HARVEST OF FOUR STRAINS OF RAINBOW TROUT, SALMO GAIRDNERII,[1] FROM BEARDSLEY RESERVOIR, CALIFORNIA

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Four strains of rainbow trout, a wild strain of Kamloops rainbow and three domestic strains utilized in California's catchable trout program, were planted as fingerlings in Beardsley Reservoir, Tuolumne County, from 1961 through 1966. Kamloops and Shastas, the most recently developed domestic strain, were decidedly superior to Whitneys and Virginias, two strains domesticated since near the turn of the century. The best time of the year to plant Kamloops was determined to be in April and May when they were 1.0 to 3.2 per ounce. Shastas planted in July and August from 2.5 to 6.2 per ounce were most successful. Comparing groups of these strains planted only at these times we found that Kamloops were harvested at a significantly higher rate than Shastas. Shastas, however, had a higher average ratio of pounds caught to pounds planted, and a lower average cost per pound in the creel.

Kamloops displayed a greater tendency to leave the reservoir during periods of spillway discharge, and were less available to shore anglers than the domestic strains.

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Moreover, they were more difficult to raise in the hatchery. The performance of Shasta's we believe, could be greatly improved if they were available for planting at a larger size in the spring.

INTRODUCTION

Water developments in California have created numerous large, fluctuating coldwater reservoirs. A large portion of the State's trout fishing effort is expended on these waters. In many of them, fishing is either unsatisfactory or highly variable from year to year. A major cause of poor fishing is inadequate natural recruitment from the tributaries. Consequently, the fisheries depend upon annual planting of large numbers of fingerling rainbow trout.

In 1961, the California Department of Fish and Game initiated the Coldwater Reservoir Study to evaluate various fisheries management practices on coldwater reservoirs and to define the characteristics of coldwater reservoirs that affect fish production. The initial objective was to determine the best strain of trout for planting in such waters. This report summarizes results of stocking one wild strain and three domesticated strains of rainbow trout in Beardsley Reservoir, Tuolumne County, from 1961 through 1966. The three domestic strains used in this report were the Virginia strain, the Whitney strain, and the Shasta strain. The Kamloops was the single wild strain studied.

Beardsley Reservoir

Beardsley Reservoir (Figure 1) was formed by an earth and rock dam on the Middle Fork Stanislaus River in Tuolumne County, California, in 1957. It lies on the west slope of the Sierra Nevada at an elevation

of 3,397 ft. Its maximum surface area covers 720 acres, and it impounds a total of 97,800 acre-feet of water, with approximate maximum and mean depths of 273 and 135 ft, respectively. The drainage area is 309 square miles.

Total annual fluctuation in Beardsley Reservoir from 1958 through 1967 averaged 106 vertical feet (range: 72 to 135 ft). The minimum operating level of 3,261 feet above mean sea level was approached during several years but only for relatively brief periods. At this point, the reservoir capacity is 19,903 acre-feet with a surface area of about 420 acres.

A power plant located at the base of the dam is operated year around. Water is drafted almost continuously at the rate of from 550 to 625 cfs. The point of withdrawal is about 252 ft below the maximum operating level (3,397 ft msl). A small afterbay just downstream from the dam regulates the outflow from the power plant into the river. It is about one mile long, has a capacity of 320 acre-feet, and a surface area of 26 acres.

The limnology of Beardsley Reservoir is described by Nicola and Borgeson (1970). In general, it has the attributes of a moderately oligotrophic lake. A wild brown trout (Salmo trutta) population and a small wild population of rainbow trout exist, along with dense non-game fish populations. The most abundant non-game fish are the western sucker (Catostomus occidentalis) and the hitch (Lavinia exilicauda).

A single major access road leads to the reservoir. A check station was established on this road, and here a census clerk interviewed all anglers leaving the reservoir.

The Beardsley Reservoir Fishery

Fishing at Beardsley occurred each year only during the general statewide trout season, from the Saturday nearest May 1 through October 31. The characteristics of the Beardsley fishery will be detailed in a later report. Only the general characteristics are summarized here. From 1962 through 1967 an average of 6,012 anglers fished a total of 29,971 hours per year, harvesting an average of 8,163 trout. The average annual catch per hour of trout was 0.27. Fishing success is generally highest during May, September and October.

Nearly 77% of the annual effort is expended by boat anglers, who catch about 85% of all trout harvested. Of the average total annual catch, 90.7% by weight and 93.6% by number are marked rainbow trout of known hatchery origin. The remainder are wild rainbow and brown trout.

DESCRIPTION OF RAINBOW STRAINS

Virtually all domesticated rainbow brood stocks originated from rainbow taken at the old U. S. Fish Commission Hatchery on the McCloud River at Baird, California (Dollar and Katz, 1964). This trout, distributed so widely throughout North America and elsewhere in the world, is probably the result of mixing resident rainbow and anadromous steelhead rainbow (Salmo gairdnerii gairdnerii), according to Needham and Behnke (1962). Existing brood stocks, however, apparently possess characteristics unlike those of the original stock.

Virginia Strain

The Virginia strain has apparently been domesticated the longest. Its origin traces back to the federal Wytheville Hatchery in Virginia (Dollar and Katz, 1964). Eggs first arrived at Wytheville in 1882 from the McCloud River Station. This original strain was crossed with rainbow from

other sources at various times until 1930 when a selective breeding program was initiated (letter from S. A. Scott to Earl Leitritz; July 30, 1956). Virginia strain eggs were shipped to California in 1955 to meet a need for rainbow eggs during the summer, and the resulting fish were first spawned at Mt. Shasta Hatchery in 1957. Spawning occurs from the middle of July through September with no well-defined peak. Eggs from August spawners usually hatch in late September or early October and are planted as fingerlings at about 2.5/oz. in April[3/].

Whitney Strain

A precise history of this strain is unavailable. It was developed at the Mount Whitney Hatchery, Inyo County, in the early 1900's; the exact year is not known. The first eggs came from spawners trapped in the Rae Lakes, Fresno County, in 1917. According to George McCloud (pers. comm. to A.J.C., June 10, 1968), the brood stock was developed from this source and also from rainbow from Big Bear Lake, San Bernardino County, and Lake Almanor, Plumas County. These three populations were all derived from the original McCloud stock. However, at various times in the past, the brood stock probably was crossed with both steelhead rainbow from the Eel River and Lahontan cutthroat (Salmo clarkii henshawi) from Lake Tahoe. The original spring spawning time has been retained, with spawning extending from March through May, and peaking in early April. Whitneys hatch in early June, and are planted as fingerlings in September at about 3/oz. Whitneys generally have comprised the bulk of the small fingerlings stocked in California cold-water lakes and reservoirs in the summer and fall.

3/ Sizes at different ages for this and other strains are only approximations.

Shasta Strain

To obtain a winter-spawning rainbow strain, trout from Hot Creek, Mono County, were crossed with rainbow from a Federal hatchery at Meader, Idaho. The original crosses were made in California in 1951 and 1952. Initially, Shasta brood stock spawned from November through February, but as a result of further selection they now spawn almost exclusively in January and February. Peak spawning takes place in early February. Progeny from these fish are planted as fingerlings at about 4-6/oz in July, August and September.

Kamloops Strain

The Kamloops rainbow trout (Salmo gairdnerii kamloops), native to interior waters of British Columbia, Canada, is characteristically a lake fish, spawning in tributaries, where the young spend variable amounts of time before migrating to the lake. From sources in British Columbia, Kamloops have been distributed throughout the western United States. They were introduced in California in 1950 (Wales, 1950). For this study eggs were obtained from British Columbia and from Diamond Lake, Oregon. In all cases, eggs were taken from wild Kamloops trapped during their upstream spawning migration in May and June.

Kamloops spawn from April through June with peak spawning in May. They commonly hatch in July and are planted as fingerlings either in October at about 20/oz, or in the following spring from 1-3/oz. The Kamloops not only grows more slowly than the domesticated strains but displays greater size variation.

METHODS

Trout Planting

All trout planted in Beardsley Reservoir were reared at Moccasin Creek Hatchery near Sonora, Stanislaus County. Standard production and

planting methods were employed. The trout were released from trucks a short distance from the dam.

All groups of planted trout were given distinctive marks, consisting of various combinations of excised fins and maxillary bones. The pectoral fin mark was used only in 1962. The anal fin mark was not used nor was the double ventral fin mark. The adipose fin mark was always included in a triple-mark combination.

The number, length, weight and mark of each lot of rainbow trout planted each year varied considerably (Table 1). Trout were actually planted in 1961, but only some of the groups were marked, and only a few were censused that year. Therefore, these fish were not included in the analysis. Similarly, these strains were also planted in 1967, but were not compared that year because returns were incomplete. Small numbers of other strains were also planted during intervening years and these are not compared either.

Evaluation

The four strains were compared with respect to total harvest in numbers and pounds, and cost per pound in the creel. Their contribution to the fishery was also compared in relation to various fishing methods, and emigration from the reservoir was examined.

Data were collected by a four day per week creel census at the reservoir from 1963 through 1967. (In 1962, the census was conducted on almost a seven day per week basis, as only 11 days were not censused out of a total of 187.) Both weekend days and two weekdays per week were censused. Weekdays were censused on a stratified basis so that each was censused at least twice a month. The basic goals were to estimate total angler hours (effort), and total number and pounds of trout caught. The method involved attaining complete use and catch data for given days of census and directly expanding these data to estimate data for days not censused. The "expansion

TABLE 1

Number, Size and Mark of Each Strain of

Rainbow Trout Planted in Beardsley Reservoir, 1961-1967

Date	Species and strain 1/	Number	No. per ounce	Mark 2/
April 18-20, 1961	RT-V	25,000	2.5	Ad
April 18-20, 1961	RT-V	25,000	2.5	-
Sept. 15, 1961	RT-W	20,000	9.6	Ad-RV
Sept. 15, 1961	RT-W	30,000	9.6	-
Oct. 19, 1961	RT-K	20,000	12.0	-
Oct. 19, 1961	RT-K	20,000	12.0	LV
Feb. 15, 16, and	RT-K	15,000	3.5	Ad-LV
19, 1962	RT-K	15,000	3.5	-
Aug. 15, 1962	RT-W	10,000	10.5	RV
Sept. 14, 1962	RT-W	10,000	8.5	RP
Oct. 15, 1962	RT-W	10,000	3.7	LP
Oct. 15, 1962	RT-K	10,000	15.0	RV-LV
April 22, 1963	RT-K	10,000	1.5	RM
April 22, 1963	RT-V	10,000	3.0	Ad-LM
May 13, 1963	RT-K	10,000	1.0	LM
July 26, 1963	RT-S	10,000	6.0	D
July 26, 1963	RT-W	10,000	20.0	D-Ad
Aug. 27, 1963	RT-W	20,000	10.3	D-LV
Sept. 25, 1963	RT-W	10,000	5.0	D-Ad-LV
Sept. 25, 1963	RT-S	10,000	2.5	D-RV
April 16, 1964	RT-V	10,000	2.8	D-LM
April 16, 1964	RT-K	10,000	2.2	Ad-LV-RV
June 18, 1964	RT-S	5,000	9.0	LV-LM
July 31, 1964	RT-S	5,000	4.5	LV-RM
July 31, 1964	RT-W	10,000	18.5	Ad-RV-LM
Aug. 31, 1964	RT-S	5,000	2.8	RV-RM
Aug. 31, 1964	RT-K	10,000	51.5	Ad
October 13, 1964	RT-K	10,000	38.0	Ad-RV

Date	Species and strain	Number	No. per ounce	Mark
May 5, 1965	RT-K	5,000	3.2	D-Ad-RM
May 24, 1965	RT-K	5,000	2.8	D-Ad-LM
May 24, 1965	RT-S	10,000	30.0	RV
June 15, 1965	RT-K	3,000	1.5	D-Ad-RV
June 15, 1965	RT-S	10,000	16.0	Ad-RM
July 16, 1965	RT-S	10,000	6.2	Ad-LM
July 16, 1965	RT-W	10,000	27.0	LV
July 30, 1965	RT-S	10,000	4.6	Ad-LV-RM
August 25, 1965	RT-S	10,000	2.5	Ad-RV-LV
May 19, 1966	RT-K	16,200	1.4	Ad-LV
June 23, 1966	RT-S	10,000	14.0	LM
July 29, 1966	RT-W	10,000	11.5	D
July 29, 1966	RT-S	10,000	5.0	LV-RM
August 25, 1966	RT-S	10,000	3.9	RM
May 19, 1967	RT-K	5,000	0.8	RV-RM
May 19, 1967	RT-K	5,000	3.8	RV
May 19, 1966	RT-K	5,000	3.8	RV-LM
August 9, 1967	RT-S	10,000	11.3	LV
September 14, 1967	RT-S	10,000	3.8	D-LV

1/ RT-W = Whitney strain, RT-V = Virginia strain, RT-K = Kamloops strain, RT-S = Shasta strain.

2/ Ad = adipose, D = dorsal, M = maxillary, V = ventral, P = pectoral, L = left, R = right.

factor" was the ratio of the number of days (weekend or weekday) in a month to the number of days censused (weekend or weekday). This procedure applied essentially to weekdays as only rarely did we fail to census on a weekend day. Data were expanded separately for weekends and weekdays and the results summarized by month. National holidays were considered as weekend days. We determined that on each census day at least 90%, and on most days, virtually 100% of the total angler catch and effort was recorded. For our analysis, we assumed that 100% of the catch and effort was sampled on all census days.

Data were obtained from each angler on time fished (to the nearest quarter hour) and method of capture. As time permitted, trout were also measured or weighed. Many anglers cleaned their trout before leaving the reservoir, reducing the number that could be weighed.

Anglers who fished in the afterbay or the river below the afterbay were also censused. They seldom fished more than one or two miles below the afterbay, as this portion of the river is accessible only by foot. A road about 4 miles below the afterbay allowed access to the river there. Anglers fishing upstream from that point toward the afterbay did not enter the Beardsley census.

Costs of raising domestic rainbow trout in California hatcheries have been determined (California Dept. Fish and Game, unpublished). The cost varies from about $1.45/lb for fingerlings 1.0/oz to $16.00/lb for fingerlings 200/oz. The cost of raising wild-strain Kamloops was determined by considering not only the actual food and manpower costs but the value of the catchable trout taken out of production as well. For example, it takes about one year to raise the Kamloops to 1.8/oz. During that time domestic

strains can be raised to catchable size of about 5.5/lb. Comparative costs for the domestics and Kamloops at this point are $0.88/lb and $2.70/lb, respectively. Therefore, for any group of Kamloops and domestics of comparable size we assigned the Kamloop a cost three times greater than that of the domestics. To determine the cost per pound in the creel, we divided the total cost to produce a given group of trout by the total pounds of that group harvested.

RESULTS

Percentage Harvest

Kamloops Rainbow

Harvest rates of Kamloops rainbow fingerlings planted in the spring were consistently high (Table 2). Seven groups released in four different years were harvested at rates ranging from about 17 to 33%. When released, these trout were between 9 and 12 months old, and ranged from 3.2 to 1.0 per ounce (3.5 to 5.0 in FL). The harvest of 32.8% for the single 1966 release was substantially greater than the remainder.

Trout planted in late spring were recaptured at a greater rate than those planted at other times of the year. A single group of Kamloops planted in February 1962 represented the sole winter release of the entire study. The harvest of this group was virtually half that realized from plants made in the spring. Four groups of fish-of-the-year, one released in August and three released in October, were harvested at a uniformly low rate.

Shasta Rainbow

Of the domesticated strains, only the Shasta strain was harvested in significant numbers. However, there was substantial year-to-year variation (Table 3). In contrast with the Kamloops fingerlings, spring releases of Shastas generally gave poor results. Because Shasta eggs usually hatch in early March, they were only available from 16.0 to 9.0 per ounce in June

TABLE 2

Harvest ~~and Yield~~ of Kamloops Rainbow Fingerlings

Planted in Beardsley Reservoir, 1961 - 1966

Date	Number per ounce at release	Number planted	Number caught	Percentage caught of number planted	Pounds planted	Pounds caught	Pounds caught / Pounds planted	Cost per pound in the creel ($)
February 1962	3.5	15,000	1,467	9.8	267.9	843.4	3.1	~~1.72~~ 2.58
April 1963	1.5	10,000	1,821	18.2	416.7	878.0	2.1	~~1.66~~ 2.49
April 1964	2.2	10,000	2,341	23.4	284.1	1,072.0	3.7	~~1.14~~ 1.71
May 1963	1.0	10,000	2,474	24.7	625.0	1,198.6	1.9	~~1.48~~ 2.22
May 5, 1965	3.2	5,000	833	16.7	97.7	360.3	3.7	~~1.42~~ 2.13
May 24, 1965	2.8	5,000	881	17.6	111.6	389.3	3.5	~~1.40~~ 2.10
May 1966 1/	1.4	16,200	5,307	32.8	723.2	2,254.8	3.1	~~1.08~~ 1.62
June 1965	1.5	3,000	598	19.9	125.0	266.4	2.1	~~1.64~~ 2.46
August 1964	51.5	10,000	183	1.8	12.1	88.1	7.3	~~2.78~~ 4.17
October 1961	12.0	20,000	1,036	5.2	104.2	593.1	5.7	~~1.78~~ 2.67
October 1962	15.0	10,000	207	2.1	41.7	90.9	2.2	~~5.14~~ 7.71
October 1964	38.0	10,000	247	2.5	16.4	130.7	8.0	~~2.16~~ 3.24
Total or Mean		124,200	17,395	14.02	2,825.6	8,165.6	2.88	~~1.95~~ 2.93

1/ Does not include third-year returns.

TABLE 3

Harvest ~~and Yield~~ of Shasta Rainbow Fingerlings

Planted in Beardsley Reservoir, 1963 - 1966

Date	Number per ounce at release	Number planted	Number caught	Percentage caught of number planted	Pounds planted	Pounds caught	Pounds caught / Pounds planted	Cost per pound in the creel ($)
May 1965	30.0	10,000	620	6.2	20.8	217.2	10.4	0.75
June 1964	9.0	5,000	377	7.5	34.7	94.4	2.7	1.63
June 1965	16.0	10,000	973	9.7	39.1	360.9	9.2	0.62
June 1966 1/	14.0	10,000	671	6.7	44.6	237.9	5.3	1.03
July 1963	6.0	10,000	2,176	21.8	104.2	1,054.5	10.1	0.35
July 1964	4.5	5,000	187	3.7	69.4	57.6	0.8	3.70
July 16, 1965	6.2	10,000	1,554	15.5	100.8	566.8	5.6	0.65
July 30, 1965	4.6	10,000	1,900	19.0	135.9	691.3	5.1	0.61
July 1966 1/	5.0	10,000	635	6.4	125.0	266.6	2.1	1.51
August 1964	2.8	5,000	295	5.9	111.6	101.5	0.9	2.68
August 1965	2.5	10,000	1,710	17.1	250.0	593.8	2.4	0.96
August 1966 1/	3.9	10,000	541	5.4	160.3	220.2	1.4	2.08
September 1963	2.5	10,000	1,014	10.1	250.0	524.1	2.1	1.09
Total or Mean		115,000	12,653	11.0	1,446.4	4,986.8	3.44	1.36

1/ Does not include third-year returns.

compared with the more successful July and August releases which ranged from 6.2 to 2.5 per ounce. Comparing plants made in the same year, mid-summer releases tended to give better results than those released either earlier or later. Although they are at a larger size when released later in the season, conditions in the reservoir then may be less favorable for survival than earlier in the summer. The most successful Shasta group was harvested at a rate of 21.8%.

Whitney and Virginia Rainbow

Except for a single group, Whitney fingerlings gave uniformly poor results (Table 4). The exception was 10,000 fish at 20.0 per ounce (2.1 in FL) released in July 1963. Percentage harvests for the remaining nine groups averaged 2.5%. All groups were fish-of-the-year released from late July to mid-October.

The progressive increase in mean size of groups planted during the summer and fall was not accompanied by higher harvest rates. In fact, an inverse relationship between size at release and percentage harvest was indicated. Earlier plants gave decidedly superior results even though the fish doubled their size each month in the hatchery. This again suggests that there is no advantage to be gained by planting fingerlings later in the summer, even though they may be larger than those planted earlier.

Virginia strain fingerlings were least successful (Table 5), averaging only 4.2%.

Distribution of Total Catch by Year of Recovery

Of the total catch for any given group planted, the greatest number and weight almost always were recovered in the second year; i.e., the second calendar year of life in the reservoir (Table 6). Next highest returns, by both number and weight, were recorded during either the first or third years, depending upon the strain. Relatively few fish of any strain were caught

TABLE 4

Harvest ~~and Yield~~ of Whitney Rainbow Fingerlings

Planted in Beardsley Reservoir, 1961 - 1966

Date	Number per ounce at release	Number planted	Number caught	Percentage caught of number planted	Pounds planted	Pounds caught	Pounds caught / Pounds planted	Cost per pound in the creel ($)
July 1963	20.0	10,000	1,084	10.8	31.2	568.1	18.2	0.35
July 1964	18.5	10,000	160	1.6	33.8	73.7	2.2	2.81
July 1965	27.0	10,000	136	1.4	23.1	47.2	2.0	3.60
July 1966 1/	11.5	10,000	123	1.2	54.3	40.8	0.8	6.59
August 1962	10.5	10,000	407	4.1	59.5	113.2	1.9	2.49
August 1963	10.3	20,000	1,377	6.9	121.4	712.2	5.9	0.80
September 1961	9.6	20,000	943	4.7	130.2	464.6	3.6	1.28
September 1962	8.5	10,000	43	0.4	73.5	11.4	0.2	27.85
September 1963	5.0	10,000	163	1.6	77.4	75.4	1.0	5.22
October 1962	3.7	10,000	40	0.4	168.9	8.3	0.04	56.77
Total or Mean		120,000	4,476	3.7	773.3	2,114.9	2.73	10.78

1/ Does not include third-year returns.

TABLE 5

Harvest ~~and Yield~~ of Virginia Rainbow Fingerlings

Planted in Beardsley Reservoir, 1961 - 1964

Date	Number per ounce at release	Number planted	Number caught	Percentage caught of number planted	Pounds planted	Pounds caught	Pounds caught / Pounds planted	Cost per pound in the creel ($)
~~April 1961~~	~~2.5~~	~~25,000~~	~~2,628~~	~~10.5~~	~~625.0~~	~~1,304.1~~	~~2.1~~	~~1.10~~
April 1963	3.0	10,000	218	2.2	208.3	96.3	0.5	5.49
April 1964	2.8	10,000	619	6.2	223.2	134.5	0.6	4.05
Total or Mean		20 ~~45~~,000	837 ~~3,465~~	4.2 ~~7.7~~	431.5 ~~1,056.5~~	230.8 ~~1,534.0~~	0.5 ~~1.45~~	4.77 ~~3.55~~

TABLE 6

Mean Percentage Harvest of Planted Rainbow Trout in Beardsley Reservoir During Four Years of Liberty, 1962-1967

Strain	Mean no./oz. at release	Mean total percent harvest	Year 1		Year 2		Year 3		Year 4+	
			By number	By weight	By number	By weight	By number	By weight	By number	By weight
Kamloops										
Feb.-June	2.2	18.6	33.1	15.7	58.7	69.6	7.8	14.0	0.3	0.6
Aug., Oct.	29.1	2.9	0.0	0.0	32.6	20.2	57.3	65.6	10.0	14.2
Shasta	8.4	11.6	25.4	10.0	69.8	80.0	4.6	9.7	0.1	0.3
Whitney	12.6	3.5	7.8	1.8	79.8	72.8	11.3	21.9	1.1	3.5
Virginia	2.8	6.3	70.3	42.1	24.9	47.8	3.6	7.7	1.0	2.3

after the third year. Generally, fish released later in the season and/or at a smaller size were recaptured at a lower rate the first year. Releases made in 1966 were not included in this analysis, and fourth-year harvests for 1965 plants were considered zero.

Recoveries of yearling Kamloops planted from February to June were greatest in the second year (Table 6). Kamloops planted in August and October, too small to harvest in the first year, returned in greatest proportion the third year. Only 0.5% by number and 1% by weight represented four-year and older returns from Kamloops yearlings stocked in 1963 and 1964. Compared with Kamloops planted in the spring, relatively fewer Shastas were recaptured the year of release, more the second year, and about the same the third (Table 6). This can be attributed to Shastas being stocked at a smaller size and later in the year. Fourth-year recaptures of Shastas were the lowest of any strain.

Because of their small size at release, relatively few Whitneys were recaptured during their first calendar year in the reservoir (Table 6). Results were more variable than those for the Kamloops and Shastas, but much of this variability was causdd by high first-year returns from the July 1964 and August 1962 plants. Ignoring these two, recovery patterns for the remaining seven groups averaged 2.1% by number and 0.4% by weight in the first year and 88.3% by number and 78.1% by weight in the second year. Third- and fourth-year recoveries were highly variable. Proportionately more Whitneys were recaptured during the third and fourth years than either the Kamloops planted from February through June or the Shasta strains.

Harvest of Virginia rainbow was greatest in the first year, decreasing progressively through the fourth year (Table 6). Greatest numbers were harvested in the first year, while the recovery by weight was about equally distributed between the first and second years.

Pounds Harvested

Although the Kamloops were harvested at a greater rate than the Shastas, the latter displayed a higher average ratio of pounds caught to pounds planted (Tables 2 and 3). Even the Whitneys (Table 4) had a ratio of pounds caught to pounds planted nearly equal to that of the Kamloops. The ratio for the Virginias, however, was substantially lower than the others (Table 5). This suggests that the Shastas were able to utilize the "productivity" of the reservoir more efficiently than the Kamloops, since for each pound of both strains planted approximately ½ lb more of Shastas were harvested.

Cost

Costs per pound in the creel for Kamloops yearlings planted from April through June were quite uniform and ranged from $1.62 to $2.49. Costs for the remaining plants were higher and more variable. Costs per pound in the creel were less than $1.00 for six of the 13 groups of Shastas. Overall, these were the lowest of all strains. Costs fluctuated from a low of $0.35 to a high of $3.70 per pound. The cost to put a pound of Whitneys in the creel was extremely variable and tended to be quite high. The cost per pound of Virginias in the creel was $4.77 for the two groups tested.

Contribution to Boat and Shore Angling

The contribution of the Kamloops and domestic strains to the catch of boat and shore anglers was compared from 1964 through 1967 (Table 7). For all but one month of the fishing season during this period the catch per hour of Kamloops rainbow was higher for the boat fishermen than for the shore fishermen, while the catch per hour of the domestic rainbow was greater for boat fishermen only about half of the time. If we can assume that catch per effort was proportional to abundance, it would appear from the above data that

TABLE 7

Boat and Shore Angler Success Rates at Beardsley Reservoir for Planted Kamloops and Domestic Rainbow Trout, 1964-1967

Year	Angler category	Strains	April and/ or May	June	July	August	September	October
1964	Boat	Kamloops	0.183	0.072	0.028	0.060	0.152	0.142
		Domestics	0.354	0.150	0.047	0.072	0.128	0.157
	Shore	Kamloops	0.083	0.035	0.021	0.021	0.040	0.178
		Domestics	0.262	0.136	0.105	0.039	0.112	0.388
1965	Boat	Kamloops	0.068	0.038	0.039	0.068	0.152	0.233
		Domestics	0.029	0.024	0.025	0.035	0.058	0.372
	Shore	Kamloops	0.014	0.024	0.003	0.012	0.018	0.040
		Domestics	0.032	0.050	0.010	0.015	0.036	0.185
1966	Boat	Kamloops	0.122	0.087	0.149	0.153	0.485	0.298
		Domestics	0.402	0.127	0.089	0.061	0.079	0.212
	Shore	Kamloops	0.068	0.011	0.008	0.010	0.043	0.068
		Domestics	0.275	0.119	0.097	0.049	0.082	0.304
1967	Boat	Kamloops	0.213	0.058	0.089	0.067	0.261	0.264
		Domestics	0.127	0.045	0.031	0.028	0.019	0.015
	Shore	Kamloops	0.034	0.036	0.086	0.036	0.050	0.050
		Domestics	0.074	0.059	0.087	0.020	0.034	0.043

Kamloops occupy the open-water areas of the reservoir more than the littoral areas, while the domestic strains were distributed more equally between the littoral and limnetic zones. Unfortunately this is the only information we have relating to the distribution of the rainbow strains in the reservoir; therefore, these inferences are only tentative.

Emigration

Trout can leave reservoirs by ascending tributaries or by descending spillways or turbine intakes. Such emigration may seriously reduce the fishery. Therefore, it is important to know to what degree a particular strain of trout is apt to emigrate.

The only tributary to Beardsley Reservoir large enough to attract emigrating trout is the Middle Fork of the Stanislaus River, which the reservoir impounds. Anglers fishing the river upstream from the reservoir did not normally enter the Beardsley census. The few who did were boat anglers who beached their crafts and walked upstream, usually for only a short distance. Only an occasional marked fish sas recorded in the census of these anglers; therefore, it was not possible to estimate the degree of upstream emigration by each of the strains.

Downstream emigration was more evident, however, as anglers fishing the afterbay and the river below entered the census in considerable numbers. Beginning in 1965, all anglers fishing downstream were interviewed. More Kamloops than domestics were caught in the downstream areas than in the reservoir each year from 1965 through 1967 (Table 8). This is somewhat surprising, since considerably more domestic trout were planted than Kamloops. It indicates that Kamloops occurred in the downstream area in greater relative abundance than in the reservoir, and suggests that they emigrated from the reservoir at a greater rate than the domestic strains.

TABLE 8

Catch Per Hour of Four Strains of Rainbow Trout in Beardsley Reservoir and Downstream from Beardsley Reservoir, 1965-1967

Strain	1965		1966		1967	
	Reservoir	Downstream	Reservoir	Downstream	Reservoir	Downstream
Kamloops	.071	.036	.146	.014	.135	.149
Shasta	.044	.009	.209	.007	.053	.022
Whitney	.008	.006	.006	.001	.005	.003
Virginia	.003	.005	.000	.001	.000	.000
$\frac{C/h \text{ Kamloops}}{C/h \text{ domestics}}$	1.268	1.800	.679	1.556	2.328	5.960

Most downstream emigrants apparently passed over the spillway. Each year since 1962 water has discharged over the spillway in varying amounts and for varying lengths of time, usually during the spring with snowmelt runoff. Coincident with the onset of spill, marked trout caught in the afterbay were found to bear extensive bruises and badly frayed fins, apparently as a result of cascading down the concrete spillway. Furthermore, in 1965 and 1967, years of unusually heavy runoff, the catch per hour of marked trout in the downstream areas was substantially greater than in 1966 (Table 8), a year of below normal runoff.

We do not know whether any trout emigrated through the turbine intakes or what mortality they may have suffered if they did. The depth of the intake is so great, however, it is doubtful that trout were lost via this route.

MANAGEMENT IMPLICATIONS

Theoretically, planted fingerling trout should be able to serve as a supplement to recruitment in reservoirs where natural reproduction is insufficient to sustain a fishery for wild trout. We have seen, however, that the harvest of fingerling rainbow trout planted in Beardsley Reservoir can be influenced greatly by the strain planted. A small literature exists which suggests there are indeed important differences in the survival and growth in nature between wild and domestic trout. These differences are not completely clear, however. Green (1951) found little difference in the average harvest rates of wild and domestic fingerling eastern brook trout (Salvelinus fontinalis) planted ina a natural pond. He noted that the "wild" strain may have been influenced in the past by domestic genes. Flick and Webster (1964), however, showed that wild strains of brook trout had higher survival rates than domestic strains in two Adirondack ponds. When Mason, Brynildson and Degurse (1967) tested wild

and domestic brook trout and their hybrids in five Wisconsin streams, they found that the wild strain had the highest summer survival, while it had the highest overwinter survival in only one stream -- where there was permanent ice cover.

Smith (1957) took eggs from a wild strain of rainbow trout and raised them in a hatchery to the fry stage. He then transferred one group to a natural pond and raised another group in the hatchery. Both groups were planted in Corbett Lake, British Columbia, as fingerlings. He found no difference in either the survival or growth rates of the two groups. Repeating the experiment with another year class, he again found no difference in the survival rates, but the pond-raised fish had a higher growth rate than the hatchery-raised fish. Nelson, Reimers and Kennedy (1956) planted catchable domestic rainbow trout in Convict Creek, California, and found no difference between their survival and that of comparable size wild brown trout, except in unusually severe or protracted winters when the survival of domestic rainbow trout was lower.

These studies, although inconclusive, suggest that while survival of wild and domestic trout may be comparable in many situations, domestic trout ~~may~~ do more poorly than wild trout in environments that are particularly rigorous. Although the size of the non-game fish populations in Beardsley were not known, they appeared to be quite large. Thus, competition and predation by non-game fish may have exacted a greater toll of planted domestic trout than of Kamloops, leading to the differences we observed in their harvest rates.

The harvest of Whitney and Virginia strain rainbow was so markedly low, we are let to conclude that it would be best to avoid their use in cold-water reservoirs. The most successful strains of those tested, using the criteria we employed, were the Kamloops and Shastas. Kamloops were harvested in greatest numbers when planted in April and May at around 1.0 - 3.2 per

ounce (Table 3). If we compared only these most successful groups (Table 9) we find that Kamloops were harvested at a significantly greater rate than the Shastas, although the latter had a higher ratio of pounds caught to pounds planted and a lower cost per pound in the creel.

There appears to be certain characteristics possessed by the Kamloops, however, that make them less than ideally suited to coldwater reservoirs. These include their apparently greater tendency to emigrate from the reservoir and their predilection for open water areas of the reservoir. The latter decreases their availability to shore anglers. These are relatively minor problems, however, and we feel they will prove superior to domestic strains in a majority of situations.

Hatchery Problems

The wild characteristics that make Kamloops a superior strain in reservoirs, apparently makes them totally unsuited to the operations of California's trout hatcheries, geared for the mass production of catchable trout. They are slow growing, display a wide variation in size and require greater care and handling. These are characteristics which make them more costly, and which have been bred out of the domestic strains of rainbow trout. These problems, we believe, could be greatly reduced if a hatchery were designed to raise wild fish. The use of automatic feeders, graders and other equipment would lower handling costs and increase the growth rate in the hatchery, leading to lower overall production costs.

If Kamloops are not used, the best alternate would appear to be Shastas. Their performance could be improved, we believe, if they could be planted earlier in the summer or in the spring at a larger size than they are presently available. Moving the Shasta broodstock spawning time back to November and December may produce this desired change.

TABLE 9

Mean Values of the Best Groups of Kamloops and Shasta Rainbow Trout Tested in Beardsley Reservoir, and Results of T-Test

	Percent caught	Pounds caught / pounds planted	Cost per pound in the creel
Kamloops (n=6)	22.23	3.00	$2.04
Shasta (n=8)	11.85	3.55	$1.57
t	2.908*	0.468	1.015

* Significant at p = .05.