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Kamloops, Madison and Donaldson Strains of Rainbow Trout in an Oligotrophic Lake[1]

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ABSTRACT

Three rainbow trout (Salmo gairdneri) strains were stocked in an oligotrophic Minnesota lake to evaluate growth, survival and return to the creel. Donaldson and Kamloops strain rainbow trout grew to larger average sizes than Madisons. Differences in growth rates by strain, however, were

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not significant. Strain survival rates were highly variable and not significantly different. Kamloops returns to the creel were highest by number and weight and had the largest average size. Madisons were the most vulnerable to angling immediately after stocking. After age II, Kamloops and Donaldson strains provided similar average CPUE's which were higher than for Madisons. Angling success for Madisons and Donaldsons was highest in May while success for Kamloops peaked in July. Benefit:cost ratios of each strain were similar and favorable. Diets of the strains were similar with invertebrates predominating. Kamloops strain rainbow trout are recommended for stocking in Minnesota's oligotrophic lakes as a single strain or in combination with Donaldson or Madison rainbow trout in order of preference, respectively.

INTRODUCTION

Fish managers have observed varying field performances of different rainbow trout (*Salmo gairdneri*) strains. Varying rates of survival, growth and catchability have been reported (Close and Hassinger 1981; Brauhn and Kincaid 1982; Hudy 1980; Hudy and Berry 1983; Dwyer and Piper 1984; Thorn 1984). Several strains of rainbow trout are available for use by Minnesota Department of Natural Resources fish managers. We compared the field performance of three strains stocked in an oligotrophic lake.

The Kamloops strain rainbow trout grows rapidly and survives well. They are notoriously piscivorous in their native range (Behnke 1979) and have been found to be piscivorous in Minnesota (D. Ash, Minnesota Department of Natural Resources, personal communication 1985). The strain's rapid growth is primarily attributable to its piscivority (Larkin and Smith 1953). Kamloops trout disperse quickly after stocking, reducing immediate angling mortality and resulting in older, larger fish in the creel (Rawstron 1972). The strain has potential for "trophy" fisheries (Cordone and Franz 1968; Johnson 1978). Boat anglers are usually more successful than shore anglers at catching Kamloops because of the strain's preference for the limnetic zone (Cordone and Nicola 1970).

The Madison strain rainbow trout is the mainstay of Minnesota's hatchery and stocking program. It is easily cultured and is stocked in both lakes and streams. Acceptable angler returns and benefit:cost ratios resulted in the development of a stream trout lake reclamation program in the late 1950's utilizing the Madison strain (Micklus and Johnson 1965). High immediate angling mortality has been reported in Lake Superior (Close and Hassinger 1981).

Donaldson strain rainbow trout grow rapidly and tolerate temperature fluctuations well (Woods 1971). The strain was developed by Dr. Lauren Donaldson through 40 years of selective breeding (Donaldson and Olson 1955). Hatchery growth is rapid at relatively warm temperatures. In Minnesota, they are stocked primarily in lakes because of their rapid growth and catchability (Johnson 1978).

STUDY AREA

Trout Lake located in Cook County, Minnesota is an oligotrophic softwater lake (Schumacher 1961). The surface area is 104 ha and maximum depth is 23.5 m. Summer stratification occurs and the hypolimnion remains well oxygenated. The littoral zone comprises 23% of the total surface area. Water color is clear, resulting in a 5.8 m secchi disc transparency. The total alkalinity is 14 mg/l and pH is 6.9 (Heiskary and Helwig 1983). The lake has two intermittent inlets and an outlet which is the headwaters of Kadunce Creek. A filter barrier on the outlet prevents fish emigration.

The Trout Lake watershed is a largely undeveloped mixed hardwood-conifer forest on a thin layer of glacial till with bedrock outcrops (Minnesota Division of Waters 1966). One resort (seven cabins) and three private cabins are located along the south shore line. Boating access is via a well developed resort launch and a primitive public access for canoes and small boats on the north shore. Trout Lake has been managed for salmonids with rainbow trout having been stocked since 1949. Lake trout (*Salvelinus namaycush*) were stocked from 1949-1967 and the population has remained stable since stocking was terminated.

Other species present include cisco (*Coregonus artedii*), yellow perch (*Perca flavescens*), white sucker (*Catostomus commersoni*), rainbow smelt (*Osmerus mordax*), sculpin (*Cottus* spp.) and minnows.

METHODS

Rainbow Trout Plants

Yearling rainbow trout cohorts were planted during early summer in 1977, 1979, 1981 and 1982 (Table 1). Unequal numbers of each strain were stocked in 1977. Stocking rates were equalized at 5,000 fish of each strain beginning in 1979. Donaldson strain rainbow were unavailable for stocking in 1981. Madison strain were progeny of captive broodstock and were reared

Table 1. Number of yearling rainbow trout stocked in Trout Lake, 1977-1982. Size at stocking (number/kg) is in parentheses.

	Year Stocked			
Strain	1977	1979	1981	1982
Kamloops	2,456 (17.6-24.3)	4,897 (23.4)	5,005 (34.0)	5,014 (13.4)
Madison	2,000 (11.0)	5,000 (17.0)	5,005 (14.3)	5,005 (15.4)
Donaldson	500 (3.5)	5,003 (15.2)	[a]	5,014 (11.9)

[a] Donaldson strain rainbow trout were unavailable for stocking.

at Lanesboro State Fish Hatchery. Kamloops and Donaldson rainbow were progeny of semi-wild broodstock in Lake Superior, and excepting the 1977 cohort, were reared at French River Coldwater hatchery. Donaldsons stocked in 1977 were reared at Spire Valley Fisheries Station. Before stocking, strains and cohorts were marked with similar but unique fin or maxillary bone clips.

Spring Trap Netting

The Trout Lake rainbow trout population was assessed annually by trap netting from 1978-1985. Netting began immediately after ice-out (usually the first week of May) and continued 2-4 weeks until the trap net catch per unit of effort (CPUE) became negligible (0.2 fish/d or less). Trap nets of 13 mm bar measure mesh were set at 10 index locations around the perimeter of the lake and lifted at 1 to 3 d intervals. Strain and cohort were determined by mark identification. Total length (mm) and weight (g) were obtained after anesthetization. Fish were then marked with either a floy tag (1978-1983) or a dorsal fin punch (1984-1985) (Wydoski and Emery 1983) and released.

Annual trap net data were used to calculate mean survival (S) and instantaneous total mortality (Z) rates for each strain and cohort. Average total lengths at age and Fulton's coefficient of condition (K_{tl}) were calculated for each strain and cohort (Ricker 1975).

Creel Census

Census data were used to estimate fishing effort (angler trips), pressure (angler hours), total salmonid harvest, rainbow trout CPUE, rainbow trout harvest and condition coefficient by strain and cohort. Summer creel surveys were conducted from 1977 through 1984 to evaluate the rainbow trout fishery from mid-May through September. All anglers accessing the lake at Trout Lake Resort were tallied and interviewed as they left. Census totals from 1979-1981 were increased by 20% to account for fishing effort originating from the public access. A stratified random sampling census

(Mendenhall et al. 1971) was conducted at the public access during 1982 following improvement of the road to the access. Fishing effort from the public access during 1983-1984 was monitored using a vehicle counter. The winter fishery was monitored during 1978-1982 by a complete census at the resort. A stratified random sampling census was utilized during the winters of 1983 and 1984. Census information recorded included: number of anglers per party; length of fishing trip; harvest by species; and individual fish lengths, weights, marks and tags.

Benefit:Cost Ratios

Average benefit:cost ratios were developed for each strain by comparing economic benefit derived from angler expenditures to production and distribution costs of rainbow trout. Annual angler expenditures were calculated as the product of fishing effort and the $26 average angler trip expenditure (U.S. Dept. Interior, Fish and Wildlife Service and U.S. Dept. Commerce, Bureau of Census 1982). Strain-specific benefits were calculated by multiplying the annual economic benefit of angler expenditure by the percent composition of each strain in the total harvest.

Food Habits

Contents of 113 rainbow trout stomachs (61 Kamloops, 14 Madison, 38 Donaldson) obtained from 1982-1984 were examined to indicate the food habits of each strain. Total food volume in each stomach was measured by water displacement and food items were identified to taxonomic order (Lagler 1956). The estimated percent volume and occurrence were calculated for each order.

Statistical Treatments

Statistical analyses were utilized to evaluate relationships of data sets. Average length at age and condition factors of each strain and cohort were compared using Student's t-test. The Kruskall-Wallis rank test was used to test the relationships between survival, stocking size and strain (Hollander and Wolfe 1973). The relationships of growth increment or annual harvest to cohort, strain and other potentially influential factors were examined by stepwise regression modeling. Strain and cohort were introduced into each model using indicator variables (Weisberg 1980). Null hypotheses were tested at the 0.05 level of significance.

RESULTS

Growth and Condition

Kamloops and Donaldson strain rainbow trout grew to a larger average size at age than Madisons (Table 2). The average length in the 1979 Madison cohort was significantly smaller than Donaldsons at Age IV while Kamloops and Donaldsons were not significantly different. The 1982 cohort of

Table 2. Average total length (mm) at age of rainbow trout of various strains in Trout Lake. Average lengths are followed by their 95% confidence intervals and the sample size (in parentheses).

		Age			
Cohort	Strain	I[a]	II	III	IV
1979	Kamloops	147	286 ± 5 (61)	339 ± 3 (63)	370 ± 11 (9)
	Madison	178	293 ± 3 (93)	336 ± 4 (60)	358 ± 7 (19)[b]
	Donaldson	165	289 ± 3 (74)	337 ± 4 (37)	378 ± 8 (18)
1981	Kamloops	128	274 ± 4 (55)	318 ± 10 (10)	391 ± 51 (2)
	Madison	186	298 ± 3 (55)	323 ± 8 (15)	368 ± 35 (2)
1982	Kamloops	197	282 ± 1 (286)	360 ± 5(22)	436 ± 20 (10)
	Madison	158	275 ± 3 (57)	404 (1)	(0)
	Donaldson	187	293 ± 2 (179)[c]	358 ± 10 (12)	(0)

[a] Average length when stocked.
[b] Significantly smaller than Donaldsons at 0.05 level.
[c] Significantly larger than Madisons and Kamloops at 0.05 level.

Donaldsons had a significantly larger average length than the other strains at age II but by age III the difference between Kamloops and Donaldsons was not significant. Madisons were the largest when stocked in 1979 and 1981 but the smallest at age IV.

Size at stocking was the most important variable in determining growth rate. Growth increments were modeled by stepwise regression as a function of size at stocking as well as cohort and strain (Table 3). Growth was inversely related to size at stocking (R^2 = 0.662). Addition of the cohort variable improved the model (R^2 = 0.967) but adding strain did not help to explain the variation in growth (R^2 = 0.968).

Table 3. Average annual and total growth increments (mm) of Kamloops, Madison and Donaldson strains rainbow trout in Trout Lake. Sample size is in parentheses.

Kamloops cohort	Average size at stocking	Growth Increment at Age II	III	II & III	IV	Total
1979	147	139 (61)	53 (63)	192	31 (9)	223
1981	128	146 (55)	44 (10)	190	73 (2)	263
1982	197	85 (286)	78 (22)	163	76 (10)	239
Madison cohort						
1979	178	115 (93)	43 (60)	158	22 (19)	180
1981	186	112 (55)	25 (15)	137	45 (2)	182
1982	158	117 (57)	129 (1)[a]	[a]	[a]	[a]
Donaldson cohort						
1979	165	124 (74)	48 (37)	172	41 (18)	213
1982	187	106 (179)	65 (12)	171	[a]	[a]

[a] Inadequate sample size.

Some differences were noted in the condition factors of the three strains. Spring condition coefficients of the 1981 and 1982 Kamloops cohorts were significantly greater than those of Madisons and Donaldsons, which were similar (Table 4). No consistent significant differences were observed in the summer condition factors of the three strains. Average Madison K factors, however, were greater than those of corresponding Kamloops. Growth and condition data were unavailable for the 1977 cohort.

Table 4. Mean spring and summer coefficient of condition (K_{tl}) of rainbow trout of various strains stocked in Trout Lake and captured during spring test netting and the summer sport fishery, 1979-1984 with 95% confidence intervals.

Strain	Cohort 1979	Cohort 1981	Cohort 1982
		SPRING	
Kamloops	0.88 ± 0.02	0.91 ± 0.03[a]	0.80 ± 0.01[a]
Madison	0.88 ± 0.02	0.85 ± 0.03	0.77 ± 0.02
Donaldson	0.89 ± 0.03	[b]	0.77 ± 0.01
		SUMMER	
Kamloops	1.02 ± 0.04	0.94 ± 0.05	0.99 ± 0.02
Madison	1.08 ± 0.06	0.98 ± 0.04	1.01 ± 0.10
Donaldson	1.08 ± 0.03	[b]	0.98 ± 0.03

[a] Significantly larger than Madison and Donaldson at 0.05 level.
[b] Information was unavailable.

Survival

Rainbow trout survival was highly variable. The 1977 Kamloops, Madison and Donaldson cohorts survived at average rates of 39%, 49% and 0%, respectively (Table 5). Mean annual survival of cohorts planted after 1977 ranged from 25% for 1982 Kamloops to 7% for 1982 Donaldsons. Instantaneous total mortality rates of the three strains were not significantly different and there was no significant correlation between size at stocking and relative survival.

Table 5. Mean survival (S) and instantaneous total mortality (Z) rates of various strains and cohorts of rainbow trout stocked in Trout Lake.

	Cohort			
Strain	1977	1979	1981	1982
Kamloops				
S	0.39[a]	0.17[a]	0.15[a]	0.25[b]
Z	0.94	1.78	1.89	1.39
Madison				
S	0.49	0.13[b]	0.15[b]	0.16[a]
Z	0.71	2.04	1.88	1.83
Donaldson				
S	0.0[b]	0.16	-	0.07
Z	-	1.82	-	2.64

[a] Smallest average size when stocked.
[b] Largest average size when stocked.

Angler Harvest

Kamloops had the highest overall angler return rate (Fig. 1) with Kamloops and Donaldson returns averaging 16% and 13%, respectively, when stocked together. Madison returns averaged 7% for all cohorts. Kamloops

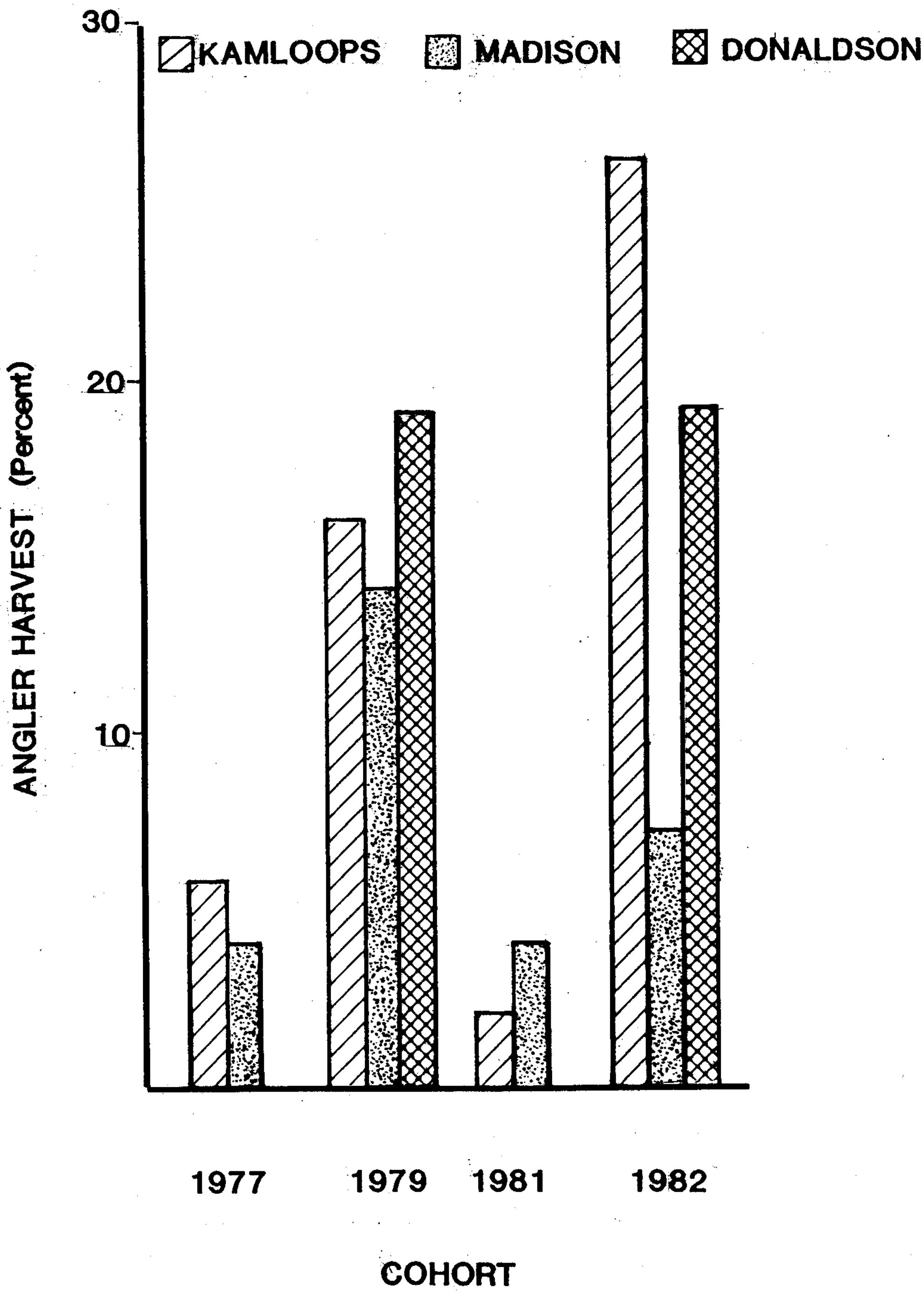

Figure 1. Percent harvest of cohorts of three strains of rainbow trout stocked in Trout Lake.

also yielded the greatest average return by weight (0.7 g/g stocked) and Madisons the lowest (0.3 g/g stocked) (Fig. 2). Creeled Kamloops averaged 302 g, Donaldsons 198 g and Madisons 165 g (Table 6). The rainbow trout winter harvest was negligible (0 to 39 fish) except in 1983 when 399 Kamloops, 305 Madisons and 47 Donaldsons were caught.

Table 6. Average weight (g) of harvested rainbow trout strains and cohorts harvested in the Trout Lake summer sport fishery, 1979-1984 with 95% confidence intervals.

	Cohort		
Strain	1979	1981	1982
Kamloops	299 ± 34	303 ± 41	305 ± 27
Madison	161 ± 9	152 ± 25	181 ± 20
Donaldson	172 ± 12	---	224 ± 15

Annual harvest of each strain was modeled by stepwise regression as a function of preseason abundance, preseason average total length, year, age, and season angling effort, as well as cohort and strain. Preseason abundance was the most important variable explaining harvest variation (R^2 = 0.737). Addition of the body size variable improved the model (R^2 = 0.804) and the relationship was inverse (large fish were less catchable). Strain improved the model somewhat (R^2 = 0.807) but was relatively unimportant. Addition of the other variables did not improve the model.

Angler catch rates differed for the three strains. Kamloops catch rates typically peaked one year after planting, while Madisons were generally most vulnerable immediately following stocking (Fig. 3). Catch

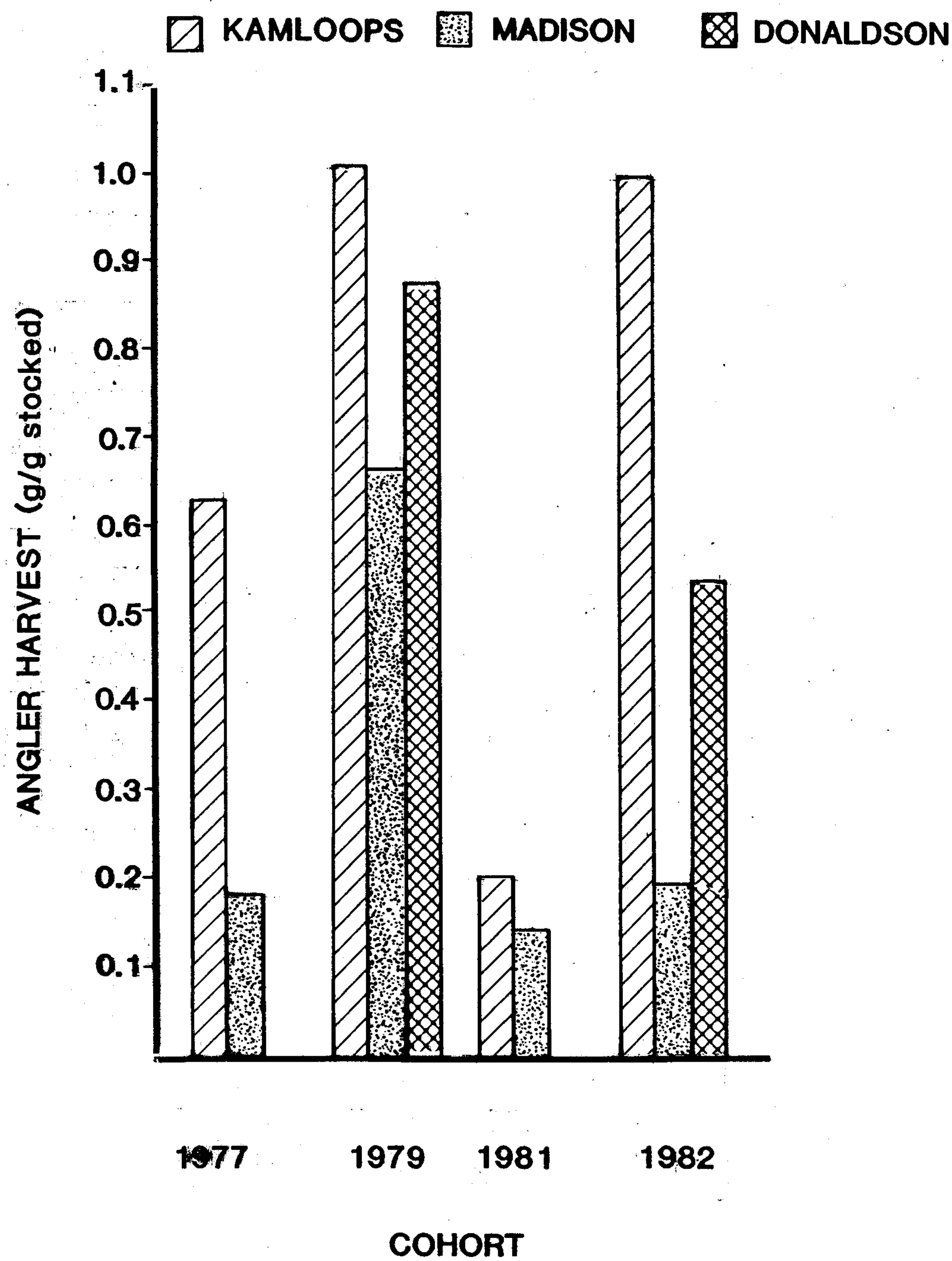

Figure 2. Relative harvest (g harvested/g stocked) of cohorts of three strains of rainbow trout in Trout Lake.

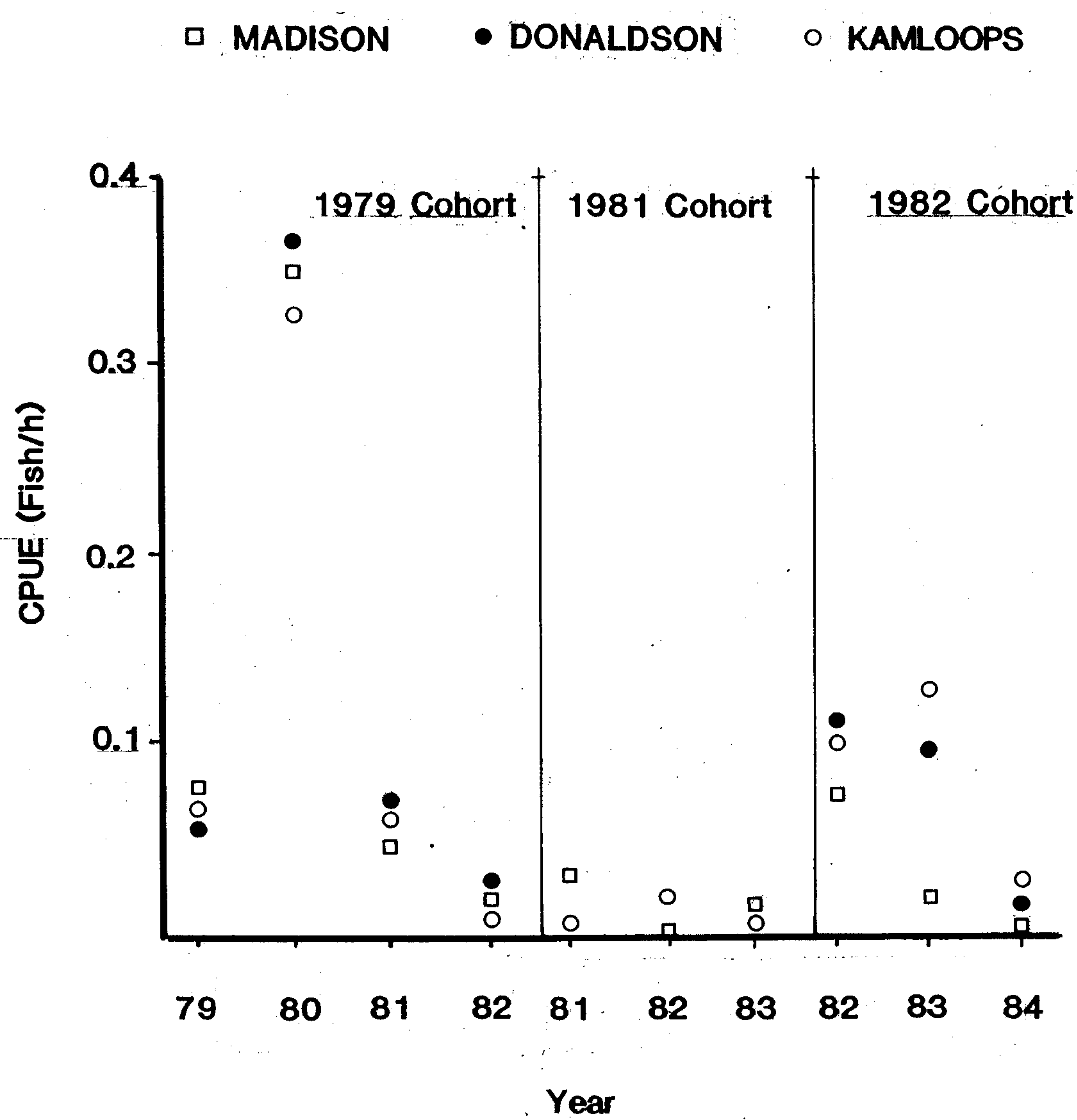

Figure 3. Average annual CPUE for cohorts of three strains of rainbow trout in the Trout Lake sport fishery, 1979-1984.

rates of age II and older Madisons were lower than those of Kamloops and Donaldsons, which were similar. During the summer fishing season, Madison and Donaldson catch rates were highest in May and declined thereafter while Kamloops catch rates did not peak until mid-July (Fig. 4).

Benefit:Cost

Average benefit:cost ratios were similar and favorable at 5.5:1 for Donaldsons, 5.1:1 for Madisons and 4.8:1 for Kamloops. Total estimated angler expenditure from 1979-1984 was $211,222 with $120,939 (57%) attributable to the rainbow trout fishery (Table 7). Since production costs were unavailable for the 1977 cohort, harvest and production data for that cohort were omitted from the benefit:cost analysis.

Food Habits

All three strains fed actively during the summer with over 92% of the examined stomachs containing food. Aquatic insects, particularly odonates and trichopterans, predominated in the diets (Table 8). Chironomids were common though rarely abundant. Fish comprised a minor portion of the diet, accounting for less than 10% of the food volume of each strain.

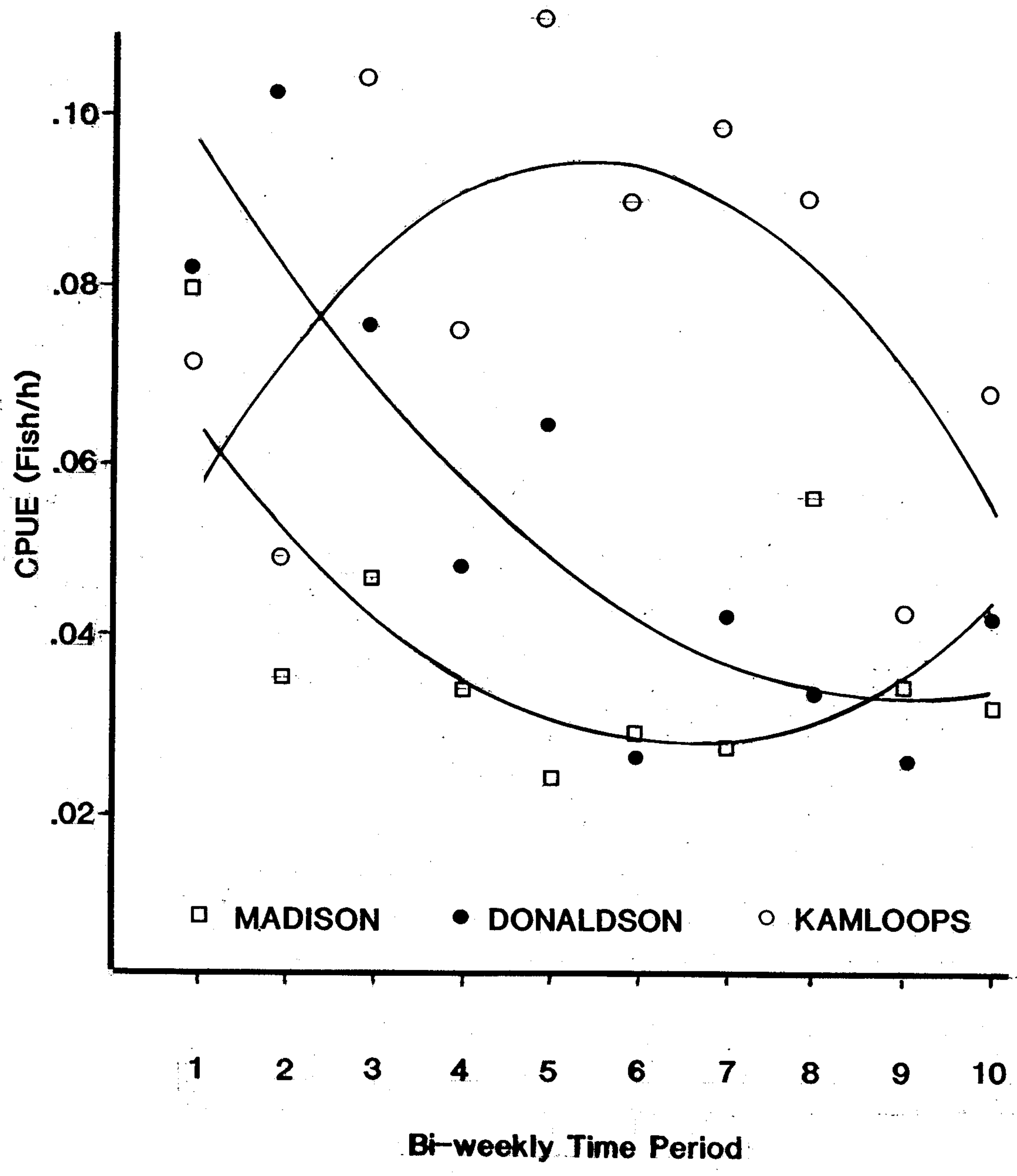

Figure 4. Average biweekly CPUE of three strains of rainbow trout, age 2 and older, in the May-September sport fishery of Trout Lake, 1980-1984. Lines were fitted to the parabolic function by least squares regression.

Table 7. Estimated angling effort, angler expenditures and production costs of rainbow trout stocked in Trout Lake, 1979-1984.

	Census Year						
	1979	1980	1981	1982	1983	1984	Total
No. angler trips	658	1,270	736	2,259	1,334	1,860	8,117
Total expenditures ($)	17,108	33,020	19,136	58,734	34,864	48,360	211,222
Percent of stocked RBT in catch[a] (%)	52.3	66.0	71.8	78.8	70.0	12.0	---
RBT expenditures ($)	8,956	21,791	13,746	46,255	24,388	5,803	120,939
Expenditures by strain ($):							
Kamloops	3,145	7,307	3,731	18,821	12,226	4,680	49,910
Madison	3,332	6,453	5,549	12,585	3,108	0	31,027
Donaldson	2,479	8,031	4,466	14,849	9,054	1,123	40,002
Planting Costs ($):		b			b	b	
Kamloops	2,825		3,188	4,447			10,460
Madison	2,356		1,827	1,909			6,092
Donaldson	2,032		--	5,199			7,231

[a] Includes only rainbow trout stocked after 1977 during this study.
[b] Fish not stocked this year.

Table 8. Summer food of age II and older rainbow trout by strain in Trout Lake, 1982-1984.

	Kamloops (N=61)		Madison (N=14)		Donaldson (N=38)	
Food type	% total volume	% occurrence	% total volume	% occurrence	% total volume	% occurrence
Cladocera	3.3	35.7	2.6	15.4	1.3	15.8
Mysidacea	0.8	7.1	0	0	1.2	5.3
Amphipoda	2.1	3.6	0	0	Trace	2.6
Ephemeroptera	1.2	7.1	0.9	15.4	9.4	26.3
Odonata	45.2	26.8	0	0	21.6	21.1
Orthoptera	0.9	3.6	0	0	0	0
Hemiptera	6.3	21.4	0	0	0.1	5.3
Coleoptera	6.6	19.7	1.2	23.1	1.0	5.3
Trichoptera	18.4	16.1	21.0	46.2	43.0	31.6
Diptera	5.2	42.9	64.4	100.0	10.1	65.8
(Chironomidae)	(5.2)	(39.3)	(19.1)	(53.8)	(9.2)	(52.6)
Hymenoptera	Trace	5.4	0	0	0.1	2.6
Unid. Insecta	0.5	16.1	3.7	15.4	0.5	5.3
Gastropoda	0.1	3.6	0	0	7.9	7.9
Pelecypoda	Trace	1.8	0	0	0	0
Acarina	Trace	1.8	0	0	Trace	2.6
Unid. Fish	9.4	7.1	6.2	7.7	3.8	5.3

DISCUSSION

Kamloops and Donaldsons have the inherent potential to be larger than Madisons at the same age. Since angler perception of trip quality increases as average size of creeled fish increases (Weithman and Anderson 1978), Kamloops and Donaldsons may provide greater angler satisfaction than Madisons. Significant differences in strain-specific growth, however, were not observed in Trout Lake. Rather, size at stocking was the most important growth rate variable. The inverse relationship between growth rate and size at stocking may indicate size-dependent mortality or compensatory growth. Small size is detrimental when fish compete for food and decreased fitness and higher mortality often result (Werner 1979). Growth rate statistics of cohorts with smaller average size at stocking may have been inflated because only the largest and most vigorous individuals survived. If size-dependent mortality occurred, we failed to detect it due to confounding variables. Our findings, however, were consistent with those of Hudy (1980). An alternate possibility is that the smaller fish actually grew faster; an effect described by Ricker (1975) as growth compensation.

The superior creel return of Kamloops in Trout Lake is particularly significant because Kamloops were also the largest fish in the creel. In many fisheries, average size of fish in the creel decreases as angler return increases. Kamloops, for example, provided superior angler return by number in Beardsley Reservoir, California but Shasta strain rainbow planted at the same time yielded larger fish to the creel (Cordone and Nicola 1970). Trout Lake Kamloops strain performed best by both measures.

Angler satisfaction increases as the number of fish in the creel increases (Bonde 1961; Duttweiler 1976; Weithman and Anderson 1978; Hicks et al. 1983). In Trout Lake, a strain's ability to survive (preseason abundance) was the most important factor in determining its contribution to the sport fishery. Although strain survival rates were not significantly different due to the high variability, Kamloops had the highest angler return suggesting that the strain had the highest survival and lowest natural mortality. In addition, despite comparable growth and CPUE's of all three strains in Trout Lake, Kamloops were consistently the largest in the creel, also suggesting superior survival. The Kamloops strain has shown exceptional survival in other lakes (Cordone and Franz 1968; Cordone and Nicola 1970; Rawstron 1972; Rawstron 1973).

Madison strain rainbow trout should be stocked if a short term increase in CPUE and fish size is of secondary importance. The Madison strain provided the highest first year CPUE and lowest CPUE after age II, indicating greater immediate vulnerability to angling. Close and Hassinger (1981) found similar immediate Madison vulnerability in Lake Superior. Dwyer and Piper (1984) concluded that domestic strains were more catchable than wild strains and the semi-wild parentage of the Kamloops and Donaldsons may explain their lower immediate vulnerability.

Fishing success may be prolonged by stocking two or more strains simultaneously. Donaldsons provided the highest early season and Kamloops the highest mid-season catch rate. Stocking both strains may provide the best fishing over the longest time.

Benefit:cost ratios were similar primarily because production costs of Madisons were lower. Rearing Kamloops at other state hatcheries with lower production costs would yield higher ratios.

Diet analyses did not show extraordinary fish consumption by any of the strains. Growth was slow, however, and samples of trout large enough to prey on fish were small. In the future, diet data should be collected from specimens larger than 500 g.

Strain performance may have been influenced by different health or condition of the fish when stocked. Rearing condition and transportation stress may have a profound impact on field performance (Burrows 1969; Eipper 1963; Hosmer et al. 1979; Pitman 1979). Hatchery records indicate that our stocked fish were in good health but incipient disease is always possible. Future investigators should eliminate these confounding variables so that only variation due to strain is evaluated. Babey (1982) suggests the use of a "control or reference strain to help define environmental effects..." and a health evaluation of fish at stocking (Goede, In Press). We also recommend that all strains be hatched, reared (same hatchery) and stocked under identical conditions. Evaluations in other areas of the state are necessary to determine strain performance in a variety of environments (Hudy 1980).

Future studies utilizing CPUE's to evaluate survival should use water temperature to determine the sampling interval. We found surface temperatures too variable to measure the vulnerable period so we netted until catches were negligible. Future investigators should establish a benchmark temperature at a depth of at least 2 m. Netting should start at ice-out and stop when the benchmark temperature is exceeded by at least 1 C for two or more days.

MANAGEMENT IMPLICATIONS

Strain selection is a viable management tool which may assist in meeting specific objectives. To increase the average size of creeled fish or to create a "trophy" fishery in oligotrophic waters, we recommend the Kamloops strain if available at favorable cost. Donaldson is the next best choice. Special regulations to reduce harvest may be necessary to realize the Kamloops' growth and survival potential unless angling pressure is very low. Combined stocking of Kamloops and one of the other strains can be used to balance early and late season angling success.

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