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California "Catchable" Trout Fisheries

By

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FOREWORD

Shortly after World War II, the Department of Fish and Game, with funds provided by the Wildlife Conservation Board, renovated and expanded the State's hatchery system substantially to meet the pent-up demand for trout. In just a few years, production of catchable-sized trout increased fourfold to about 7,000,000 annually. Simultaneously, their distribution spread from the southern part of the State to many roadside waters throughout California.

High costs dictate prudence in using "catchables," so that anglers will take most of them. This was easier said than done with such a rapidly expanding program. For a time logistics alone swamped the personnel involved. Moreover, no one had yet developed ways to measure returns of these fish quickly and cheaply.

It is difficult now to realize how unsure we were about many phases of this program 10 years ago. Unless anglers were catching most of the fish, the whole operation was open to serious question, and indeed many skeptics were expressing serious doubts about it in those days.

I recall agreeing that a tentative estimate of 25 percent returns at Big Bear Lake seemed reasonable for designing tagging studies there. I also remember a heated public controversy in Fresno about the same time. A columnist there questioned if returns at Huntington Lake, a big reservoir east of Fresno, reached 50 percent, the minimum required by Fish and Game Commission policy. Many of us shared his skepticism, and no one could say if he was right or wrong.

It is not surprising, under these circumstances, that demands to evaluate this program mounted steadily. The Department responded by initiating the "Catchable Trout Study" in 1954.

It found that anglers regularly caught two-thirds of the "catchables" stocked in Big Bear Lake. This was a considerable surprise to many of us. Then it showed 80 percent returns at Huntington Lake. It eventually demonstrated average returns on the order of 70 percent for the whole program, thereby eliminating a major area of controversy.

To obtain these results, the study had developed a rapid, inexpensive way to measure returns of planted fish. This new technique has since been widely applied in California. It is a significant contribution to fisheries management.

Department fishery biologists accepted the new facts and methods which the study contributed as they became available, integrating them into both their thinking and their field operations. However, this happened so gradually that it was never obvious.

Like many other long-range programs which produce significant results over a period of years, the real contributions of this project are only apparent when reviewed over a period of time. Such a perspective reveals that the "Catchable Trout Study" has largely shaped our current thinking about "catchables" and their use.

Its influence should become increasingly significant in the future, as its findings guide program expansion along channels that maximize the recreational benefits of stocking "catchables" and minimize their undesirable side-effects. For example, it will encourage the use of the larger waters, where the program is at its best, and discourage further spread to small streams, which exaggerate all of its undesirable features.

In conclusion, a few words about this bulletin: its purpose is to record the technical results of a substantial research project. It is intended primarily for fisheries workers. However, many nonprofessionals will also enjoy its less mathematical sections. I particularly recommend the summary to everyone interested in trout angling.

Alex Calhoun

1. INTRODUCTION

Trout fishing has long dominated California's freshwater angling picture. In 1936 roughly half of the State's 300,000 angling licensees caught trout. In 1962, with 1,588,000 licensees, the proportion remained unchanged.

Heavy angling pressure early depleted trout in many roadside waters. The stocking of "catchable-sized" hatchery trout soon followed, beginning in southern California before World War II. It spread rapidly throughout the State after the war, as the Wildlife Conservation Board provided more than $4 million for trout hatcheries.

Currently, about seven million 7-to-8-inch rainbow trout (Salmo gairdnerii) are stocked annually in California, at a cost of $1,366,000 (Fiscal Year 1962–63). The 1956 distribution of fish is shown in Figure 1. The same general pattern continues.

This program created a need for rapid, inexpensive survey methods to determine if the many new "catchable" fisheries were functioning satisfactorily. Accordingly, a research project, D-J F-14-R, "Evaluation of Catchable Trout Stocking," was set up in 1954 to develop such a method, and to evaluate the new program. In 1956, this project was incorporated into the broader "Trout Management Study," D-J F-8-R.

This project answered many troublesome questions. It quickly developed the desired new survey methods (Butler, 1957; von Geldern, 1961) and used them to inventory a series of widely scattered fisheries in various types of lakes and streams (Jensen, 1958; Delisle, 1959; Jensen and Butler, 1959; Kabel and Butler, 1959; Kabel, 1960; von Geldern and Kabel, 1960; Weidlein, 1960). The results, summarized in this report, provide insight into the program as a whole.

2. ACKNOWLEDGMENTS

Butler supervised the field work of the study and prepared a preliminary draft of the findings. Borgeson reworked much of the data and wrote the final report. Charles E. von Geldern, W. Donald Weidlein, Clarence S. Kabel, Paul T. Jensen, and Glenn E. Delisle contributed substantially to the project's success. Others too numerous to name helped in various ways. Critical reviews by William Ricker and Kenneth Watt were much appreciated.

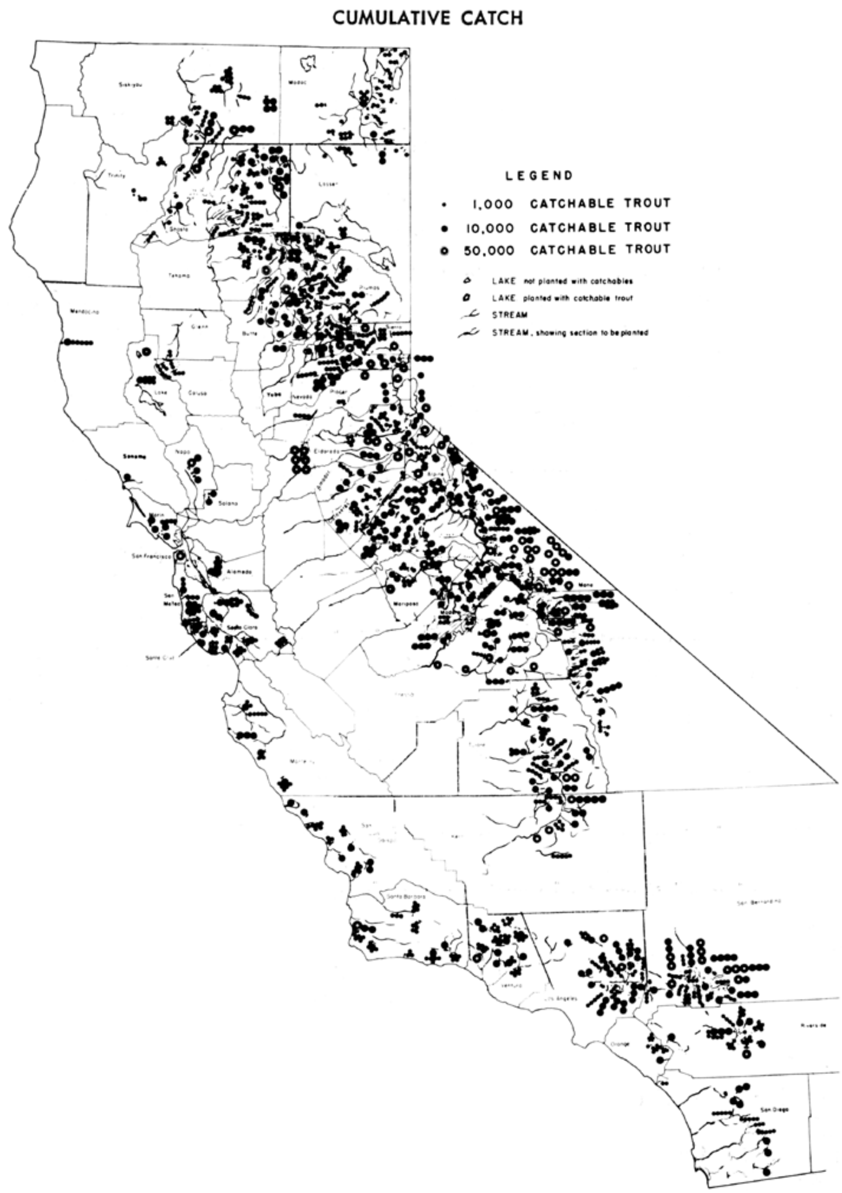

FIGURE 1. Statewide distribution of catchable-sized trout in 1956.

FIGURE 1. Statewide distribution of catchable-sized trout in 1956

3. METHODS

The procedure generally used in this study was to measure the characteristics of individual catchable trout fisheries of various types immediately following experimental plants of marked rainbow trout. Routine stocking procedures were followed on all but two waters: Erskine Creek, Kern County, and East Carson River, Alpine County, where experimental management programs were evaluated. Lake plants were usually made at one point, while stream plants were scattered in the usual way, as much as manpower permitted. Test fish were finclipped or tagged with subcutaneous tags (Butler, 1957). This was done at the hatchery a few days before stocking. The weight of trout planted ranged from 3 to 6 per pound, with the average about 5.

3.1. Catch and Use Estimates

An angling inventory began as soon as a test plant was made. Creel checks for tagged trout only, complete angler checks, and combined angler use count and partial creel census were the three types of inventory used.

3.1.1. Creel Check for Tagged Trout Only

During 1955 and 1956, limited creel checking was done in conjunction with tagging experiments. An effort was made to sample all segments of each fishery. Anglers were interviewed to determine fishing locality, hours of effort, and the number and size of tagged and untagged trout. The primary purposes of creel checking in this instance were to stimulate tag returns, determine the extent of fish movements, measure growth rates, and relate catchability to size.

3.1.2. Complete Creel Checks

Complete angler checks are not feasible on most catchable trout waters, since such waters usually have many access points. However, at Erskine Creek and South Lake, Inyo County, essentially complete creel checks were made. Hours fished and the number and species of marked and unmarked trout caught were recorded. In addition, at Erskine Creek the census clerk recorded each angler's name, residence, period of day fished, and whether the angler was a man, woman, or child, so that individual use patterns could be studied. At South Lake, shore and boat anglers were distinguished.

3.1.3. Partial Creel Census—Angler Use Count Method

This method was developed as the project progressed, and it became a more or less standard inventory procedure during 1957 and 1958. Basically, it consists of a partial creel census to estimate the mean daily catch per hour, and angler counts to estimate the total hours fished. The product of these two estimates equals the estimated total catch for the day.

Each census was designed to provide estimates of mean catch per hour. Sections of shoreline or stream were usually checked every 2 or 3 hours. Boat fishermen were censused when they returned to shore. All anglers encountered were interviewed or, when that was not possible because of large numbers, a representative sample was censused. Usually between 30 and 60 percent of the estimated daily catch was actually checked (Table 1).

Shore and stream fishermen were frequently censused more than once. In such cases, only their hours fished and trout caught since the previous interview were recorded. Portions of a fin were removed from each fish checked, for identification in future interviews.

TABLE 1

Sampling Level and Duration of Creel Census Studies

Name of water	Planting date	Length of census (days)	Average percentage of 14-hour day censused	Percentage of estimated daily catch actually checked
Butt Creek	8 /1/57	20	48	42
Big Butte Creek	8/ 1/58	10	79	56
East Carson River				
1957	7/26/57	9	47	25
	8/23/57	11	44	31
1958	7/ 3/58	19	95	53
	7/ 7/58	15	99	60
	7/10/58	12	99	56
West Carson River	8/16/57	10	40	16
Erskine Creek	5/16/58	31	107	100
	5/29/58	18	107	100
	6/ 3/58	13	107	100
Feather River, West Branch	6/20/58	10	95	62
	8/18/58	9	87	59
Kern River	5/ 2/58	12	93	48
	8/19/58	13	88	31
Kings River, South Fork	7/30/58	13	81	39
Kings River, below Pine Flat Dam	5/13/58	13	92	31
	8/19/58	13	94	46
	8/19/58	13	94	43
	8/26/58	6	100	45
Merced River				
Exchequer Section	5/27/58	13	85	40
Briceburg Section	7/ 8/58	7	98	50
Rush Creek	8/26/57	10		
Stanislaus River	7/22/58	9	81	43
Tule River				
Belknap Section	6/24/58	13	94	47
	6/30/58	7	96	48
	7/ 3/58	4	103	52
Soda Flat Section	6/24/58	13	94	47
	6/30/58	7	96	48
	7/ 3/58	4	103	52
Tuolumne River	6/11/58	12	92	64
Little Truckee River	7/24/57	7	57	39
Lake Arrowhead	5/29/57	28		
Convict Lake	7/19/57	20	87	42
8.0-8.9 in. trout	7/ 1/58	13	101	52
7.0-7.9 in. trout	7/ 1/58	13	101	51
Green Valley Lake	7/18/57	10	79	33
Gregory Lake	6/28/57	16	55	38
Huntington Lake				
Southwest Shore plant	7/16/58	27	95	36
Rancheria Cr. plant	7/16/58	27	95	32
Scattered plant	7/23/58	20	96	37
North Shore plant	7/30/58	13	93	38
June Lake	6/28/57	19	77	59
South Lake	8/ 8/57	13	85	93

TABLE 1

Sampling Level and Duration of Creel Census Studies

In most lake studies, anglers were stratified into groups suspected to have characteristic catches per hour. Shore and boat anglers were the basic strata, but these were sometimes subdivided, e.g., into north and south shore anglers, and rental and private boat anglers.

The mean daily catch per hour was estimated by dividing the total fish checked by the total angler hours. For waters where the anglers were stratified, the mean daily catch per hour was weighted by the hours fished in each stratum.

The total hours fished per day were estimated from periodic counts of anglers (use counts) (Tarzwell and Miller, 1942; Carlander, 1956; Rose, 1956). Valid estimates of total hours require these counts to be made at intervals shorter than the average angler day (Moyle and Franklin, 1955). In these studies, counts were usually made at 2-hour intervals from an hour after dawn to the nearest hour before dark. This is less than the average angler day on California waters which have been studied (Vestal, 1954; Kabel and Butler, 1959; Wales and Borgeson, 1961).

Each angler count is assumed to be the average number of anglers fishing during the counting interval. For example, when anglers are counted every 2 hours, the 10 o'clock count would be an estimate of the average number of anglers fishing between 9 and 11 o'clock. The product of the angler count and the length of the interval (hours) is an estimate of the angler hours expended in the interval. Similarly, the product of all anglers counted during the day and the length of the interval is an estimate of total angler hours for the day.

When anglers were stratified during lake censuses, angler counts were stratified similarly. Separate estimates of total hours fished were made for each stratum and these were summed to estimate daily totals.

When samples were not stratified, total catch was estimated by multiplying the mean daily catch per hour by the total hours fished. When samples were stratified, total catch was estimated similarly for each stratum and these data were summed to estimate total catch.

On some study waters, no census was conducted on some mornings or afternoons. In these cases, angling effort during the uncensused half day was estimated by multiplying the effort recorded for the censused half day by the ratio of morning to afternoon effort observed in all-day censuses (Jensen, 1958; Delisle, 1959; Weidlein, 1960). Catch per hour during missed half days was estimated similarly at June Lake and Convict Lake, Mono County, in 1957 (Delisle, 1959). On other waters, the catch per hour estimate obtained during the censused portion of the day was used for the whole day (Jensen, 1958; Weidlein, 1960). There were minor variations from these procedures in some studies (Delisle, 1959; Weidlein, 1960).

The census on each water continued until it was obvious that only a small fraction (usually less than 25 percent) of the experimental trout remained to be caught. This occurred within one to three weeks on most waters (Table 1).

3.2. Total Harvest Estimates

The total harvest of 1956 plants was estimated from returns of subcutaneous reward tags (Butler, 1962).

During 1957 and 1958, the total harvest of test plants was estimated using the method of Leslie and Davis (1939). Daily catch per hour was plotted on the *Y*-axis against mean daily cumulative catch[3] on the *X*-axis. A straight line was then fitted to these points by the least squares method. Its *X*-axis intercept is an estimate of total catch, since it represents the cumulative catch when the catch per hour (and, therefore, the population) is reduced to zero. The slope of the line is the instantaneous total mortality rate or, better, the total rate of disappearance from the census area, per angler hour.

Use of this method assumes that instantaneous fishing and total mortality rates per hour of angling effort (including emigration from the test area) remain constant or fluctuate frequently and randomly, and that recruitment does not occur. Recruitment does not occur, of course, and the other assumptions are generally justified, since the fisheries studied were of extremely short duration and the regressions were typically linear, especially after the first few days of census. The frequent non-linearity during the first few days is attributed to post planting changes in catchability.

Regression calculations for estimating total catch were always based on the linear portion of each regression[4] . Thus, two regressions were calculated for some plants: one to estimate total catch and another to obtain a more representative value for average instantaneous total mortality rate per angler hour.

When the hourly catch of marked trout reaches zero, we assume that no more experimental fish are left in the study area. The total catch estimate, *C*, is then subtracted from the number planted, *D*, to estimate "unaccounted mortality[5] , *B*. *C/D* and *B/D* equal the expectations of death due to fishing, *u*, and unaccounted causes, *v*, respectively, and their sum equals the total expectation of death plus emigration (total mortality rate), *a*, which in this instance is unity: $C/D = u$ $B/D = v$ $u+v = a = 1$

The total instantaneous mortality rate per angler hour, *i*, (which is the slope of the regression line) can be subdivided into instantaneous fishing mortality rate per angler hour, *p*, and unaccounted mortality rate per angler hour, *q*, using the relationship: $i/a = p/u = q/v$

The longevity of a plant of catchable-sized trout is determined primarily by the amount of fishing effort exerted upon it. But this fishing effort differs greatly among waters. Therefore, instantaneous rates

[3] Mean cumulative catch for a particular day was calculated by adding half the catch for that day to the cumulative catch at the end of the previous day. This refinement was essential since a large fraction of a plant was often harvested in one day.

[4] When the point where the regression became linear was not obvious it was chosen subjectively. In making this decision, our tendency was to drop early points, thus adding to the importance of the latter part of the regression. This procedure differs from that used early in our studies. In previous reports all regressions were calculated from the point of maximum daily catch per hour (method described by von Geldern, 1961). Thus, some harvest and mortality estimates in this report differ slightly from earlier estimates.

[5] "Unaccounted Mortality" includes emigration, poaching, hooking mortality, and true natural morality. Also, it probably includes some fish which, though caught legally, were deliberately not reported to the census clerk.

based upon a unit of fishing effort are more useful than annual or daily rates for comparing various waters and for computing the effects that a change in stocking will have on individual waters. Ketchen (1953) used a unit of fishing effort as a base in computing the instantaneous rate of fishing, immigration, and emigration in a migratory population of English sole (Parophrys vetulus) (example in Ricker, 1958).

The instantaneous fishing mortality rate per angler hour, *p,* can be defined as the fraction of the *average* [6] fish stock under consideration which is caught during an hour of angling effort. If this fraction is 1 percent or less of the population, it can be considered equal to the catchability, *c,* of the fish. Catchability, as defined by Ricker (1958, p. 18) is "The fraction, *of the whole fish stock under consideration,* which is caught by a defined unit of the fishing effort actually used. This fraction is nearly always small—say, less than 0.01—so it can be used as an instantaneous rate in computing population change." It can also be defined as the rate of exploitation resulting from one unit of fishing effort.

In these studies, *p* was always less than 0.01. Thus, catchability is used in the text in place of the slightly more precise but lengthy phrase, instantaneous fishing mortality rate per angler hour.

4. RESULTS AND DISCUSSION

4.1. Total Harvest Estimates

A high percentage of the catchable-sized trout stocked was harvested. Seventeen of the 20 test waters had harvests that met the minimum 50 percent required by Commission policy ([Table 2] , Figures 2 and 3) The mean return for 7 lakes was 83 percent and for 13 streams 73 percent.

The harvest was always rapid. The time required to catch 50 percent of the eventual harvest from streams ranged from 2 to 9 days, with an average of 3.6 days (Table 2). An average of 6.5 days was needed to harvest 75 percent of the catch from streams.

The harvest from lakes was not quite as rapid. The time required to take 50 percent of the catch ranged from 4 to 12 days and averaged 6.6 (Table 2). An average of 11 days was required to harvest 75 percent of the catch from lakes.

Three studies showed that a greater proportion of trout 8.0 to 8.9 inches long was harvested than of 7.0- to 7.9-inch trout. During the 1956 studies at Big Bear Lake, San Bernardino County, 689, 8.0- to 8.9-inch trout were stocked to compare their returns with those of 1,100, 7.0- to 7.9-inch fish. Four plants (May 15, July 5, August 21, August 22) of fish from each size class were compared. The percentages returned from the larger and smaller fish, respectively, were 72.4 and 62.4, 71.8 and 58.6, 69.5 and 59.9, and 74.3 and 64.5, with means of 72 and 62. A study at Convict Lake in 1958 resulted in a 99 percent return of 8.0- to 8.9-inch trout, while 85 percent of 7.0- to 7.9-inch fish was

TABLE 2

Harvest and Mortality Rates of Experimental Plants of Catchable-sized Rainbow Trout *

Name of water	Planting date	Number planted	Estimated percentage harvested	Days to harvest 50 percent of eventual harvest	Days to harvest 75 percent of eventual harvest	Instantaneous mortality rates per angler hour times 10^4: Total	Fishing (catch-ability)	Un-accounted	Plant-to-plant survival: Fraction of experimental plant surviving to day of next plant	Fraction of total catch provided by other than experimental trout	Average survival
Butt Creek	8/ 1/57	1,495	76	7	11	13.4	10.2	3.2	0.20	0.18	0.19
Big Butte Creek	8/ 1/58	1,600	33	2	6	26.9	8.8	18.1	0.06	0.43	0.24
E. Carson River, 1957			**61.0**	**3**	**4.5**	**15.85**	**9.75**	**6.10**	**0.18**	**0.32**	0.25
	7/26/57	2,000	56	3	5	14.3	8.0	6.3	0.20	0.38	
	8/23/57	2,000	66		4	17.4	11.5	5.9	0.15	0.25	
1958			**76.3**	**5.3**	**11.7	**10.0**	**7.6**	**2.4**	**0.61**	**0.70**	0.65
	7/ 3/58	700	67	4	10	10.8	7.2	3.6	0.45	0.71	
	7/ 7/58	900	86	7	**14	10.4	8.9	1.5	0.84	0.66	
	7/10/58	900	76	5	11	8.89	6.75	2.14	0.53	0.73	
W. Carson River	8/16/57	800	70	3	3	36	25	11	0.18	0.19	0.19
Erskine Creek			**76**	**3**	**6**	**12.9**	**9.2**	**3.7**	**0.15**		0.15
	5/16/58	1,500	68	3	8	12.6	8.5	4.1	0.14		
	5/29/58	1,500	75	2	4	13.2	9.9	3.3	0.18		
	6/ 3/58	921	86	4	6	19.5†	16.8†	2.7†	0.13		
Feather River, West Branch				**6**	**8						
	6/20/58	3,600	51†	9	**10	12.0†	6.1†	5.9†			
	8/18/58	4,240	13†	3	6	22.2†	3.0†	19.2†		0.33‡	0.33‡
Kern River			**82.2**	**4.5**	**10.5	**3.18**	**2.60**	**0.58**			
	5/ 2/58	4,995	69.6	4	**12	3.28	2.28	1.00			
	8/19/58	2,500	94.9	5	9	3.08	2.92	0.16	0.24	0.46	0.35

TABLE 2
Harvest and Mortality Rates of Experimental Plants of Catchable-sized Rainbow Trout

Kings River, South Fork	7/30/58	2,159	58.1	--	--	9.03	5.25	3.78		0.22‡	0.22‡
Kings River below Pine Flat Dam			**59.8**	**3**	**8.2**	**8.27**	**5.18**	**3.08**	**0.12**	**0.16**	0.14
	5/13/58	2,800	89	2	5	10.1	9.0	1.1	0.09	0.19	
	8/19/58	3,299	52	2	4	7.75	3.87	3.88	0.12§	0.20§	
	8/19/58	1,758	42	5	12	3.02	1.27	1.75	0.40§	0.20§	
	8/26/58	3,349	56	2	12	12.2	6.6	5.6	0.02	0.09	
Merced River											
Exchequer Section	5/27/58	3,000				11.1†	3.1†	8.0†		0.36‡	0.36‡
Briceburg Section	7/ 8/58	2,988				--	--	--		0.45‡	0.45‡
Rush Creek	8/26/57	2,250	92	2	4	5.67	5.19	0.48	0.61	0.17	0.39
Stanislaus River	7/22/58	2,400	71	3	4	9.72	6.92	2.80	0.06	0.29	0.18
Tule River											
Belknap Section			**100.7**	**3**	**4.5**	**19.7**	**18.4**	**1.3**	**0.34**	**0.33**	0.34
	6/24/58	821	105	3	5	22.2	22.2	0.0	0.17	0.19	
	6/30/58	779	82	4	4	21	17	4	0.57	0.32	
	7/ 3/58	657	115	2	**4	16	16	0.0	0.28	0.47	
Soda Flat Section			**111.3**	**3.3**	**5.7**	**63.4**	**60.7**	**2.7**	**0.38**	**0.47**	0.43
	6/24/58	208	142	4	8	44.1	44.1	0.0	0.28	0.31	
	6/30/58	217	91	4	5	91	83	8	0.61	0.55	
	7/ 3/58	193	101	2	4	55	55	0.0	0.24	0.57	
Tuolumne River	6/11/58	2,800	58	3	5	6.63	3.86	2.76	0.09	0.26	0.18
Little Truckee River	7/24/57	2,010	104	4	**7	8.40	8.40	0.00	0.36	0.27	0.32
Lake Arrowhead	5/29/57	3,000	43	11	17	1.82	1.04	0.78	0.96	0.83	0.90
Convict Lake			**92**	**5**	**8**	**1.79**	**1.63**	**0.15**	**0.46**	**0.57**	0.52
	7/19/57	2,000	--	--	--	1.90	1.70	0.20	0.55	0.44	
7.0-7.9″ trout	7/ 1/58	1,200	85	5	8	1.56	1.32	0.24	0.42§	0.70§	
8.0-8.9″ trout	7/ 1/58	1,200	99	5	8	1.90	1.88	0.02	0.35§	0.70§	
Green Valley Lake	7/18/57	1,400	98	5	7	3.58	3.52	0.06	0.33	0.53	0.43
Gregory Lake	6/28/57	2,800	92	5	9	0.660	0.606	0.054	0.69	0.83	0.76

TABLE 2—Cont'd.

TABLE 2

Harvest and Mortality Rates of Experimental Plants of Catchable-sized Rainbow Trout *—Continued

Name of water	Planting date	Number planted	Estimated percentage harvested	Days to harvest 50 percent of eventual harvest	Days to harvest 75 percent of eventual harvest	Instantaneous mortality rates per angler hour times 10^4: Total	Fishing (catch-ability)	Un-accounted	Plant-to-plant survival: Fraction of experimental plant surviving to day of next plant	Fraction of total catch provided by other than experimental trout	Average survival
Huntington Lake			**81**	**9.2**	**18.0**	**0.573**	**0.452**	**0.121**	**0.57**	**0.71**	0.64
Southwest Shore	7/16/58	2,730	88	12	23	0.496	0.435	0.061	0.64§	0.56§	
Rancheria Creek	7/16/58	2,730	92	5	17	0.404	0.370	0.034	0.40§	0.56§	
Scattered	7/23/58	2,880	74	9	14	0.911	0.678	0.233	0.51	0.72	
North Shore	7/30/58	3,800	68	11	**13	0.481	0.326	0.155	0.67	0.84	
June Lake	6/28/57	5,012	102	7	11	0.787	0.787	0.000	0.70	0.41	0.56
South Lake	8/ 8/57	2,500	74	4	7	4.43	3.28	1.15	0.23	0.31	0.27
Grand Lakes	unweighted	means,‡‡	83.0	6.6	11.0	1.95	1.62	0.33	.56	0.60	0.58
Grand Streams	unweighted	means,‡‡	73.1	3.6	**6.5	15.02	10.71	4.31	0.23	0.30	0.26

* Boldface figures are unweighted means.
** Minimum figure—75 percent of eventual harvest not taken during census period or, if mean value, during all census periods used to compute mean. Not used to compute mean value unless it exceeds other values observed for water. Not used in computing grand means if only value for water.
† Considered unreliable because of non-linear regression and/or insufficient returns during census. Not used in calculating means.
‡ Not considered reliable enough to be used in calculating average survival for streams.
‡‡ Each *water* weighted the same, i.e., values for the two sections of the Tule River were averaged as were those for the 1957 and 1958 East Carson River studies to obtain a single set of means for each water.
§ Weighted one half since two groups of fish comprised one plant.

TABLE 2
Harvest and Mortality Rates of Experimental Plants of Catchable-sized Rainbow Trout

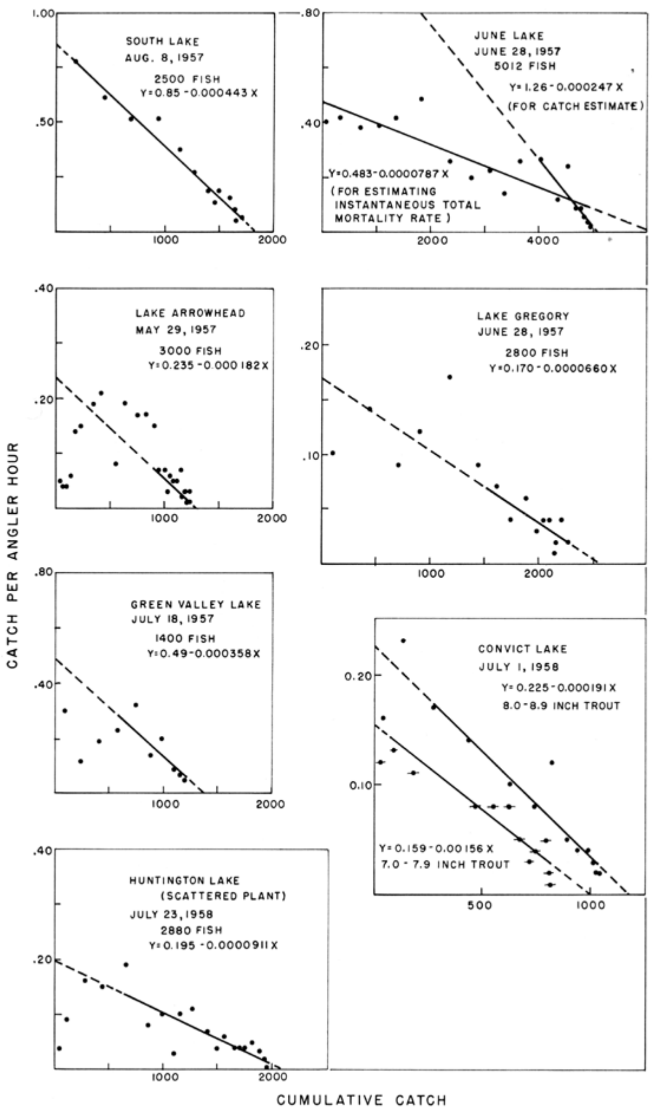

FIGURE 2. Relationships between mean daily catch per angler hour and cumulative catch, showing estimated harvest (X-intercept) of experimental trout from study lakes.

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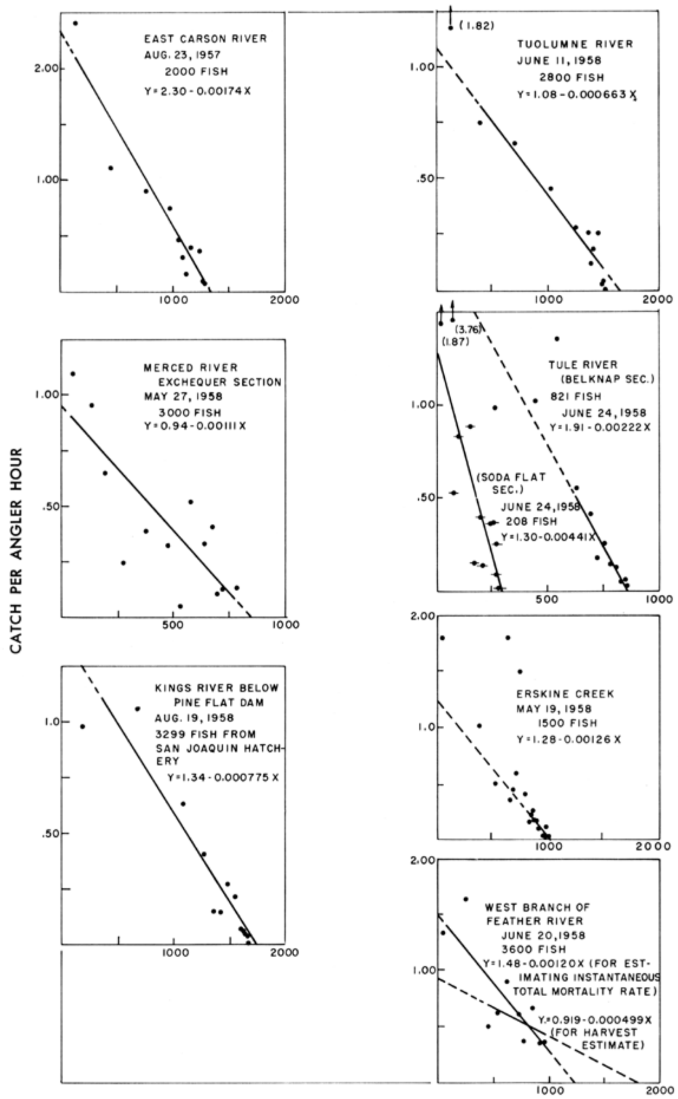

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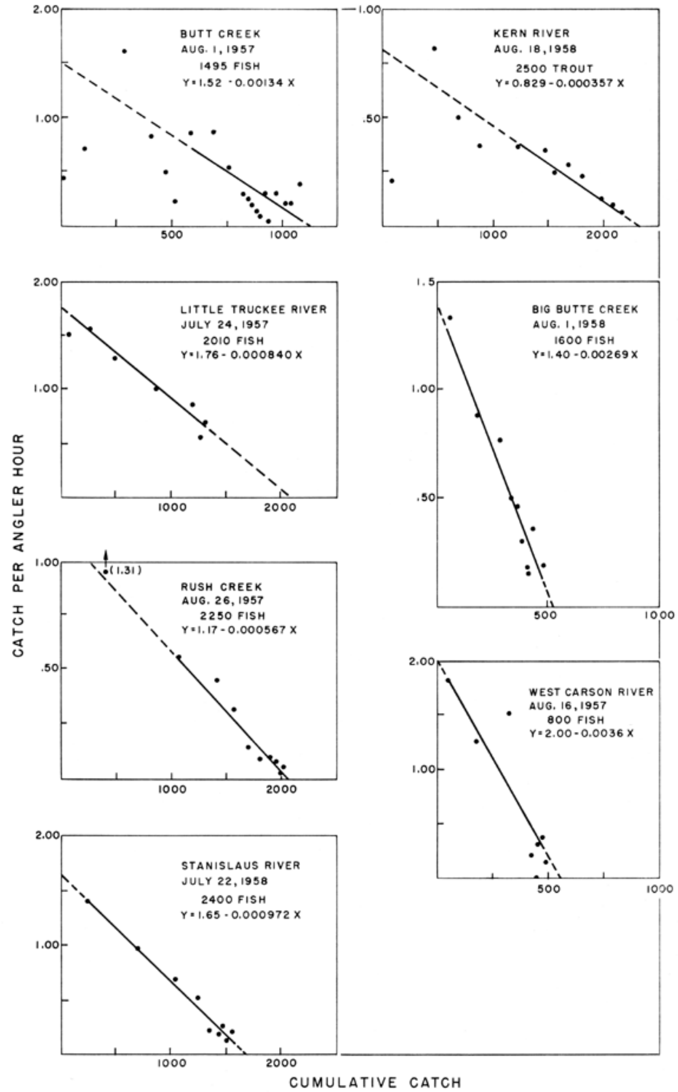
FIGURE 3—Continued



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harvested. On the Kings River below Pine Flat Dam in 1958, 89 percent of a May plant of trout averaging 3.1 per pound was harvested, while the harvest of two August plants weighing 5.8 and 6.0 per pound was 50 and 56 percent, respectively.

4.2. Mortality Rate Estimates

Catchable-sized trout did not survive long in study waters because of high angling intensities. Survival rate, *s*, depends upon the instantaneous total mortality rate per angler hour, *i*, and the number of hours fished, *t*. These three are related as follows:

$$s = e^{-it}$$

FORMULA

Thus, the survival rate decreases as *t* and/or *i* increases.

According to this formula, when time is measured in hours of angling effort, survival would be 1.0 (no mortality) regardless of how much time passed if there was no angling. We know that this is not true. True natural mortality alone would eventually claim all of the fish, because it is not dependent upon angling effort. In practice, however, this relationship is applicable to catchable trout fisheries, because angling intensities are always great and total mortality occurs rapidly.

Furthermore, unaccounted mortality rates on study waters were much too high to represent true natural mortality alone, suggesting that much of the unaccounted mortality *was* actually caused by angling and therefore depended upon angling effort. For example, of the fisheries studied over half had instantaneous 100-day unaccounted mortality rates[7] over 5.0 and one-third had rates which ranged from 10 to 25. Even without the recorded fishing, an instantaneous unaccounted mortality rate of 5.0 would result in a 100-day survival of only 0.6 percent of a plant, while only 0.0045 percent of a plant would survive 100 days under an instantaneous unaccounted mortality rate of 10.0.

In contrast, the 100-day survival (Aug.-Nov.) of 23 large groups of catchable-sized rainbow trout in unfished study sections of Convict Creek, Mono County, ranged from 70.3 percent to 97.1 percent, with an average survival of 87.1 percent (Reimers, 1963). This corresponds to an instantaneous 100-day natural mortality rate of only 0.14. Ninety percent of the waters studied had rates of unaccounted mortality at least 10 times this.

Also, two experimental plants of catchable-sized trout stocked in relatively lightly fished Castle Lake, Siskiyou County, on July 8, 1952, and July 15, 1955, returned 81 and 85 percent to the angler. Forty-three and 9.1 percent, respectively, of these fish survived to the year after planting, and 3.7 and 5.5 percent, respectively, of the catch was harvested from 3 to 5 years after stocking (Wales, 1956; McCammon and Borgeson, 1960). These figures also indicate much lower unaccounted mortality rates than occurred at our study waters.

Clearly, we are dealing with more than ordinary natural mortality and migration. Ordinary natural mortality and migration should occur

[7] The instantaneous unaccounted mortality rates per angler hour for study waters were converted to a 100-day time base by multiplying them by the estimated number of angler hours expended per 100 days (the approximate length of the vacation season during which most of California's catchable-sized trout are stocked).

at rates that are independent of the rate of fishing. But in these studies, high instantaneous unaccounted mortality rates (per angler hour) were invariably accompanied by high rates of fishing (catchability) (Table 2).

High apparent natural mortality rates (unaccounted mortality) might be due to very low catchability of a certain fraction of the plant or to a fraction of the plant becoming unavailable to anglers immediately following planting. If this were the answer, "unavailable" fish would be recovered in significant numbers by draining or electroshocking stream sections or treating lakes with rotenone. This type of work was done on two study waters.

During 1958, two studies on the West Branch of the Feather River, Butte County, indicated an exceptionally high unaccounted mortality of planted fish. An estimated 51 percent of the June 20 plant and only about 13 percent of the August 18 plant was harvested. In an attempt to determine the cause of these high unaccounted losses, three stream sections in the planted area totaling 1,000 feet in length were electrically shocked and a 580-foot section was drained on October 19. Only 9 of the 4,240 fish stocked in August and none of the 3,600 stocked in June were recovered.

In 1956, 91,858 catchable-sized trout, of which 3,390 were tagged, were stocked in Big Bear Lake. Tag returns indicated that approximately 72 percent of the fish were harvested during the season. During the night of October 11, five standard experimental gill nets and two 300-foot, 3-inch stretched mesh gill nets were set in the lake. Only eight of the planted trout were caught, along with over 1,000 black crappie (Pomoxis nigromaculatus) . On October 13 the lake was treated with rotenone to eliminate the stunted black crappie population. The treatment was widely publicized and hundreds of people were present to salvage the dying fish. A count of recovered fish at one of the more popular boat landings recorded only 123 trout, of which 3 were from the most recent plant of tagged trout. Several hundred crappie but no trout were recovered in three sardine nets that were spread on the lake's bottom to recover fish that sank.

These data refute the hypothesis that high rates of unaccounted mortality were due to the immediate unavailability or low catchability of a significant fraction of the planted trout. However, the data are not strong enough to completely discount this factor and logic suggests that some planted fish would become unavailable in some situations, e.g., brushy, hard-to-fish stream sections. But it is not conceivable that this factor could be a major cause of the high unaccounted mortality rates we recorded.

Delayed planting mortality can not be considered a major cause of accounted mortality either, because project personnel would have witnessed and heard reports of excessive planting mortalities if they had occurred frequently.

Immediate migration of a fraction of the plant from the study area would have the observed effects on instantaneous mortality rates but the data on trout movement (see that section) indicate that very little emigration occurs. Emigration from the seven lakes listed in Table 2 is especially unlikely.

Taken as a whole, the above sources of trout loss do not adequately explain the observed instantaneous rates of unaccounted mortality.

The fact that high instantaneous unaccounted mortality rates were always accompanied by high rates of fishing suggests a cause and effect relationship. In pursuing this line of reasoning, it became obvious that any unrecorded angling mortality would fall under natural mortality. Undetected angling mortality from the following sources is believed to constitute an important fraction of the calculated unaccounted mortality.

1) Underestimates of angling intensity: During the periodic angler counts, only anglers observed fishing were recorded. Undoubtedly, some anglers were not observed. Therefore, estimates of angling effort are necessarily minimal. The magnitude of underestimates of angling effort is unknown but undoubtedly varied among waters. The accuracy of these estimates was undoubtedly in-influenced by the size of the waters, the terrain, and the individual census clerks.

2) Poachers: Project personnel rarely observed overlimits, yet wardens, working on the same waters, made frequent overlimit citations. This problem is believed most serious on small streams where angling effort is very high following a plant. Anglers who took more than one limit per day or were so inclined understandably avoided project personnel. Since the sizes of the plants in such waters were small, missing just a few of these anglers could add appreciably to the unaccounted mortality. The estimate of angling effort as well as the average daily catch per hour would be lowered.

3) Expert anglers: Expert legal anglers, who caught limits quickly and left, were less likely to be interviewed than most anglers. This would cause underestimates of the mean catch per hour and total catch. This problem would also occur most often on small streams immediately following a plant.

4) Hooking mortality: Some fish die after being hooked and lost. This is probably not an important factor, but it would add to angler-caused unaccounted mortality.

We do not know how much undetected angling mortality is credited to unaccounted mortality on individual waters but the chance of this occurrence is obviously greater when the estimated percentage harvest is low.

The instantaneous total mortality rates per angler hour of catchable-sized trout were considerably greater for streams than lakes primarily because their catchability was much greater in streams (Table 2). Catchabilities ranged from 2.6×10^{-4} to 87.8×10^{-4} for the stream sections studied (average 10.71×10^{-4}) and ranged from 0.48×10^{-4} to 3.5×10^{-4} and averaged 1.62×10^{-4} for lakes. The catchability of planted trout was generally higher in small lakes and streams than in their larger counterparts.

In the 1958 Convict Lake study, the catchability of trout 8.0 to 8.9 inches long was somewhat greater than that of trout 7.0 to 7.9 inches long. Also, in the 1958 Kings River studies the catchability of trout weighing 3.1 per pound (May 13 plant) was greater than that of trout weighing 5.8 per pound (August plants).

of course, other factors besides the type of water and the size of trout affect catchability. The catchability of stocked trout is determined by (i) the fish themselves (size, strain, condition, and hatchery life); (ii) the environment (size of water, temperature, turbidity, weather conditions, availability of natural food, stream gradient, lake depth, and cover, and in streams, the length of the stocked section and the distribution of trout) and; (iii) the effectiveness of the unit of fishing effort (one angler hour). But *at any given water with a stable planting program, catchability is primarily dependent upon the fish's environment*, since the hatchery trout, their distribution, and the average unit of fishing effort[8] are nearly constant. Thus, catchability should be quite stable under fairly stable environmental conditions, especially on a year-to-year basis. This is supported by data from study waters in which two or more experimental plants were made (Table 1). The catchability of planted trout was quite stable in individual study waters.

Most of these studies were made during the vacation season, when waters in California generally present a fairly stable environment. More variation in catchability should be expected under less stable conditions. For example, the catchability of planted trout during the spring runoff, when the water is cold, high, and roily, would probably be much lower than during the low, cool flows of September.

It must be emphasized that the catchability of planted trout in streams can be grossly affected by planting procedures. The fish planter determines to a great extent the fish's environment and their catchability in streams. The environment of 500 trout stocked in the bridge pool is that pool, not the mile of stream above and below, and their catchability is much greater than if they were scattered over a mile of stream. Differences in the distribution of trout in the stream sections studied certainly contributed to the observed differences in catchability, as did differences in the lengths of the sections planted. Poor access and rough terrain make good distribution difficult in many streams, and planting costs mount if a great deal of time is spent distributing trout. Since distributional practices affect catchability, they also affect plant-to-plant survival, fluctuations in angling quality, and "truck following." Therefore, the catchabilities recorded for the study streams apply only to the *study sections* under present distributional practices. If these practices change, so will the catchability of the planted trout and related aspects of the fishery.

Since lakes generally present more stable environments than streams, and since planted trout distribute themselves within lakes (see section on movement), less variation in the catchability of planted trout occurs, regardless of planting practices.

Knowledge of the catchability of stocked catchable-sized trout in any water is of utmost importance to the fisheries manager. If the catchability is known, it can be used to compute the plant size that will provide

[8] The ability of individual anglers varies considerably, but the average angling ability of all anglers fishing a particular water should not change much from day to day or from one year to the next.

a satisfactory fishery at minimum expense. A formula for this computation is presented in the following section.

4.3. Angling Intensity and Angling Quality

A striking characteristic of nearly all catchable trout waters is the relatively high angling intensity exerted upon them as compared with wild or fingerling supported trout fisheries.

Average daily angling intensity (in hours per surface acre) on seven study lakes ranged from 0.6 (Lake Arrowhead, San Bernardino County) to 58.8 (Green Valley Lake, San Bernardino County), with a median value of 3.5 (Table 3) . Comparable figures for three readily accessible wild and fingerling stocked Californian trout lakes were Spaulding Reservoir, Nevada County (1962) 0.06; Beardsley Reservoir, Tuolumne County (1962) 0.20 (D. P. Borgeson, unpublished data); and Castle Lake, Siskiyou County (1958 to 1961) 0.33 (Wales and Borgeson, 1961).

Average daily angling intensity (in hours per stream mile) on 14 study streams ranged from 41.0 (Erskine Creek) to 314.9 (Rush Creek), with a median value of 102.5 (Table 3).

Comparable figures for three readily accessible wild or near-wild Californian stream trout fisheries were: Squaw Creek 1.2 (Randle and Cramer, 1941); Sagehen Creek 1.5 (P. R. Needham, unpublished data); and lower Rush Creek (¼ catchable brown trout) 4.6 (Kabel and Butler, 1959).

Angling intensity varied considerably on all study waters from day to day. Weekend intensities were usually greater than weekday intensities, but the ratio of average weekend day effort to average weekday effort varied greatly from water to water (Table 3). The median value for the 22 study waters was 1.50 and the extremes were 0.87 (South Lake) and 4.27 (Erskine Creek). Waters in heavily used vacation areas generally had low ratios, e.g., Rush Creek 1.66, June Lake 1.10, Huntington Lake 1.26, Stanislaus River 1.00, and South Lake 0.87. Since most studies lasted only one or two weeks, the above figures do not represent overall averages for each water. They are included to illustrate the variability in effort that was encountered. The ratio of weekend day to weekday effort varied considerably from week to week on individual waters. For example, excluding holiday weekends the ratio ranged from 1.03 to 1.99 at Lake Pillsbury during the summer, with a coefficient of variation of 22 percent (Kabel, 1960).

Most studies were too short to compare statistically day-to-day variability in angling effort with weekly variability, but the available data indicate that weekly variability is smaller. For example, the coefficient of variation of weekday angling effort at Lake Pillsbury was 20 percent compared with 12 percent for weekly effort (Kabel, 1960).

On most study waters angling intensities were greater during the first half of the planting interval than during the last half (Table 3). This is an indication of "truck following", and is caused by a sharp decline in angling quality as the trout population is heavily cropped by fishing. Since "truck following" is caused by fluctuations in angling quality, it will be discussed further under that topic.

TABLE 3

Angling Intensity and Angling Quality on Waters Studied

Water and county	Size of water (surface acreage of lakes and approximate stream flow in c.f.s. with miles of stream studied in parentheses)	Number of trout planted per stream mile (in study sections) or surface acre (lakes) during 1958	Mean number of angler hours expended per surface acre (lakes) or per stream mile per day	Mean weekend day angling effort divided by mean weekday angling effort	Percentage change in angling effort from first half to second half of planting interval	Range of daily catch per angler hour for all trout	Mean catch per angler hour for all trout
Butt Creek, Plumas County	20 (1.7)	1,778	69.6	0.94	— 9.5	0.10–2.62	1.01
Big Butte Creek, Butte County	20 (1.2)	4,949	76.3	2.65	—11.0	0.14–3.54	1.05
East Carson River, Alpine County 1957	25 (2.5)	13,360	76.8	----	—26.8	0.15–3.06	1.06
1958	25 (2.5)	13,360	65.9	----	+16.1	0.69–2.07	1.40
West Carson River, Alpine County	14 (1.2)	6,497	88.6	1.12	—44.9	0.00–2.39	0.80
Erskine Creek, Kern County	4 (3.0)	1,840	41.0	4.17	—57.1	0.13–5.86	0.71
Feather River, West Branch, Butte Co.	473 (1.5)	15,215	74.1	1.54	—22.8	0.17–1.83	1.01
Kern River, Tulare County	615–2,808 (2.7)	24,982	180.6	----	----	0.45–1.44	0.76
Kings River, South Fork, Fresno Co.	2,000 (8.0)	3,890	32	1.04	— 5.1	0.17–1.02	0.63
Kings River below Pine Flat Dam, Fresno County	3,725 (3.8)	19,814	110.8	1.68	—14.9	0.21–2.34	0.89
Merced River, Mariposa County Exchequer Section	6,300 (7.0)	7,645	25.2	4.27	+47.6	0.25–2.00	0.76
Briceburg Section	2,000 (9.3)	3,990	12.3	1.70	----	0.44–1.72	1.14
Rush Creek, Mono County	30 (2.2)	18,353	314.9	1.66	----	0.42–1.57	0.77

TABLE 3
Angling Intensity and Angling Quality on Waters Studied

TABLE 3

Angling Intensity and Angling Quality on Waters Studied—Continued

Water and county	Size of water (surface acreage of lakes and approximate stream flow in c.f.s. with miles of stream studied in parentheses)	Number of trout planted per stream mile (in study sections) or surface acre (lakes) during 1958	Mean number of angler hours expended per surface acre (lakes) or per stream mile per day	Mean weekend day angling effort divided by mean weekday angling effort	Percentage change in angling effort from first half to second half of planting interval	Range of daily catch per angler hour for all trout	Mean catch per angler hour for all trout
Stanislaus River, Tuolumne County	280 (3.2)	8,351	100.1	1.00	—44.8	0.44–1.52	0.78
Tule River, Tulare County Belknap Section	20 (0.8)	8,468	176.1	1.34	—25.6	0.69–3.88	1.14
Soda Flat Section	20 (0.3)	8,468	170.8	1.15	— 5.7	0.24–2.6	1.13
Tuolumne River, Tuolumne County	3,000 (2.2)	16,086	177.2	2.04	—59.9	0.18–1.44	0.80
Little Truckee River, Sierra County	10 (1.9)	7,626	69.5	2.55	—33.3	0.78–3.65	1.56
Lake Arrowhead, San Bernardino Co.	782	122	0.6	2.35	+ 7.4	0.17–1.50	0.40
Convict Lake, Mono County	168	227	5.0	1.32	— 3.6	0.30–0.99	0.54
Green Valley Lake, San Bernardino Co.	12	1,858	58.8	1.51	+ 8.7	0.26–2.01	0.75
Gregory Lake, San Bernardino Co.	96	799	19.1	1.40	—24.8	0.36–0.89	0.63
Huntington Lake, Fresno County	1,441	48	0.9	1.26	+ 7.3	0.23–0.97	0.45
June Lake, Mono County	310	268	3.5	1.10	+ 5.1	0.29–1.11	0.74
South Lake, Inyo County	177	171	2.5	0.87	+32.3	0.34–1.28	0.69

TABLE 3
Angling Intensity and Angling Quality on Waters Studied

Average angling intensity on the lakes and streams studied was strongly correlated with the sizes of the catchable-sized trout allotments (Figures 4 and 5, Table 3). On the surface, this relationship might be attributed to one of two factors: either (i) trout fishermen congregate where stocking is heaviest, or (ii) trout are stocked in proportion to angling intensity. But it is common knowledge that fish attract fishermen. This axiom is supported by the results of this and other studies. Four examples follow:

1) Sagehen Creek is a tributary of the Little Truckee River and although Sagehen is the smaller, the two are similar in many respects, including accessibility. Yet the stocked section of the Little Truckee receives more than 40 times the angling intensity of unstocked Sagehen Creek (P. R. Needham, unpublished data). Angling intensity on the unstocked but readily accessible sections of the Little Truckee River is similar to that on Sagehen Creek (numerous observations by authors and project personnel).

2) Before 1959, Murray Lake, a 150-acre reservoir in San Diego County, annually provided about 7,000 angler days of black bass and sunfish angling. In 1959, private stocking of trout was begun. By 1961, angling intensity had increased to 50,000 angler days, even though the open season had been cut two-thirds. The catch per angler day has remained fairly constant at 1 pound of fish under both types of management (Calhoun, 1962).

3) The study section of lower Rush Creek is a few miles downstream from heavily stocked upper Rush Creek. They are equally accessible, yet the angling intenisty on upper Rush Creek was 70 times that on lower Rush Creek when the latter was a near wild trout fishery (Kabel and Butler, 1959).

4) At lower Rush Creek, the effects of varying the annual allotment of catchable-sized trout from 20,000 to 540 over a 10-year period (1947 to 1956) were measured. Angling effort was so closely geared to the number of trout stocked that angling quality (catch per angler hour) was apparently unaffected (Table 4). Annual angling effort ranged from 36,417 angler hours in 1949, when 19,975 trout were stocked, to 3,071 angler hours in 1956, when only 540 were stocked and 75 percent of the catch consisted of wild brown trout. The average catch per angler hour for these 2 years was 0.49 and 0.50, respectively.

Thus, *the stocking of catchable-sized trout is the cause of the unusually high angling intensities exerted upon waters so stocked.*

There was no relationship between mean catch per angler hour and the number of catchable-sized trout stocked per unit of water or between mean catch per angler hour and angling intensity on waters studied (Figures 6 and 7). Although annual allotments and angling intensity varied tremendously among study waters, angling quality did not. This is consistent with the lower Rush Creek results, which leads to the generalization that *the average yearly catch per angler hour from individual waters is unaffected by changes in the annual allotment of catchable-sized trout because angling effort adjusts proportionally.*

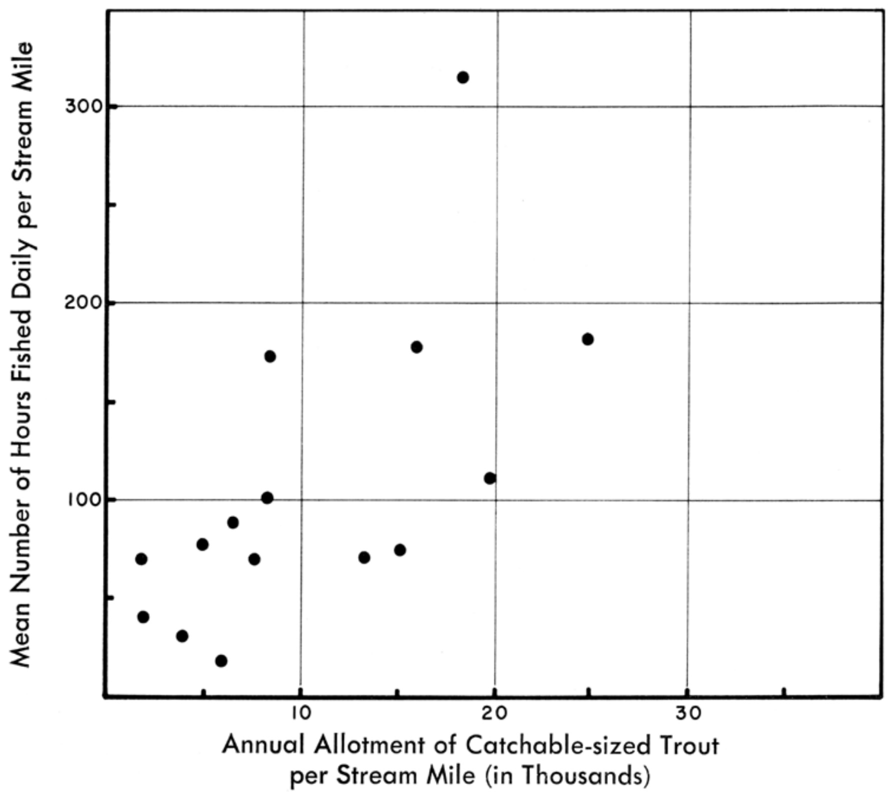

FIGURE 4. Relationship between annual allotment and angling effort of study streams.

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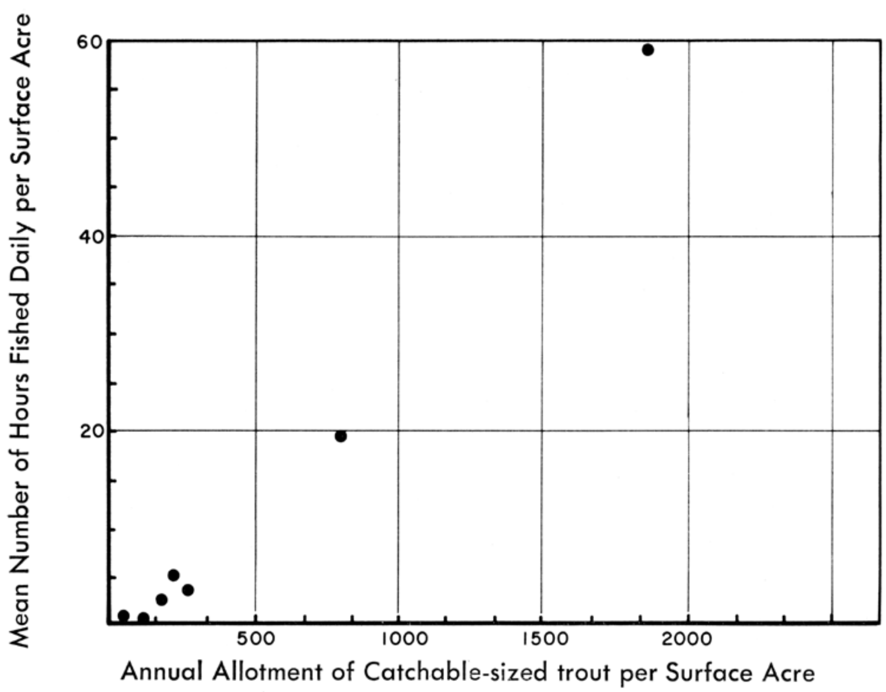

FIGURE 5. Relationship between annual allotment and angling effort of study lakes.

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TABLE 4

Lower Rush Creek Creel Census Data--1947–1956 *

	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
Hours fished	19,569	31,962	36,417	19,070	11,390	--	5,632	9,198	4,018	3,071
Catchable-sized trout planted	10,000	19,945	19,975	10,000	9,984	--	5,000	5,250	6,018	540
Catch/hour	0.53	0.64	0.49	0.46	0.74	--	0.31	0.46	0.84	0.50
Percent zero catches	49.2	39.2	41.5	43.0	48.6	--	72	64	63	66
Catch of wild brown trout	1,104	1,131	1,373	938	1,170	--	697	1,730	915	1,161

* From Vestal (1954), P. E. Giguere and C. H. von Geldern (unpublished data), and Butler and Kabel (1959).

TABLE 4 Lower Rush Creek Creel Census Data—1947–1956

There are, of course, obvious exceptions to this generalization. On waters with access limited by regulations or by natural obstacles, angling effort would not increase in proportion to increases in the annual trout allotment. Also, if angling intensity on a particular water is allowed to become so great through heavy stocking that congested and distasteful angling conditions result, additional stocking may not attract a proportional amount of angling effort.

These exceptions should be quite rare. To begin with, a water with severe natural obstructions to access is a questionable water for a catchable trout fishery. Also, increasing the annual trout allotment on a water already suffering from too much angling is ill advised.

Increased planting does not increase overall catch per angler hour until some factor, such as limited access or inadequate parking, limits angling effort. The sole purpose of a "catchable" program is to provide angling recreation. Therefore, *stocking should not go beyond the point at which it no longer proportionally increases angling recreation*.

Many factors besides the availability of fish attract anglers to a particular water. Accessibility, nearness, scenic beauty, climate, camping facilities, and boat launching areas all influence the angler's choice for a fishing trip. Thus, trout planted in waters that rate high in these factors will provide more recreation per fish than those stocked in less attractive waters. Paradoxically, the waters most suitable for catchable trout stocking typically have a relatively low overall catch per hour. These waters provide maximum angling recreation per fish stocked. Conversely, an unusually high overall catch per hour on a particular water is cause for concern, since it indicates that the trout are not providing as much recreation as they should.

In light of the above discussion, the following facts have important implications for future catchable trout programs.

The average catch per angler hour for study streams ranged from 0.63 to 1.56 and averaged 0.94, but for lakes it ranged from 0.40 to 0.75 and averaged only 0.60 (Table 3). Assuming these data represent the overall situation, about three trout must be stocked in streams for every two in lakes to provide equal numbers of angling days. The difference is even greater when the observed 14 percent greater average harvest from lakes is considered.

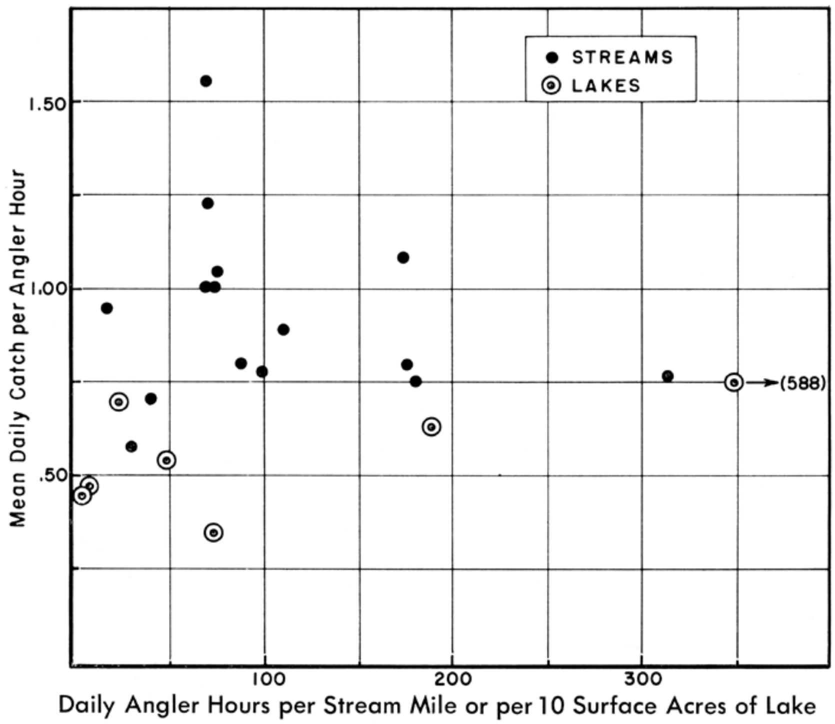

FIGURE 6. Relationship between annual catchable-sized trout allotment and catch per angler hour of study waters.

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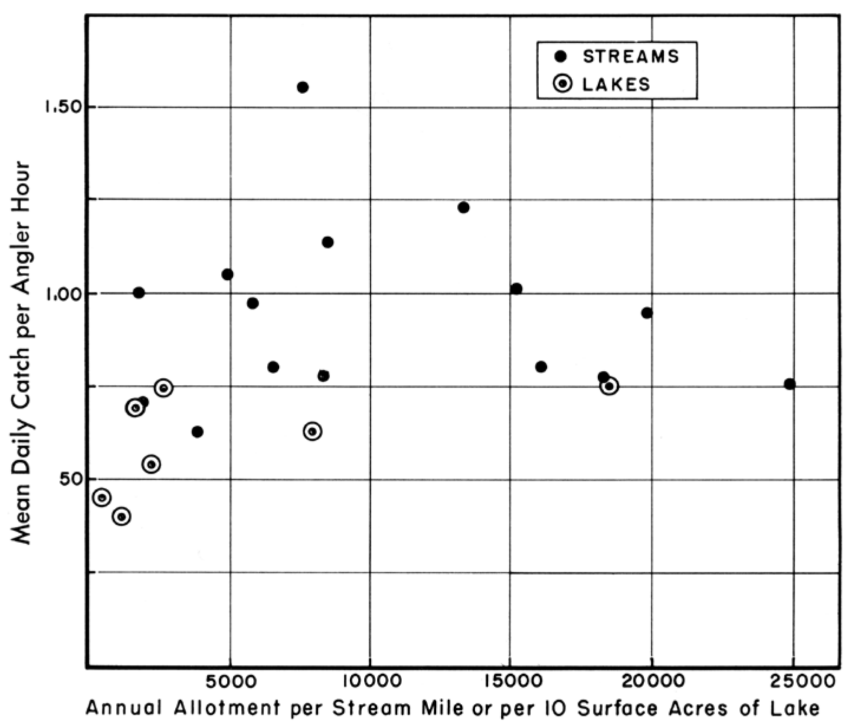

FIGURE 7. Relationship between angling intensity and mean catch per angler hour of study waters.

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Fluctuations in catch per angler hour were much more pronounced on streams than on lakes (Table 3).

To the fisheries manager, fluctuations in catch per angler hour are not the most useful measures of the stability of fishing quality on catchable trout waters. Day-to-day fluctuations in catch per hour occur on most stable natural fisheries, even without appreciable changes in the fish populations. Fisheries managers can control fluctuations in angling quality on catchable trout waters only to the degree that they can control the number of trout in such waters. Some natural fluctuation is unavoidable and possibly even desirable.

In managing a fishery, a knowledge of fluctuations in abundance of catchable-sized trout, i.e., the fraction of the population that survives from one plant to the next, is of more value than a knowledge of fluctuations in catch per unit of effort. Two different measurements of plant-to-plant survival of catchable-sized trout were obtained for most experimental plants. The first measurement is the fraction of an experimental plant surviving until the next plant is made. The second is the fraction of the total catch provided by other than experimental trout during the interval between the experimental plant and the following plant. The first survival measurement reflects plant-to-plant changes in abundance of stocked catchable trout, while the second reflects changes in the abundance of all trout of catchable size, including wild fish. Since the fishery manager is usually concerned with the overall quality of the fishery, the second survival measurement will be most useful in waters containing substantial populations of wild trout. But wild trout contributed little or nothing to the catch from the waters studied, so the two survival measurements for each water were averaged (Table 2).

These survival measurements represent overall plant-to-plant survival only as accurately as the experimental plants represent routine plants. As previously mentioned, our experimental plants were nothing more than routine plants of marked fish except for the 1958 East Carson River and Erskine Creek plants. But routine plants were not always the same size, nor were planting intervals constant for all waters. Consequently, considerable variability sometimes occurred between the two survival measures for an individual plant and between the values for different plants in the same water (Table 2). The averaging of the two survival measurements for each experimental plant compensates for some of this variability.

For lakes, plant-to-plant survival ranged from 0.27 (South Lake) to 0.90 (Lake Arrowhead), with a mean value of 0.56 (Table 2). The mean survival for streams was 0.26 ranging from 0.14 (Kings River below Pine Flat Dam) to 0.65 (east Carson River under experimental management). It is apparent that the lakes studied had more stable populations of catchable-sized trout than study streams.

The great fluctuations in abundance of catchable-sized trout and the associated fluctuations in angling quality that take place on most streams occur simply because the individual plants are too large. Immediately after too large a plant, fishing is very good and local anglers, familiar with planting schedules, flock to the stream and take a heavy toll of trout. This heavy fishing effort immediately following a plant is aptly termed "truck following". Opportunities for poaching and greediness are very great at this time and angling etiquette suffers. The good fishing does not last long, however, and angling effort drops off until the next plant is made. The average catch per hour on such waters is lowered by anglers who "should have been here last week", the vacationers and weekend anglers who must take "the lean with the fat" (this is discussed under "Distribution of catchable trout among anglers").

The solution of this problem is to reduce the size of the plants. This will reduce the initial catch per angler hour by lowering the initial number of available fish. But the data indicate that the overall catch per hour will not change. Thus, the closer the initial catch per hour is to the average, the less catch per hour will fluctuate during the planting interval. Obviously, if the plants are small enough, truck following will be discouraged, since the plants will not greatly increase chances of success.

Planting more frequently without reducing the size of the plant will not reduce fluctuations in catch per hour; it will only increase their frequency.

But how large should the plants be? Small, daily plants would eliminate truck following and minimize fluctuations in catch per hour, but would make planting costs prohibitive for most waters. For the sake of economy, plants should be as large as possible without causing truck following. More precisely, plant-to-plant survival of catchable trout should be just large enough to prevent a drop in angling effort during the planting interval.

The relationship between plant-to-plant survival and the change in angling effort between the first and second halves of the planting interval for study waters (Figure 8) indicates that a plant-to-plant survival of about 0.50 was large enough to prevent a drop in angling effort. Thus, to provide a satisfactory catchable trout fishery at least cost, the size of the plants should be adjusted to allow a plant-to-plant survival of about 0.50.

This "optimum" plant-to-plant survival is probably not the same for every water. Also, everyone will not agree on the definition of a satisfactory catchable trout fishery. But, regardless of the desired survival, the plant size needed to provide it can be calculated for any water, using estimates of mean catch per angler hour and catchability of stocked trout in that water. This can be done as follows, using formulas of Ricker (1958).

From Ricker's definition of catchability, it follows that the catch per angler hour, *C/h*, produced by a group of fish equals the product of their number, *N*, and the catchability, *c*. $C/h = Nc$ (Ricker's 6.1) (1)

Similarly, the average number of fish (

$$(\overline{N})$$

FORMULA

) needed to produce a given average catch per hour is:

$$\overline{N} = \frac{\overline{C/h}}{c} \qquad (2)$$

FORMULA

Also, the total number of fish that die during a period of time (our planting interval) equals the average population density times the total instantaneous mortality rate during that period.

$$\text{Total deaths} = \overline{N}i \text{ (from Ricker's 1.10)} \qquad (3)$$

FORMULA

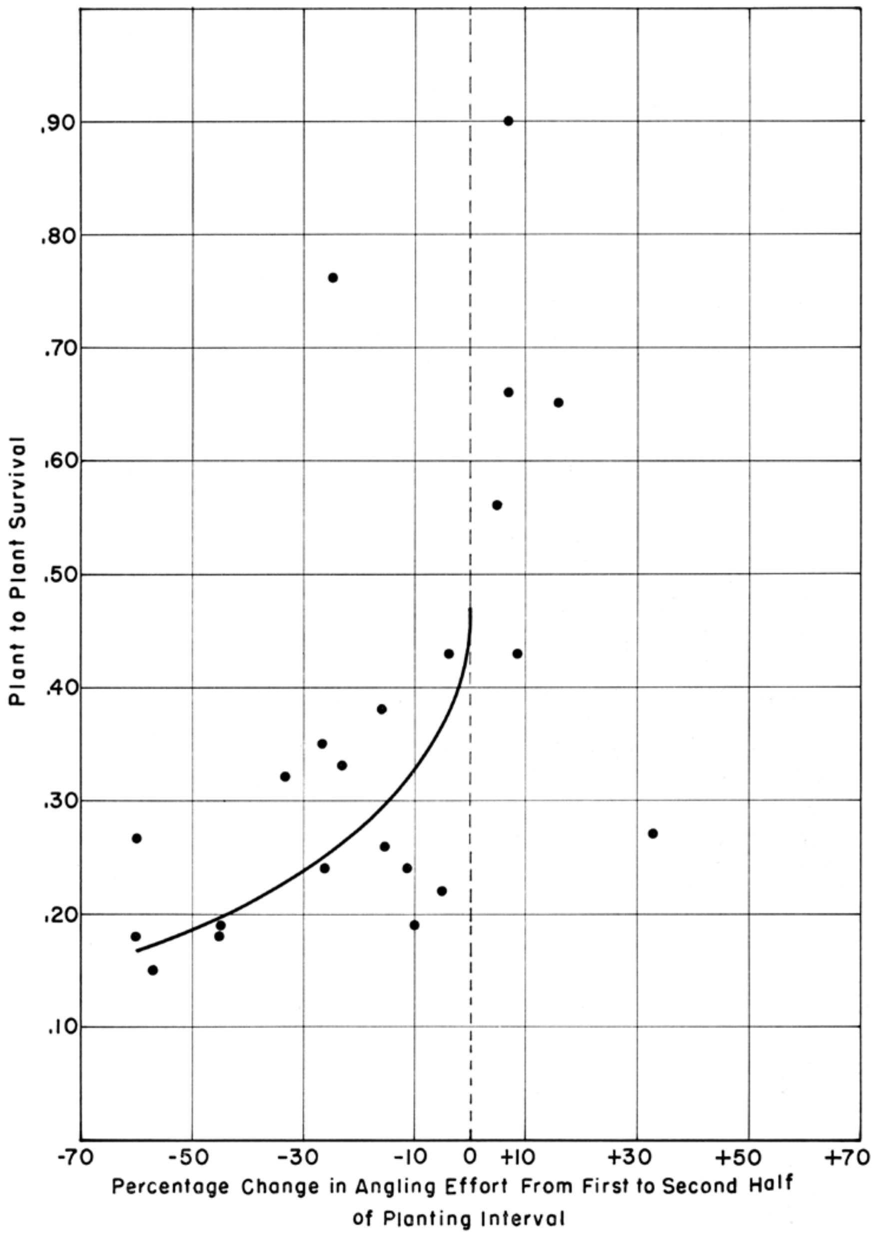

FIGURE 8. Relationship between plant-to-plant survival of catchable-sized trout and fluctuations in angling effort of study waters.

FIGURE 8. Relationship between plant-to-plant survival of catchable-sized trout and fluctuations in angling effort of study waters

In catchable trout fisheries we periodically replace total deaths with an equal number of recruits (*R*) which is our plant size.

$$\text{Thus:} \quad R = \bar{N}i \text{ (from Ricker's 1.16)} \qquad (4)$$

$$\text{But:} \quad i = -\log_e s \text{ and } \bar{N} = \frac{\overline{C/h}}{c}$$

$$\text{Substituting:} \quad R = \frac{(\overline{C/h})(-\log_e s)}{c} \qquad (5)$$

FORMULA

This formula can be used to calculate the plant size that will produce any desired plant-to-plant survival from estimates of mean catch per angler hour and catchability. Its reliability is based solely on the accuracy of the estimates of mean catch per angler hour and catchability for a particular water.

The population of catchable-sized trout is at a maximum immediately following a plant of *R* trout. Its size at that time is:

$$N = R/a \text{ (Ricker's 1.13)} \qquad (6)$$

where $a = 1\text{-}s$, the fraction of the population that dies during the planting interval.

FORMULA

Expression (6) applies only after a succession of equal plants has been made in a given year. If there are *P* fish from over-winter, and *R* fish are planted each time, the population after each successive planting is:

$$\begin{aligned} &R + P \\ &R + (R + P)_s \\ &R + R_s + (R + P)_s{}^2 \\ &R + R_s + R_s{}^2 + (R + P)_s{}^3 \text{ etc.} \end{aligned} \qquad (7)$$

FORMULA

This converges to *R/a* as the higher powers of *s* become negligible.

But, if the first plant, R_1, is such that $R_1 + P = N = R/a$, then the "equilibrium" situation is established at once and will be maintained by subsequent plantings of *R* each time (assuming *s* is constant, of course).

Therefore, winter carryover should be estimated and the season's first plant adjusted to bring the population up to *R/a* trout. This estimate need not be precise, since the effect of even a large error will not be noticeable after a few plants (see (7)). For most Californian fisheries, R_1 can be set equal to *R/a,* since stocking usually ceases 2 months before the trout season ends, making winter carryover negligible.

The following example illustrates the use of the above formulas in calculating plant sizes.

Assume that two 14-day creel censuses of a given catchable trout fishery provided the following data:

Average catch per angler hour	0.80
Average catchability	0.0006
Average plant-to-plant survival	0.20
Average drop in angling effort from first to second half of planting interval	30 percent

Also, census personnel observed that the present plants of 2,145 trout were attended by a considerable amount of truck following and that anglers complained of poor fishing toward the end of the planting interval.

Assume that this prompts an attempt to increase plant-to-plant survival to 0.50. The adjusted plant size, *R,* is calculated by substituting the above data in formula (5), thus:

$$R = \frac{0.80\ (-\log_e 0.50)}{0.0006} = \frac{0.80\ (.693)}{0.0006} = 924 \text{ trout}$$

FORMULA

Assuming that few fish will survive the winter, the season's first plant must number:

$$\frac{R}{a} = \frac{924}{0.5} = 1{,}848 \text{ trout}$$

FORMULA

To maintain the same level of angling recreation at this water (keep the same annual allotment), stocking must be about twice as frequent.

The results of experimental stocking in the East Carson River illustrate that, in practice, smaller plants *will* increase plant-to-plant survival, and reduce plant-to-plant fluctuations in angling quality and angling intensity. In 1957, weekly plants of 2,000 trout produced plant-to-plant survival that averaged 0.24. Catch per angler hour ranged from 0.15 to 3.06 and angling effort dropped an average of 27 percent from the first to the second half of a planting interval. During 1958, semi-weekly plants averaged 700 to 900 trout. Plant-to-plant survival increased to 0.65, catch per angler hour ranged from 0.69 to 2.07, and angling effort showed an increase during the interval between plants. Project personnel noted a marked drop in truck following.

The plant size per mile for most streams must be quite small in order to provide a satisfactory catchable trout fishery under present distributional practices (Table 5) . Unless these streams are close to planting bases or are on the route to other catchable trout waters, stocking them properly is relatively expensive.

The scope of catchable programs for small streams is limited not only by the small size of plants but also by physical restrictions. It takes relatively little angling effort to create crowded fishing conditions on small streams. In contrast, there always seems to be room for more angling effort at most lakes.

Unfortunately, small roadside streams with wild fish populations are usually the first waters to suffer from overfishing. This has resulted in widespread stocking of small streams with catchable sized trout, even though they are much less suitable for the program than larger streams and lakes. California's stocking program could be strengthened substantially by dropping small streams and transferring their allotments to more suitable waters. Unfortunately, it is difficult to discontinue an established stocking program. As the overall program grows in the future, however, additional fish should be allotted to lakes and larger streams insofar as possible.

TABLE 5

A Comparison of Study Plant Sizes with Plant Sizes Calculated to Produce Plant-to-Plant Survival of 0.5

Name of water	Size of water (stream miles or lake surface acreage)	Mean size of study plants (marked routine plants)	Plant size calculated to produce plant-to-plant survival of 0.5
Butt Creek	1.7	1,495	690
Big Butte Creek	1.2	1,600	830
East Carson River (1958)	2.5	833	1,120
West Carson River	1.2	800	220
Erskine Creek	3.0	1,300	530
Feather River, West Branch	1.5	3,920	1,560
Kern River	2.7	3,748	2,030
Kings River (South Fork)	8.0	2,159	830
Kings River (below Pine Flat Dam)	3.75	3,735	1,190
Merced River (Exchequer Section)	7.0	3,000	1,700
Rush Creek	2.2	2,250	1,030
Stanislaus River	3.2	2,400	780
Tule River (Belknap)	0.8	752	430
Tule River (Soda Flat)	0.3	206	130
Tuolumne River	2.2	2,800	1,440
Little Truckee River	1.9	2,010	1,290
Lake Arrowhead	782	3,000	2,670
Convict Lake	168	2,200	1,870
Green Valley Lake	12	1,400	1,480
Gregory Lake	96	2,800	7,200
Huntington Lake	1,441	4,047	6,900
June Lake	310	5,012	6,510
South Lake	177	2,500	1,460

TABLE 5 A Comparison of Study Plant Sizes with Plant Sizes Calculated to Produce Plant-to-Plant Survival of 0.5

4.4. Planting Frequency and Annual Allotments

Annual allotments for catchable trout waters are influenced by many factors, the most important being: (i) the demand for trout fishing in the area weighed against that in other areas of the state; (ii) the total number of trout available; (iii) the number of other catchable trout waters in the area; and (iv) the capacity of the water and the surrounding area to absorb angling effort (size of the water, campsites, etc.).

Once the annual allotment is chosen and the proper plant size is determined from creel census data, the number of plants per year becomes fixed.

The proper spacing of these plants throughout the season is not as easy. Angling effort is a far more important factor in reducing stocked trout populations than is time. Thus, *all planting intervals should include, as nearly as possible, equal amounts of angling effort regardless of their length in days or weeks.*

In choosing these intervals, differences between weekend and weekday angling effort must be considered, as well as heavy holiday effort and seasonal changes. For example, planting should ordinarily be more frequent during the vacation season than during the spring and fall, and an extra plant may be necessary following opening day or a major holiday. Local fisheries managers will have to estimate variations in angling effort for the individual waters in their charge. Fortunately, rough approximations of seasonal changes will suffice, since angling effort should adjust to compensate for fairly sizeable miscalculations.[9]

Ordinarily, in applying creel census results to a particular fishery, the annual allotment will not be changed drastically. This supposes that the water's suitability and capacity for stocked trout was considered in determining the original allotment. However, if a gross change in the annual allotment is made in the light of creel census results, a follow-up census is recommended to check for a change in overall catch per hour. If the allotment is substantially cut, some factor that limited angling effort, e.g., crowded and distasteful angling conditions or inadequate parking or camping facilities, may be eliminated with a resultant drop in mean catch per hour. A large increase in annual allotment could have the reverse effect. Thus, the proper plant size may change somewhat following a gross change in the annual allotment.

4.5. The Distribution of Catchable Trout Among Anglers

It is tempting to assume that heavy stocking of catchable-sized trout provides easy angling and that most fishermen at stocked waters have good success.

However, we have shown that angling intensities keep pace with stocking, so that fishing success is equal on heavily stocked and lightly stocked or unstocked waters. High angling intensities on stocked waters also result in a distribution of trout that is no better than occurs under natural conditions. Creel census data from several trout waters in California (Table 6) substantiate this statement. Regardless of whether the fishery is based on stocked rainbow or brown trout, on wild brook, brown, or rainbow trout, or on plants of fingerling rainbow trout, a large proportion (usually between 35 and 70 percent) of the angling efforts are unsuccessful and 50 percent of the catch is usually taken by less than 10 percent of the fishermen.

Erskine Creek, Kern County, was the only study water where access was controlled and where information on the distribution of trout among anglers was obtained. Erskine Creek is fairly typical of the small streams studied in that large fluctuations in catchable-sized trout populations occurred (plant-to-plant survival averaged 0.15) and resulted in truck following (angling intensity decreased an average of 54 percent from the first half to the second half of the planting interval).

of the 1,381 persons who fished the stream during the study period, 86 (6 percent) individuals caught 50 percent of the total catch of 3,400 marked trout. These anglers, whom we shall call the most successful anglers, each caught between 11 and 50 fish during the study. They had the highest mean catch per hour, the greatest number of individual trips to the stream, and the highest daily number of hours fished (Table 7) .

Most of the most successful anglers were Kern County residents. Sixty-seven percent of them lived within 100 miles of the stream, whereas 57 percent of the less successful (those who caught the remaining 50 percent of the catch) and only 40 percent of the unsuccessful

[9] Angling effort has been shown to adjust to the available trout on an annual basis and, to some extent, during a single interval between plants (as witnessed by the drop in angling effort during planting intervals on waters where the plant size was too large). Certainly, substantial seasonal adjustments to the number of trout stocked can also be expected.

TABLE 6

Distribution of Trout Among Anglers

Name of water	Year	Percentage of angler days		Percentage of individual anglers taking 50 percent of catch	Type of fishery	Reference
		Zero catches	50 percent of catch			
Rush Creek, lower	1947–51	43.3	--	--	Planted catchable-sized rainbow trout	Vestal (1954)
	1953–55	66.3†	3.0†	--	Planted catchable-sized brown trout	Kabel & Butler (1959)
	1956	65.7†	7.4†	4.8	¾ wild brown trout	Kabel & Butler (1959)
Crystal L.	1952	65.5†	--	--	Planted catchable-sized rainbow trout	Evans (1957)
San Gabriel River, West Fork	1954	48.0†	--	--	Planted catchable-sized rainbow trout	P. E. Giguere (Unpub. data)
Castle L.	1952	33	--	7.7	½ planted catchable-sized rainbow, ½ wild eastern brook trout	Wales & Borgeson (1961)
	1953–1961	40.6 (31 to 49)	--	10.6 (6.7 to 22)	Planted fingerling rainbow-wild eastern brook trout	Wales & Borgeson (1961), D. P. Borgeson (Unpub. data)
Feather River	1954	70.8	5.5	--	Wild rainbow trout	Rowley (1955)
Beardsley Res.	1962	53.5	--	--	Planted rainbow fingerlings	D. P. Borgeson (Unpub. data)
Spaulding Res.	1962	85.9	--	--	Wild rainbow and brown	D. P. Borgeson (Unpub. data)
Icehouse Res.	1962	55.7	--	--	Planted rainbow and Kokanee fingerling	D. P. Borgeson (Unpub. data)
Upper Salmon Lake	1957–59	61.4	--	6.3	¾ planted catchable-sized rainbow trout, ¼ planted fingerling and wild rainbow trout	H. D. Boles (Unpub. data)
Lower Sardine Lake	1957	58.1	8.9	4.9	Mostly planted catchable-sized browns	H. D. Boles (Unpub. data)
	1958	43.9	11.3	7.4	Mostly planted catchable-sized browns	H. D. Boles (Unpub. data)
	1959	34.2	10.8	8.2	Planted catchable-sized browns and rainbows	H. D. Boles (Unpub. data)
	1960	31.8	17.0	11.5	Planted catchable and subcatchable-sized rainbows	H. D. Boles (Unpub. data)
Erskine Cr.	1958	54.7‡	--	6.2		

† Expressed in terms of angler efforts. An angler who fished once in the morning and returned to fish once in the afternoon is represented by two angler efforts. The sum of his two efforts represents an angler day.
‡ Expressed in terms of individual anglers (who may have fished several times during the season).

TABLE 6 ***Distribution of Trout Among Anglers***

anglers lived within 100 miles. One statistic gathered from the Erskine Creek census represents an important inequity in the distribution of stocked trout among anglers that has nothing to do with angling skill and is common to most catchable trout fisheries on small streams—the most successful anglers expended 52 percent of their effort on the day of or the day after a plant, whereas the less successful spent 38 percent and the unsuccessful only 32 percent of their effort on these two days. Anglers who are familiar with planting schedules and are able to fish immediately following a plant (truck followers) derive the greatest benefits from catchable-sized trout stocking in small streams. In fairness to the average trout fishermen, such streams should be stocked with the proper-sized plants or not at all.

TABLE 7

Distribution of Catchable-sized Trout Among Anglers Fishing Erskine Creek, Kern County, between May 16 and June 15, 1958

	Most successful anglers (least number of anglers taking half of total catch)	Less successful anglers (largest number of successful anglers taking half of total catch)	Unsuccessful anglers (Zero catch)
Number and percentage of individuals	86 (6)	539 (39)	756 (55)
Number and percentage of total hours fished	986 (20)	2,314 (47)	1,586 (32)
Hours fished per day	4.5	3.3	1.9
Mean catch per angler hour	1.7	0.7	0.0
Percentage of days fished on weekends and holidays	62	68	76
Percentage of angler days expended on the first two days following a plant	52	38	32
Percentage of Kern County residents	73	56	40
Percentage of Los Angeles County residents	20	32	47
Percentage of residents from other counties	7	12	12

TABLE 7 ***Distribution of Catchable-sized Trout Among Anglers Fishing Erskine Creek, Kern County, between May 16 and June 15, 1958***

4.6. Movement of Stocked Trout

4.6.1. Lake Movement

Planted trout disperse quite rapidly in lakes. At South Lake in 1957, fish distributed themselves around the lake by the day following the test plant. Studies at Convict Lake during July 1958, indicated that trout took two days to spread to all areas of the lake. The July 1 plant was made on the southeast side of the lake. South shore anglers received immediate benefit but north shore anglers did not take appreciable numbers until July 3. After July 2, angling quality produced by this plant was roughly equal on both sides of the lake.

The work at Huntington Lake provides further information on trout movements. One plant was made in Rancheria Creek, near the mouth, where flows ranged between 550 and 1,050 cubic feet per second during the study period. These fish aligned themselves to the inflow and remained in sight for several days. Eighty-nine percent of the shore catch of this plant was taken in the northeast section of the lake (Rancheria Creek area) and most of this plant was taken near the mouth of the creek. Only 48 percent of the lake's shore angling effort was expended in this section.

Trout from three other plants in Huntington Lake dispersed throughout the lake (Table 8) . Angling quality produced by a plant was always a little better near the planting site than in other areas. This is not surprising. Even though the trout may disperse randomly from the planting site, many are caught before they disperse. The plant that was scattered at four locations produced no better distribution of trout among shore anglers than the one made at one point. This indicates that scattering of trout in lakes is unnecessary, but that they should not be planted near heavy inflows.

TABLE 8

Distribution of Catchable-Sized Rainbow Trout Among Shore Anglers at Huntington Lake, July and August, 1958

Planting site	Catch per angler hour produced by each plant along four sections of shoreline: Northeast shore	Northwest shore	Southeast shore	Southwest shore
Northeast (Rancheria Creek Bridge)	0.12	0.02	0.01	0.01
Southwest	0.06	0.09	0.03	0.11
Scattered (North, Northeast, Northwest, and Southwest)	0.05	0.07	0.03	0.08
North	0.05	0.07	0.02	0.04
All trout (including unmarked fish)	0.52	0.46	0.23	0.41

TABLE 8 ***Distribution of Catchable-Sized Rainbow Trout Among Shore Anglers at Huntington Lake, July and August, 1958***

The catchability of trout stocked in lakes often increased for a few days following a plant (Figure 2). This may be due to incomplete dispersal within the lake. Planted trout dispersing in schools from the planting site are probably not as vulnerable to the overall angling effort at the lake as they are when they become well distributed. Certainly, other factors could cause the observed increases in catchability, but since the increase was most noticeable in the large lakes (Arrowhead and Huntington) but did not occur in the Rancheria Creek plant in Huntington Lake or in streams (Figure 3), incomplete dispersal seems to be a logical explanation.

Trout planted in Lake Pillsbury, Lake County, migrated downstream into the Eel River while the reservoir was spilling. Twelve percent of the returns from the April 26 plant of 2,750 tagged fish were taken in the Eel River below the impoundment. There was no evidence of downstream migration from a plant of 1,050 tagged trout made on June 27 of that year. The dam was not spilling then, although water was being released through a valve at a lower level.

4.6.2. Stream Movement

Extremely high harvest rates from most streams studied usually obscured any tendencies toward movement, but some information was obtained. As a test on movement, two rainbow strains were planted at different points in the Kern River in the fall of 1956. Trout of Hot Creek fall-spawning strain were planted in late October farther upstream than fish of a November plant of Mt. Whitney spring-spawning strain. The following spring, after six-months' freedom (the trout season closed October 31), most recoveries occurred within ¼ mile of the planting sites.

Fifteen of the 22 recoveries of Hot Creek strain were caught within ¼ mile of the planting site, while 5 were caught ¼ to 2 miles downstream, and 2 were taken more than 2 miles downstream. Forty of the 62 recoveries of Mt. Whitney strain were taken within ¼ mile of the planting site, while 14 were caught between ¼ and 2 miles upstream, 5 between ¼ and 2 miles downstream, and 3 more than 2 miles downstream.

Mt. Whitney spring-spawning strain were planted at two sites on the South Fork of the Yuba River on August 16, 1955. Fifty-two of the 57 recoveries were caught within ¼ mile of the planting sites.

Individuals experienced in planting catchable-sized trout have noted that trout in poor condition often drift downstream when planted in rapidly flowing water. For example, one of three plants made in 1958 in the Big Sur River, Monterey County, exhibited excessive downstream movement (Fisher, 1961). Less than 10 percent of two plants was recovered in a weir and trap below the planted area, whereas 32 percent of a third plant was taken there. Fish of the latter plant moved downstream as a body during daylight hours and were observed by departmental personnel to be listless and in poor condition. Downstream movement of the other two plants occurred principally during the night and early morning.

Cooper (1951) and Newell (1958) noted marked downstream movement of trout planted in waters colder than 50 degrees F. It was thought that low temperatures in the West Branch of the Feather River might have caused downstream movement there. To test this, a plant of 200 marked trout was made on October 14, 1958 in the West Branch of the Feather. The stream temperature was 47 degrees F. Five days later, three sections of stream (1,000 feet in all) below the planting site were electrically shocked and a 580-foot section at the planting site was drained. of the 200 fish recovered, 168 were recovered in the drained section, most of them from the pool in which they had been planted. None was recovered downstream; hence, in this instance, cold water temperatures did not result in a downstream movement of consequence.

In the Truckee River, Nevada County, three plants of fall-spawning rainbows from Idaho hatcheries exhibited upstream movement. Adams (1960) stated that marked trout were being caught over one mile upstream from the planted area within a few days of the 1958 and 1959 plants. Twenty-three, 34, and 62 percent of the returns from these plants was caught upstream from the planting site, whereas only 1, 2, and zero percent, respectively, were taken downstream.

In 10-mile-long study sections of the Big Laramie River in Wyoming, Millis and Kanaly (1958) found that tagged catchable-sized brown and rainbow trout usually remained near the planting site and that downstream movement was more common than upstream movement. Nearly 80 percent of the trout recovered by anglers or by post-season electrical shocking were taken within one mile of the planting site. Only 3 percent were recovered within 3 to 7 miles. Since daily angler pressure was light (6.9 angler hours per mile), the planted fish had ample opportunity to move before being caught.

A few rivers in California wider than 50 feet are planted with catchable trout. Although plants are often made on only one side of these streams, dispersion to the other side occurs in a short time. For example, on opening weekend (May 3 and 4, 1958) on the Kern River, catch per angler hour resulting from a May 2 plant was essentially the same from both sides of the river. From the relatively inaccessible north side, 196 angler hours produced a catch per hour of 0.50, whereas 1,253 angler hours expended from the accessible south side (planted side) resulted in a catch per hour of 0.49.

In conclusion, catchable trout generally exhibit only minor movements in streams and substantial fish losses due to movement probably do not frequently occur. By the same token, movement cannot be relied upon to distribute trout throughout a stream section.

5. SUMMARY

Trout fishing has long dominated California's freshwater angling picture. In 1936 roughly half of the state's 300,000 angling licensees caught trout. In 1962, with 1,588,000 licensees, the proportion remained unchanged.

Heavy angling pressure early depleted trout in many roadside waters. The stocking of "catchable-sized" hatchery trout soon followed, beginning in southern California and the Mono-Inyo area before World War II. It spread rapidly throughout the state after World War II, as the Wildlife Conservation Board provided more than $4 million for trout hatcheries.

Currently, about seven million 7- to 8-inch rainbow trout (Salmo gairdnerii) are stocked annually in California, at a cost of $1,366,000 (fiscal year 1962–63).

This program created a need for rapid, inexpensive survey methods to determine if the many new "catchable" fisheries were functioning satisfactorily. Accordingly, a research project, D-J F-14-R, "Evaluation of Catchable Trout Stocking," was set up in 1954 to develop such a method, and to evaluate the new program. In 1956, this project was incorporated into the broader "Trout Management Study," D-J F-8-R.

This project answered many troublesome questions. It quickly developed the desired new survey methods and used them during 1957 and 1958 to conduct many short-term (one- to three-week) creel census studies on a cross section of California's catchable trout fisheries.

Marked catchable-sized trout were planted in a routine manner and their contribution to the fishery was measured by creel census combined with angler counts.

Total harvest was estimated by plotting daily catch per hour against cumulative catch and fitting a straight line to the linear portion of this relationship. The *X* intercept of this line is the estimated total harvest, since it is the cumulative catch when catch per hour (and also the population) drops to zero. The slope of the line is the instantaneous total mortality rate per hour of angling effort. It is the sum of the instantaneous fishing mortality rate per angler hour (catchability) and the unaccounted mortality rate per angler hour.

Seventeen of the 20 test waters had harvests that met the mimimum 50 percent required by Fish and Game Commission policy. The average return from 7 lakes was 83 percent and from 13 streams 73 percent.

The fish were always caught rapidly. Fifty percent of the fish eventually harvested were taken within 2 to 9 days (average 3.6 days) from the study streams and within 4 to 12 days (average 6.6 days) from the study lakes.

Returns of trout 8.0 to 8.9 inches long were consistently about 15 percent greater than those of 7.0- to 7.9-inch fish.

The catchability of planted trout averaged about 7 times greater in the study streams than in the study lakes. It was generally greater in small streams and lakes than in their larger counterparts.

Variations in catchability depended primarily on differences in the waters stocked rather than on differences in the trout or the fishermen. Data from waters receiving more than one experimental plant showed little variation in catchability from month to month during a given summer or from one summer to the next.

Planted trout do not disperse readily in streams. Hence, their catchability can be greatly influenced by distributional practices. Conversely, planted trout disperse rapidly in lakes, so that distributional practices affect catchability very little.

Compared with wild trout fisheries, angling effort was extremely high on all study waters. Effort was proportional to the number of trout stocked. On lakes, daily angling effort ranged from 0.6 to 58.8 angler days per acre and averaged 3.5. The daily effort on streams ranged from 41.0 to 314.9 angler hours per mile and averaged 102.5.

The generalization may be made that the yearly average catch per angler hour from individual waters is unaffected by changes in the annual allotment of catchable-sized trout because angling effort adjusts proportionally. Increased planting does not increase overall catch per angler hour unless some factor, such as limited access or inadequate parking, limits angling effort.

The average catch per angler hour for study streams ranged from 0.63 to 1.56 and averaged 0.94; for lakes it ranged from 0.40 to 0.75 and averaged only 0.60. Thus, to provide equal numbers of angling days, three trout must be stocked in streams for every two in lakes (assuming equal harvest).

Fluctuations in catch per angler hour were much more pronounced on streams than on lakes.

"Truck following" results when the plant size for a given water is too large. Anglers familiar with planting schedules are attracted by the successful fishing that briefly follows a large plant. The opportunities for poaching and greediness are great at this time and angling etiquette suffers. The average catch per hour is lowered by uninformed anglers who "should have been here last week." Most of the planted trout are caught before the next plant is made (plant-to-plant survival is low). Among the waters studied, truck following was most evident on small streams.

The key to eliminating truck following and attendant distasteful conditions lies in reducing the plant size, thereby increasing the survival of stocked trout from one plant to the next. When nearly all stocked fish are caught before the next lot is stocked, catches drop off to nothing toward the end of the planting interval. Conversely, when most of the plant survives, angling is nearly as good at the end of the planting interval as at the beginning, discouraging truck following.

The data indicate that the largest (and, therefore, the most economical) plant size that will effectively eliminate truck following is one that allows about half the planted fish to remain uncaptured until the next plant is made.

Using the following formula, creel census data similar to those obtained in these studies can be used to calculate the most economical plant size that will produce a satisfactory fishery on a given water:

$$R = \frac{(\overline{C/h})(-\log_e s)}{c}$$

where

R = routine plant size (recruitment)

$\overline{C/h}$ = overall catch per angler hour

c = catchability of planted trout

s = desired plant-to-plant survival (lowest that will provide a satisfactory fishery)

FORMULA

Stream plants of catchable-sized trout must be quite small to create satisfactory fisheries, because of the high catchability of such trout in streams. The scope of stocking programs for small streams is further limited by physical restrictions. It takes relatively little angling effort to create crowded fishing conditions on small streams.

Small roadside streams with wild trout populations are usually the first to suffer from overfishing. As a result, many of them have been stocked with catchable-sized trout even though they are much less suitable for the program than larger streams and lakes. California's trout program would be strengthened considerably if these waters were not stocked and their allotments were planted in more suitable waters.

Angling effort is a far more important factor than time in reducing stocked trout populations. Thus, all planting intervals should include, as nearly as possible, equal amounts of angling effort regardless of their length in days or weeks.

The distribution of trout among anglers in catchable trout fisheries is no better than in wild trout fisheries. A large proportion (usually between 35 and 70 percent) of the fishermen catch nothing and 50 percent of the catch is taken by less than 10 percent of the fishermen.

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Now with Pennsylvania State University.

This must be a true weighted average computed through calculus, not merely the average of the initial and final stock. Thus, the average fish stock, $N1a/ -\log_e (1 - a)$, present during an hour of angling effort equals $N_1 a/ -\log_e (1 - a)$, where N_1 equals the initial fish stock and a the fraction of the stock that dies during the interval. (See expression 1.10 of Ricker, 1958.)