22		65	86	94	115	
	0.890(2)	0.903(5)		0.945(9)	0.872(9)	0.688(5)	0.654(2)	
1961—July			158	191	212			
			36	63	79			
			0.890(5)	0.907(11)	0.826(3)			
August			170	190	212	234	271	
			43	60	80	92	87	
			0.869(2)	0.879(6)	0.848(12)	0.721(4)	0.434(2)	
1962—July			169	192	209	230		
			45	58	68	75		
			0.932(6)	0.819(41)	0.7446(20)	0.616(6)		
August	123	149	168	191	208	242		
	22	35	46	64	75	81		
	1.207(3)	1.057(1)	0.969(3)	0.915(24)	0.843(22)	0.575(1)		
1963—Aug.	103	142	173	194	209	227		
	10	32	53	65	71	74		
	0.915(1)	1.117(1)	1.005(2)	0.897(21)	0.784(17)	0.633(1)		
1964—Aug.		132	170	190	210	234		
		28	56	63	76	65		
		1.217(2)	1.145(3)	0.925(63)	0.840(48)	0.507(1)		

[1] K(T.L.): The coefficient of condition (K) is used to describe the length-weight relationship of a fish. $K=\frac{W10^5}{L^3}$ Where W is weight in grams, L is total length in mm and 10^5 is a factor to bring the value of K near unity.

[2] This sample ranged in length from 221-305 mm. Wts. were not taken. ( ) indicates sample size.

TABLE 3. Comparison of Length, Weight, and Condition K(T.L.) of Brook Trout in Lake X-26. (Control)

Year	101-125	126-150	151-175	176-200	201-225	226-250	251-275	276-300	301-325	326-350
					Length Class					
1957—Sept. Av. length								292 (8)[1]		
1959—Sept. Av. length Av. weight K(T.L.)				180 60 1.029(1)		245 150 1.020(1)	252 160 1.000(1)		325 304 0.886(1)	
1960—July	123 20 1.076(2)	142 28 0.985(5)	160 41 1.010(6)	196 71 0.936(7)	210 92 0.951(28)	232 116 0.928(2)				
August					211 90 0.958(20)	229 108 0.8962(2)			320 — — (1)	
1961—July				191 — — (5)	217 88 0.863(5)	237 114 0.856(1)				
August				192 75 1.056(4)	216 92 0.908(10)	236 110 0.835(4)				
1962—July			156 43 1.130(2)	187 68 1.000(5)	215 97 0.973(13)	234 120 0.931(9)				
August					214 122 1.287(2)	238 148 1.090(31)	259 181 1.042(6)			
1963—Aug.						243 157 1.095(5)	263 173 0.955(11)	285 216 0.926(3)		
1964—Aug.			168 56 1.181(3)	195 75 1.012(1)		245 148 1.006(6)	266 182 0.966(13)	282 212 0.945(5)		

[1] This sample ranged in length from 203-317 mm.
Wts. were not taken.
( ) indicates sample size.

TABLE 4. Least Squares Analysis of Variance—a Comparison of Condition Factors within and between Lakes.

	Source of Variation	DF	Mean Squares
Lake X-25 176-200 1960-64	Year Error	4 102	.0063* .0045
Lake X-25 201-225 1960-64	Year Error	4 110	.1650* .0071
Lakes X-25, X-26 201-225 1960-62	Lake Year Lake-Year Error	1 2 2 74	.4003** .0987** .1108** .0037
Lakes X-25, X-26 200-250 1960-64	Lake Year Lake-Year Error	1 4 4 197	1.2806** .0824** .0726** .0090

** Significant at 1 per cent level.
* Significant at 5 per cent level.

Poisoning Operation

Rotenone (Chem-Fish Regular) was applied in Lake X-25 from a rubber raft with a Hudson Heavy Duty Sprayer. One man handled the operation. The spray nozzle was placed in the water and lever locked, thus permitting application while rowing around the lake. A gallon could be dispersed before additional pumping was necessary. This procedure was conducted late in the afternoon. More rotenone was applied the next morning, and by noon most of the fish in the lake were presumed dead. One gallon per six acre foot yielded a concentration of 0.5 mg per liter (30 gallons). Half the amount may have been sufficient to kill fish in these extremely oligotrophic waters.

We collected 195 trout around the periphery of the lake after the first day of poisoning. An additional 100 fish were found the second day. The rubble and boulders in the littoral offered places of retreat for stricken fish. Nearly half the trout spotted were found with only a small portion of their body visible after wedging between or under the rocks. It is not known how many fish were passed over. Counts of dead fish on the bottom were impossible because of turbid water conditions.

I believe that the sample recovered is representative of the true population in regard to proportionate numbers of different length classes. It does not seem reasonable that the fish selectively positioned themselves in the lake after poisoning. Prior to treatment groups of large as well as small trout were commonly observed to "cruise" the littoral zone, indicating a somewhat uniform dispersal.

Sampling Comparisons

The day before treatment, brook trout were caught from different locations in the lake. This sample was compared with that collected after poisoning to determine if those fish caught by hook and line were representative of the true population. A length class distribution of both types of sampling is presented in Table 5. Weights and conditions were not figured for the poisoned sample since these measurements were assumed to be identical to the rod sample. Chi square analysis over the entire length range shows that the ratio of the two sampling techniques is different at the 1 per cent *level. However, if one compares the longest length classes, 176-200 and 201-225 mm,* then both samples have a similar ratio at the 1 per cent level (Table 6).

TABLE 5. Comparison of Samples Collected by Rod and Reel and Samples from Rotenone Operation, August, 1964.

Length Class mm	No. of Fish	Av. Wt. Grms.	Av. Length Mm	Av. Cond. K(T.L.)
Rod and reel				
126-150	2	28	132	1.217
151-175	3	56	170	1.145
176-200	60	63	190	0.918
201-225	48	76	210	0.820
	113			
Poisoned				
44-61 (young-of-the-year)	4	....	50	....
101-125	10	....	121	....
126-150	17	....	131	....
151-175	16	....	168	....
176-200	104	....	192	....
201-225	90	....	209	....
	241			

TABLE 6. Contingency Table To Compare Methods of Collecting Samples.

Entire Sample

Length Class mm	Rod and Reel O	E	Poisoned O	E	
151-175	5	15.5	43	32.5	48
176-200	60	52.9	104	111.1	164
200-225	48	44.6	90	93.4	138
	113		237		350

Chi square = 12.3
Chi Square .01, 2 d.f. = 9.21.
The ratios are different at 1 per cent level.

176-225 mm Sample

Length Class mm	Rod and Reel O	E	Poisoned O	E	
176-200	60	58.6	104	105.4	164
200-225	48	49.4	90	88.6	138
	108		194		302

Chi square = 0.11
Chi Square .01, 1 d.f. = 6.63.
The ratios are not different at the 1 per cent level.

Assuming that the sample recovered after poisoning is representative of the true population, then the brook trout over seven inches caught by angling are representative of fish in those lengths in the lake.

Summary and Discussion

Environmental conditions appeared to be less limiting in X-25 early in the study. Trout attained lengths of 300 mm and more and compared favorably with brook trout growth and condition in an adjacent water.

Extensive shoal areas and inlet stream in X-25 provide suitable spawning areas which are not present in X-26. Overpopulation in X-25 resulted in a drastic reduction of fish-food biomass. Trout production then became much slower as attested by condition factors, scale analysis, and empty stomachs.

The trout population in X-25 appeared to be in relatively good shape as records indicate from 1957 to 1959. However, in the next few years larger fish began to degress in condition and assume a snaky appearance. Finally these long thin fish were seldom observed. In fact, no trout over 250 mm were seen or collected from 1962 to 1964.

Thus over an eight-year period fish which formerly grew to lengths of 300 mm rarely exceeded 225 mm as noted during the last two years. Trout from 175-225 mm changed little in condition over the years. X-26 fish in all length classes were in much better shape than comparable X-25 trout. The X-26 population also did not show the extreme length reduction.

The total number of fish recovered following poisoning X-25 was low as compared with an estimate of 18,000 in 1960. Collection problems consisted of (1) turbid waters in the limnetic zone limiting vision, and (2) the tendency of dying trout to conceal themselves in rubble along shore.

Regardless of the number of fish collected following treatment, it is conceivable that adult survival lessened together with decreased fecundity due to excessive nutritional demands (Reimers, 1958). Any increase in mortality on a fish population results in a decrease or elimination of the older and larger length groups as shown. I also observed fewer young of the year in the shallow areas of X-25 in 1963 and 1964 compared with earlier years, and few were found after poisoning. There is hardly any doubt that the small fish-food biomass was used primarily for maintenance requirements and that growth and formation of reproductive products had virtually ceased. Young fish were possibly also being cannibalized by their impoverished kin.

Trout biomass in X-26 is about half that of X-25. Spawning sites are limited, and from eight years of records fish have been consistently in good condition. Winter conditions are believed to be more severe in this higher lake (Rabe, 1966), which may help reduce population density. Comparatively few sportsmen visit these alpine waters so that fishing mortality is of no consequence as a density-governing factor.

Conclusions

1. Size of fish decreased progressively with time in a lake where fish-food biomass was low and production of young was possible.
2. Brook trout from 175-225 mm remained in the same condition over a long period of observation in the experimental lake. The control showed an upward trend in condition of fish from comparable length classes.
3. Brook trout from various length classes in the control lake were in better condition than the fish of comparable size in the experimental one. This contrast was greatest when larger fish from both waters were compared.
4. Sampling a high lake by angling yielded samples proportional in number to the size distribution of trout in the lake for fish above seven inches. This assumption is supported by recovery of a portion of the fish population following poisoning.
5. Immediate effects of the rotenone on the fish were apparent in water exhibiting extremely low alkalinity. Much less toxin could have been used as effectively.

Acknowledgments

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Association News

The forty first annual meeting will be on the campus of Central Washington State College in Ellensburg on March 22 and 23, 1968. A total of 178 papers are scheduled. The programs and other information will be sent to all members, recent members, and institutions near the end of February. Nonmembers may obtain programs or information from the Secretary-Treasurer (Bruce V. Ettling, Engineering Research Division, Washington State University, Pullman, Washington 99163).

Donald R. Johnson, Pacific Northwest Regional Director, Fish and Wildlife Service, will be the featured speaker at the Friday evening banquet. He will speak on "The Outlook for Columbia River Salmon." The Botany-Zoology and Soil and Water sections will hold a joint symposium on "The Biological Effects of Pulp Liquor Wastes in Puget Sound."

Abstracts of papers to be presented at the 1968 meeting of the Northwest Scientific Association

(Following are abstracts of papers received by presstime to be presented at the 41st Annual Meeting of the Northwest Scientific Association to be held at Ellensburg, Washington, on March 22 and 23.)

Optimal Dividend Policy under Uncertainty

L. P. Anderson
Harvard University
Cambridge, Massachusetts
V. V. Miller
Sacramento State College
Sacramento, California
and
R. Singh and P. Solomon
University of Oregon
Eugene, Oregon

Recent theories regarding optimum dividend policy under conditions of uncertainty have challenged the traditional view that dividends influence the market price of common stocks. The most notable presentation of this argument has been set forth by Modigliani and Miller.

On the other hand some authors have argued against Modigliani and Miller. Falling into this group have been such distinguished theorists as Myron Gordon, John Lintner, and James Walter. The issue, rather than being cleared up, has remained confused and unsettled.

An attempt is made to review the arguments and counterarguments to show why this discrepancy exists. The authors take issue with M & M and contend that M & M lead practitioners to erroneous conclusions. Further it is shown that Myron Gordon's arguments may be valid but for different reasons than originally presented. The issues which authors believe are important are presented in the light of this controversy.

Evaluating Tree Seed Crops and Seedbed Conditions in Northern California

Frank J. Baron
Humboldt State College
Arcata, California

Prompt regeneration of forested areas frequently poses problems of timing and allotment of effort. Not only must there be adequate sources of seed, but the seedbed conditions must be favorable for germination and survival. In California the actual amounts of seed collected by major seed-using agencies have been compared with predicted crops for over 10 years. The results are sufficiently encouraging to suggest extension and amplification of the effort. Total collections and predictions both show a pronounced tendency toward "seed years" and "off years" which can be anticipated. Irregularities among the major species could usually be related to depredations by various damaging agents. Closer association with the pest-detection agencies is needed to improve the basis for seed-crop predictions. Similarly, the seedbed conditions vary greatly from place to place and from year to year. Recent studies indicate the potential benefit from relating microsite conditions to existing Fire Danger Rating data. Preliminary evidence shows meaningful relationships between a key station and selected study areas. Only a few variables were studied, such as air temperature and relative humidity, fuel moisture, and soil moisture. Additional factors offer a broader basis for interpretation, especially since the analytical procedures now in existence permit rapid processing. Thus, it seems reasonable to expect rapid progress in this rather complex field by combining efforts with other disciplines and obtaining results which might not be otherwise available.

Contribution of Rime Ice to Winter Water Balance in Upper-Slope Forests of Eastern Washington

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Forest Hydrology Laboratory
Wenatchee, Washington

Rime ice occurs when supercooled moisture droplets comprising winter fog collide with obstructions in the windstream. The quantity