F-13-1

North American Journal of Fisheries Management 7:91–105, 1987

Effects of Stocking Catchable-Size Hatchery Rainbow Trout on Two Wild Trout Species in the Madison River and O'Dell Creek, Montana

E. RICHARD VINCENT

Montana Department of Fish, Wildlife and Parks, 8695 Huffine Lane
Bozeman, Montana 59715, USA

Abstract.--The fall population of 2-year-old and older wild brown trout (*Salmo trutta*) more than doubled (160% increase), in both total numbers and biomass, 4 years after the last catchable-size hatchery rainbow trout were stocked in the Varney section of the Madison River, Montana; wild rainbow trout (*Salmo gairdneri*) numbers increased eight times (868%) and their biomass increased 10 times (1,016%) during the same period. Brown trout biomass peaked within 2 years after stocking ceased, whereas wild rainbow trout biomass continued to increase for 4 years. Numbers of wild brown and rainbow trout 10.0–17.9 in long showed the greatest increases after stocking ceased. Flow variations had little effect on the total biomass of 2-year-old and older wild trout during stocking years ($t = 1.24$), but stocking had a significant negative correlation ($r = -0.953$) with total biomass. When catchable-size hatchery rainbow trout were stocked for three consecutive years into a previously unstocked section of O'Dell Creek, Montana, the 2-year-old and older wild brown trout population was reduced 49% in total number and biomass. Wild brown trout 10.0–17.9 in long showed significant declines in numbers after stocking was initiated, whereas those smaller than 10.0 in showed no significant change in numbers. A temporary decline in growth rates of yearling through 4-year-old brown trout was observed in O'Dell Creek during the first 2 years of stocking. Measurable movement of marked wild trout in the lower (stocked) section of O'Dell Creek accelerated during years of stocking. Stocking of catchable-size hatchery rainbow trout had no detectable adverse effect on wild brown trout through their first 18 months of life in either lower O'Dell Creek or the Varney section of the Madison River.

The use of hatchery-reared, catchable-size trout to supplement existing wild stream-dwelling trout populations has been an accepted fisheries management practice. However, little attention has been given to any effects stocking had on the wild trout. Some studies have examined stresses on hatchery trout stocked in trout streams. Miller (1958) found that hatchery trout lost weight and had high initial mortality when stocked in sections of George Creek, Alberta, with resident wild cutthroat trout (*Salmo clarki*). He attributed these losses to stress from social struggles between hatchery and resident wild trout. Shetter (1947), Brynildson and Christenson (1961), and Mason et al. (1967) found higher survival of stocked hatchery trout in streams with the lowest numbers of wild trout, which suggested detrimental social interaction with wild trout.

This study was conducted in 1967–1976 to evaluate the effect of stocking catchable-size, hatchery-reared rainbow trout (*Salmo gairdneri*) into two Montana streams supporting self-sustaining wild brown trout (*Salmo trutta*) and wild rainbow trout populations. The primary objectives of the study were to determine: (1) if wild trout populations were affected by stocking; (2) what size or age-groups, if any, were affected; and (3) if stocking did have adverse effects, what the length of the recovery period was after stocking was discontinued. Other factors examined were growth, mortality, movement, angling pressure, and flow levels.

Prior to 1948, little annual stocking of hatchery-raised trout occurred in the Madison River and O'Dell Creek because wild brown and rainbow trout were able to sustain a fishery via natural reproduction. From 1948 to 1954, stocking was limited to small (2–5-in-long) brown and rainbow trout in both the Madison River and O'Dell Creek. The first catchable-size (8–12-in) rainbow trout were stocked in 1955. By 1969, annual stocking had increased to an average of 1,600 fish/mi for the 51-mi section of the Madison River from Quake Lake to Ennis Reservoir (Figure 1). Catchable-size fish were stocked monthly from April through August with some stream reaches receiving more fish than others due to more favorable access. Stocking was discontinued in the 6-mi section from Varney bridge to Burnt Tree in 1970 and in the remaining 45 mi of the middle Madison River in 1974. From 1955 to 1964, O'Dell Creek received a small number of catchable-size rainbow trout.

From wild trout population estimates for the Norris and Varney study sections, estimated total

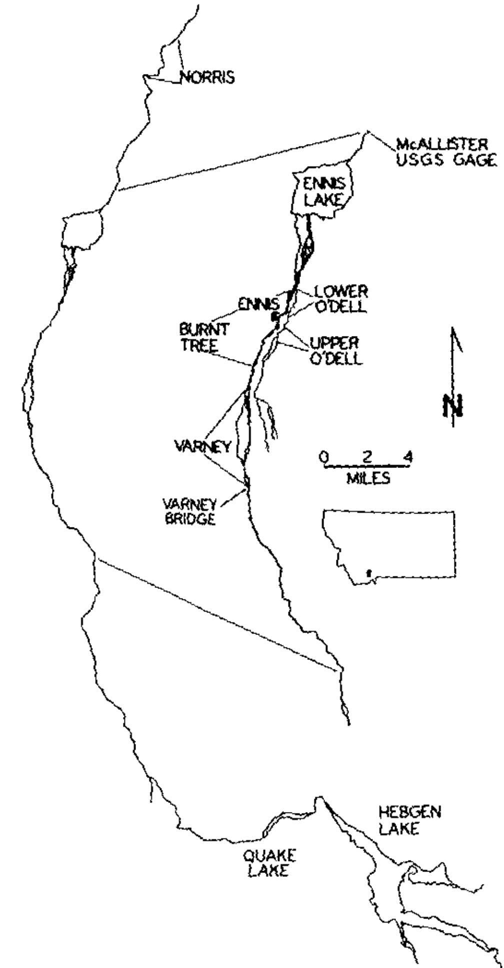

FIGURE 1.—Map of the Madison River and O'Dell Creek study areas.

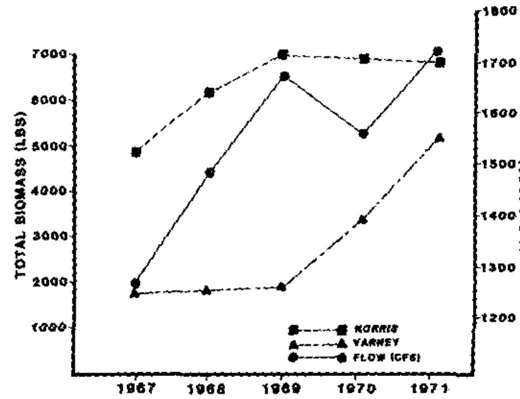

FIGURE 2.—Comparison of mean winter (December 1–April 30) flow (cubic feet per second) to estimated total biomass (lb) of 2-year-old and older wild brown and rainbow trout in each of two sections of the Madison River, 1967–1971. Norris estimates were made in April, Varney estimates in September.

biomasses (lb/4-mi section) of 2-year-old and older wild brown and rainbow trout were compared with mean winter flows (December 1–April 30) preceding the estimates (Figure 2). April estimates for the Norris section showed that, as the mean winter flow increased from 1967 to 1969, the total pounds of wild trout increased. However, September estimates of wild trout biomass from the Varney section showed no appreciable change. A correlation between mean winter flow and total biomass (lb/mi) showed that mean winter flow fluctuations accounted for 87% ($r = 0.9347$) of the variation in wild trout biomass in the Norris section, but only 34% ($r = 0.583$) of the variation in the Varney section. The correlation was significant ($P < 0.05$) for the Norris section ($t = 4.55$), but not significant for the Varney section ($t = 1.25$). Some factors other than flow must have been controlling wild trout biomass in the Varney section. Overharvest of larger trout by anglers was ruled out as one of the factors due to lower (18%) angler use in the Varney section (Vincent 1969a). One major difference between the sections was that the Varney section had been stocked annually since 1955 with catchable-size rainbow trout, whereas the Norris section had received none after 1960.

Study Area

Madison River.—The Madison River originates in Yellowstone National Park with the junction of the Gibbon and Firehole rivers in Wyoming. It enters Montana via the northwestern corner of the park, then flows 120 mi in a northerly direction before joining the Gallatin and Jefferson rivers to form the Missouri River. Its total drainage area is approximately 2,500 mi².

Fish native to the Madison River are cutthroat trout, Arctic grayling (*Thymallus arcticus*), mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catostomus platyrhynchus*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), longnose dace (*Rhinichthys cataractae*), and mottled sculpin (*Cottus bairdi*). Brown trout, rainbow trout, and brook trout (*Salvelinus fontinalis*) were introduced into the Madison River during the late 1800s. Utah chub (*Gila atraria*) was introduced into Hebgen Reservoir by fishermen in the 1930s and subsequently gained access to the Madison River.

Two 4-mi-long study sections were established on the Madison River: Varney, 41 mi downstream from Quake Lake; and Burnt Tree, 1.5 mi downstream from the lower boundary of the Varney section (Figure 1). These two study sections were located within a reach of river characterized by a braided channel with long riffles interspersed with fast runs and a few pools having maximum depths of 7 ft. The average stream width was approximately 200 ft and the average stream gradient was 30 ft/mi. Woody vegetation covered much of the banks and undercut areas provided good cover for trout. The streambed consisted of large- to medium-size rocks with ample areas of smaller spawning-size gravel. The average annual discharge at the U.S. Geological Survey McAllister gage (9.7 mi below the end of the Burnt Tree section) was 1,400 ft^3/s, with peak flows near 5,000 ft^3/s in June and a low flow of about 1,000 ft^3/s for the winter months of December–March (U.S. Geological Survey 1966–1975).

O'Dell Creek.—O'Dell Creek, a tributary to the Madison River, originates near Varney bridge and flows northward, parallel to the Madison, for approximately 10 mi. The primary water source is a series of springs emerging along the east side of the Madison River. It has a very sinuous riffle–pool channel that flows through the brushy Madison River floodplain. Flows are usually very stable (approximately 100 ft^3/s) except during some winter periods when ice gorging on the Madison River diverts some water into the O'Dell channel. Because of its more stable flows and lower gradient (20 ft/mi), the streambed has a much finer substrate than the Madison River.

Fish native to O'Dell Creek are the same as those found in the Madison River. Nonnative game fish found in O'Dell Creek include brown, rainbow, cutthroat, and brook trout. The bushy undercut banks and overhanging vegetation provide ideal habitat for brown trout, the predominant species.

Two study sections were established on O'Dell Creek. The lower section, ending 0.5 mi from the mouth, was 1.8 mi long; the upper section was 1.0 mi long. The average channel width was 25 ft for the upper section and 35 ft for the lower section; maximum depths reached 8 ft.

Methods

Population estimates were made in the spring (April–May) and fall (September) for each study section when possible. Fish were sampled from an electrofishing boat floating through the study section. The boat contained a stationary negative electrode, a mobile positive electrode, a portable 2,500-W AC generator with a rectifying unit, and a live box to retain captured fish. Captured fish were weighed periodically to the nearest 0.02 lb, measured to the nearest 0.1 in, marked, and released within the study section. Fish were marked either with a partial fin clip or tagged with a numbered Floy anchor tag.

Population estimates were made by the Peterson mark-and-recapture method with an adaptation of formula 4 of Ricker (1958). The multiple mark-and-recapture method was used in the Madison River estimates, where the daily trip capture efficiencies ranged from 5 to 7%. The single mark-and-recapture method was used in O'Dell Creek where daily trip capture efficiencies ranged from 25 to 35%. A 7–14-d interval was allowed between marking and recapture periods to allow sufficient time for marked trout to randomly mix with unmarked trout. Estimates of total numbers, total weight, numbers per size group, numbers per age-group, and mortality rates were made by methods described by Vincent (1971, 1982). Variances for total number and weight were obtained by using Seber's (1973) formula. Confidence intervals were calculated at the 95% level.

Student's *t*-test was used to test the null hypotheses of no difference between the mean weight or numbers of wild fish in stocking years versus nonstocking years. A normal distribution was assumed in all comparisons. In no instances were *t*-tests used where a heterogeneous variance was detected, as determined by an *F*-test (Snedecor 1956). When two or more population estimates were averaged to make stocking and nonstocking comparisons, the variances for each estimate were incorporated into the statistical *t*-test analysis. All levels of significance were at the 5% level or less. A linear regression was used to determine correlations of mean winter flow with total biomass of 2-year-old and older wild trout in the Madison River and of stocking with total biomass.

The Varney section was set up as the primary study section, where stocking of catchable fish had been continuous from 1955 through 1969. With the end of stocking in this section in 1970, a comparison of wild trout populations during stocking (1967–1969) and nonstocking periods (1970–1976) could be made. However, an unscheduled stocking of catchable fish during the summer of 1972 somewhat altered this approach.

The Burnt Tree section was used as a control, where stocking of catchable fish would continue through 1973. Any population change occurring

TABLE 1.—Spring estimates of total numbers and biomasses of 3-year-old and older wild brown trout in the Varney section of the Madison River after years rainbow trout were and were not stocked. Confidence intervals (95%) are in parentheses; values of t above 2.78 are significant ($P \leq 0.05$).

	Year after stocking					Year after nonstocking			
Total	1967	1968	1969	1970	Average	1971	1972	Average	t-value
Number (fish/mi)	261 (±123)	247 (±172)	300 (±114)	255 (±96)	266	354 (±137)	432 (±198)	393	4.25
Biomass (lb/mi)	365 (±153)	408 (±110)	417 (±147)	377 (±108)	392	478 (±169)	570 (±293)	524	3.92

in the Varney section after stocking ceased was compared with population changes in the stocked Burnt Tree section to rule out or confirm that factors other than stocking could have caused any change. This section had very similar habitat conditions to the Varney section. Even if each section had some natural differences in total wild trout biomass, both sections were exposed to the same flow levels, water temperatures, and other climatic trends.

O'Dell Creek had not experienced any appreciable stocking of catchable fish prior to this study; the last stocking had occurred in 1964. The lower O'Dell Creek section was monitored for 3 years (1967–1969) under a nonstocking sequence, followed by three consecutive years of stocking (1970–1972), then three additional years of nonstocking (1973–1975). Approximately 4,000–4,500 catchable-size rainbow trout were stocked in each of the planting years over a lower 1.8-mi section. An upper section was maintained as a field control where a nonstocking policy was in effect (1970–1974). Both the upper and lower study sections had very similar habitat conditions, although water flows were 20–30% higher in the lower section.

Each major study section was divided into smaller subsections 1,250–2,500 ft long in order to study fish movement. Wild trout from each subsection were marked with a Floy anchor tag. Recapture information was gathered either from subsequent electrofishing operations or from angler tag returns. Angler tag returns also were used to estimate a relative yearly angling pressure or harvest. It was assumed that the ratio of tags returned to the number of fish actually caught by anglers was constant throughout the study period. Identification of hatchery rainbow trout in the stream was based on the degree of eroded and deformed fins, especially the dorsal. Hatchery trout examined prior to stocking exhibited such extreme erosion of the dorsal and pectoral fins that no appreciable portion of these fins remained. The average size of the catchable rainbow trout was 12 in long when planted. Since few wild rainbow trout in O'Dell Creek exceeded 8 in, identification of hatchery rainbow trout was even more accurate there.

Wild trout responses to stocking or nonstocking carried beyond 1 year and it was necessary to place fall trout estimates into categories based on the length of time from the last stocking or nonstocking date. These categories for brown trout and rainbow trout were: (1) "stocking" years—stocking had occurred for at least two consecutive summers prior to the estimates; (2) "transition" years—the estimate had been preceded by only one summer of stocking or nonstocking; and (3) "poststocking" years—at least two consecutive summers of no stocking preceded the estimate. These categories were not used for spring estimates due to insufficient numbers of spring estimates after stocking ceased in the Madison River and lower O'Dell Creek.

Mean winter discharge rates (ft^3/s) were computed from December 1–April 30 discharge rates at the McAllister water-level gage located 1.5 mi below Ennis Dam. The winter flow period was selected because it is the low-flow period each year. If flows were controlling population changes, some correlation between these variables could be expected.

Results

Madison River

Brown trout.—Spring estimates of number and biomass of 3-year-old and older brown trout in the Varney section showed immediate increases in 1971 following the first summer (1970) of no stocking (Table 1). By the second spring (1972), total biomass had increased 34% over the 1967–1969 average. Statistically significant differences were found in both biomass and number of fish between stocking and nonstocking years.

Fall biomass estimates of 2-year-old and older

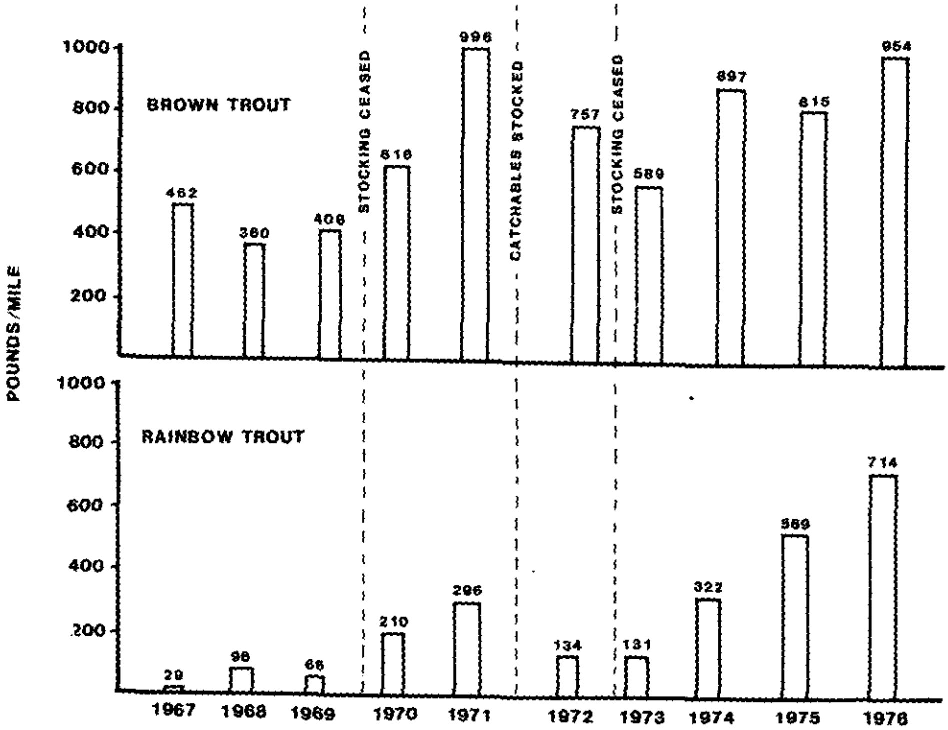

FIGURE 3.—Fall biomass (lb/mi) estimates for 2-year-old and older wild brown and rainbow trout in the Varney section of the Madison River during years when rainbow trout were and were not stocked.

brown trout also showed immediate increases following the 1970 cessation of stocking. By September 1971, the total biomass had increased 143% from the 1967–1969 average (Figure 3). Following an unscheduled stocking of catchable rainbow trout during the summer of 1972, the brown trout biomass declined 24% from its September 1971 level. After two more years of no stocking (1973–1974), the September 1974 brown trout biomass estimate was within 11% of the 1971 levels. Comparisons of mean numbers and biomasses for 2-year-old and older brown trout between stocking (1967–1969) and poststocking years (1971, 1974–1976) showed values in the latter years to be 153 and 123% higher, respectively, the differences being statistically significant (Table 2). Mean numbers and biomasses for the transitional years (1970, 1972, and 1973) were between means for stocking and poststocking years, and were significantly greater than those for stocking years.

All age-groups of brown trout increased in numbers when stocking ceased. Mean numbers and biomasses of 2- and 3-year-olds showed significant increases of 169 and 142%, respectively between stocking and poststocking periods. Four-year-old and older brown trout also showed large increases in mean numbers in two of the four poststocking years, but the overall increase of 120% was not statistically significant (Table 2).

To determine whether or not certain sizes of brown trout were more affected by stocking than others, fish from the fall numerical estimates were separated into three size categories (Table 3). Only the brown trout 10.0–17.9-in size group showed a significant increase in numbers following the cessation of stocking.

When stocking years for the Varney section (1967–1969) and the Burnt Tree control section (1971–1973) were compared, no significant difference in the biomasses of 2-year-olds and older was found. This would suggest similar populations for brown trout in the two sections. In 1971, the poststocking biomass of 2-year-old and older brown trout in the Varney section was 122% greater than the biomass in the stocked Burnt Tree section (Table 4). Since the 95% confidence intervals do not overlap between the two estimates, the difference is considered significant. The 1972 and 1973 comparisons between the two sections are comparisons of stocking years (Burnt Tree) versus transition years (Varney), when the Varney section showed a significant 39% increase over the Burnt Tree

TABLE 2.—Fall population and biomass estimates of wild brown trout for the Varney section of the Madison River during years rainbow trout were and were not stocked. Confidence intervals (95%) are in parentheses; t-values are shown for comparisons between stocking and poststocking years, and values of t greater than 2.57 are significant ($P < 0.05$).

	Number of fish/mi				Age II and older fish	
Year	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Stocking years[a]			
1967	395	201	99	55	355 (±129)	462 (±168)
1968	1,060	154	95	38	287 (±75)	360 (±96)
1969	788	171	102	44	317 (±117)	408 (±150)
Average	748	175	99	46	320	410
			Transition years[b]			
1970	997	231	139	69	439 (±113)	616 (±158)
1972	753	386	189	95	670 (±248)	757 (±280)
1973	902	426	89	72	587 (±153)	589 (±154)
Average	884	348	139	79	565	654
			Poststocking years[c]			
1971	924	407	192	165	764 (±229)	996 (±298)
1974	1,003	542	258	51	851 (±230)	897 (±242)
1975	1,209	465	256	78	799 (±124)	815 (±126)
1976	1,969	468	254	109	831 (±220)	954 (±253)
Average	1,276	471	240	101	811	916
			t-value			
	1.69	8.92	7.75	1.88	17.90	10.08

[a] Estimates made in years preceded by two or more summers of stocking.
[b] Estimates made in years preceded by one summer of stocking or no stocking.
[c] Estimates made in years preceded by two or more summers of no stocking.

section (Table 4). The first fall estimates following cessation of stocking in the Burnt Tree section showed a 74% increase in the 2-year-old and older brown trout biomass over the average for 1971–1973.

Rainbow trout.—Following the cessation of stocking after 1969, there was an immediate increase in the fall population of 2-year-old and older wild rainbow trout in 1970 in the Varney section (Figure 3) and, by September 1971, the rainbow trout biomass had increased three-fold (363%) over the average during the 1967–1969 stocking period. After the unscheduled summer 1972 stocking, the biomass decreased 55% in 1972 and 1973 from that of September 1971, then proceeded to increase dramatically. By 1976, after four consecutive years of no stocking, the total biomass had increased 11-fold over the mean during the stocking years. Similar comparisons by age-group showed that yearlings increased 474%, 2-year-olds 640%, and 3-year-old and older fish 942% over the 1967–1969 means (Table 5). The differences were not statistically evaluated due to heterogeneous variances caused by the large annual increases in numbers. However, comparisons of mean numbers and biomass of all 2-year-old and older wild rainbow trout between stocking and poststocking years showed the latter values to be 733 and 642% higher, respectively, the differences being statistically significant.

Fall wild rainbow trout population estimates also were separated into two size groups to determine if there was a size-related response to stocking in the Varney section (Table 3). Both the 10.0–17.9-in and the larger size groups showed large increases in numbers after stocking ceased. The mean number of 18-in and larger rainbow trout quadrupled after stocking ceased. There was a statistically significant increase in the 10.0–17.9-in group also. In the Burnt Tree section, the first fall estimate of 2-year-old and older wild rainbow trout (1974) following the cessation of stocking showed a 317% increase in numbers and a 145% increase in biomass over the mean for the 1971–1973 stocking years.

Population estimates of hatchery-reared fish in the Varney section were made each fall during the stocking years to evaluate their survival rates. These numerical estimates ranged from 32/mi in 1972 to 151/mi in 1969. The average biomass estimate

TABLE 3.—Fall population estimates (number/mi) for various size groups of wild brown and rainbow trout during stocking and poststocking years for the Varney section of the Madison River. Values of t greater than 2.57 are significant ($P < 0.05$).

Year	Size group (in) and species				
		10–17.9		18.0 and larger	
	5.0–9.9[a] Brown trout	Brown trout	Rainbow trout	Brown trout	Rainbow trout
	Stocking years[b]				
1967	381	328	32	40	1
1968	1,019	303	96	25	2
1969	776	300	67	29	5
Average	725	310	65	31	3
	Poststocking years[c]				
1971	925	669	262	93	16
1974	1,040	791	417	19	7
1975	1,256	730	714	18	4
1976	1,962	795	552	37	20
Average	1,296	746	486	42	12
	***t*-value**				
	1.89	9.30	2.82	0.54	

[a] No estimates for rainbow trout due to insufficient sample sizes.
[b] Estimates made in years preceded by two or more summers of stocking.
[c] Estimates made in years preceded by at least two summers of no stocking.

for these surviving hatchery fish was 40 lb/mi. Spring electrofishing yielded too few hatchery fish to make estimates. Estimates of the number and biomass of hatchery rainbow trout in the Burnt Tree section averaged 128/mi and 91 lb/mi, respectively, for the 1971–1973 period.

Effect of flow rates.—Total biomass of 2-year-old and older wild brown and rainbow trout was compared with mean winter flow for both stocking and nonstocking years in the Madison River (Figure 4). When total biomasses in stocking years were compared to mean winter flows, no significant correlation was found ($r = 0.538$, $t = 1.24$), whereas a correlation was significant for poststocking years ($r = 0.740$; $t = 2.69$). This indicates that stocking was limiting the numbers of 2-year-old and older wild trout. Numbers of yearling brown trout increased significantly with increased flow levels during both stocking ($r = 0.8949$, $t = 4.48$) and poststocking ($r = 0.9302$, $t = 5.78$) years.

Mortality.—Annual mortality of 2-year-old and older wild brown trout was similar between stocking and poststocking years—55 and 58%, respectively. During transitional periods following cessation or initiation of stocking, however, mortality rates deviated from the norm. After stocking ceased, the average annual mortality was 33%, whereas it was 70% following the 1972 stocking. Summer mortality rates of wild trout averaged 43% for the stocking years versus less than 20% for poststocking years. Winter mortality rates for yearling brown trout were highest in the stocking years (68%) and lowest in poststocking years (16%).

Movement.—No comparisons were made of differential movement between stocking and nonstocking years. To determine if movement could explain some of the changes in the Varney study section, tag returns from electrofishing of wild trout were used. Twenty-five percent of the brown trout and 29% of the rainbow trout sampled moved more than 2,000 ft. Seven percent of the brown trout and 8% of the rainbow trout moved distances greater than 1.5 mi. No substantial directional movement was detected—45% of the tag returns showed movement upstream and 55% downstream. Hatchery rainbow trout that were stocked either in the lower 1 mi or upper 0.5 mi of the Varney section dispersed throughout the Varney area.

Angling pressure.—Angling pressure was not measured directly in the study sections but some

TABLE 4.—Fall biomass estimates of 2-year-old and older wild brown trout in the Varney and Burnt Tree sections of the Madison River (1971–1973). Confidence intervals (95%) are in parentheses.

Year	Biomass (lb/mi)			Difference (%)
		Varney		
	Burnt Tree, stocking[a]	Poststocking[b]	Transitional[c]	
1971	448 (±123)	996 (±298)		122
1972	405 (±101)		756 (±280)	87
1973	565 (±120)		589 (±154)	4
Average (1972–1973)	485		673	39

[a] Estimates made in years preceded by two or more summers of stocking.
[b] Estimate made in year preceded by two summers of no stocking.
[c] Estimates made in years preceded by one summer of stocking or no stocking.

TABLE 5.—Fall population and biomass estimates of wild rainbow trout for the Varney section of the Madison River during stocking and nonstocking years. Confidence intervals (95%) are in parentheses; *t*-values are shown for comparison of stocking and poststocking years, and are significant ($P < 0.05$).

Year	Number of fish/mi			Age II+ and older fish	
	Age I+	Age II+	Age III and older	Number/mi	Biomass (lb/mi)
			Stocking years[a]		
1967	82	30	5	35 (±22)	29 (±18)
1968	[b]	64	28	92 (±65)	96 (±68)
1969	[b]	32	25	57 (±40)	66 (±47)
Average	82	42	19	61	64
			Transition years[c]		
1970	217	186	45	231 (±95)	210 (±104)
1972		26	79	105 (±43)	135 (±58)
1973	644	74	40	114 (±47)	131 (±108)
Average	431	95	55	150	159
			Poststocking years[d]		
1971		184	97	281 (±104)	296 (±104)
1974	622	389	45	434 (±166)	322 (±107)
1975	350	471	256	727 (±174)	569 (±136)
1976	440	198	393	591 (±269)	714 (±325)
Average	471	311	198	508	475
			***t*-value**		
				3.00	2.64

[a] Estimates made in years preceded by two or more summers of stocking.
[b] No estimates due to insufficient sample size.
[c] Estimates made in years preceded by one summer of stocking or no stocking.
[d] Estimates made in years preceded by two or more summers of no stocking.

information on angler use was available. Vincent (1969b) estimated that fishing pressure on the 51 mi of the Madison River between Quake and Ennis lakes averaged 680 angler-days per mile in 1969. A statewide survey estimated angling pressure for this reach to be 953 angler-days per mile in 1975. This was an increase in angling pressure of 40%, so there was much more angling pressure in nonstocking years than in stocking years. Tag returns from 3-year-old and older trout caught by anglers were used as an indicator of relative harvest between study years. Tag returns declined from 12% in stocking years (1967–1969) to 8% in nonstocking years (1970–1971) for brown trout; there was a 4% drop for wild rainbow trout as well. Although the percent harvest decreased for brown trout and wild rainbow trout in the nonstocking years, the larger populations present in the nonstocking year 1971 made the total harvests similar between stocked and unstocked years.

O'Dell Creek

Brown trout.—Little change between 1970 spring and fall biomasses of 2-year-old and older wild brown trout was noted following the June–July stocking of 4,000 hatchery-reared, catchable-size rainbow trout that year (Figure 5). However, biomass estimates made the following spring (1971) showed a 39% decrease from the 1967–1969 prestocking average. With continued stocking in 1971, a further decline was observed, the spring 1972 biomass estimate being 57% below the 1967–1970 average. Stocking continued in 1972, but further declines were not measured. After stocking ceased in 1973, the spring 1974 biomass estimate returned to the prestocking average of 332 lb/mi.

Mean spring biomasses of 2-year-old and older brown trout were significantly higher (42%) in nonstocking than in stocking years ($t = 4.79$: Table 6). No significant difference was found in the mean numbers of 2-year-old and older fish, although there was an estimated 25% reduction in mean numbers during the stocking years, due to the large number of 2-year-olds found in the spring 1973 estimate. Spring yearling numbers were not significantly different between stocking and nonstocking years. Only 3-year-old brown trout showed a significant (47%) decline in mean numbers during the stocking years. However, 2- and 4-year-old fish declined 15 and 23%, respectively. Comparison of

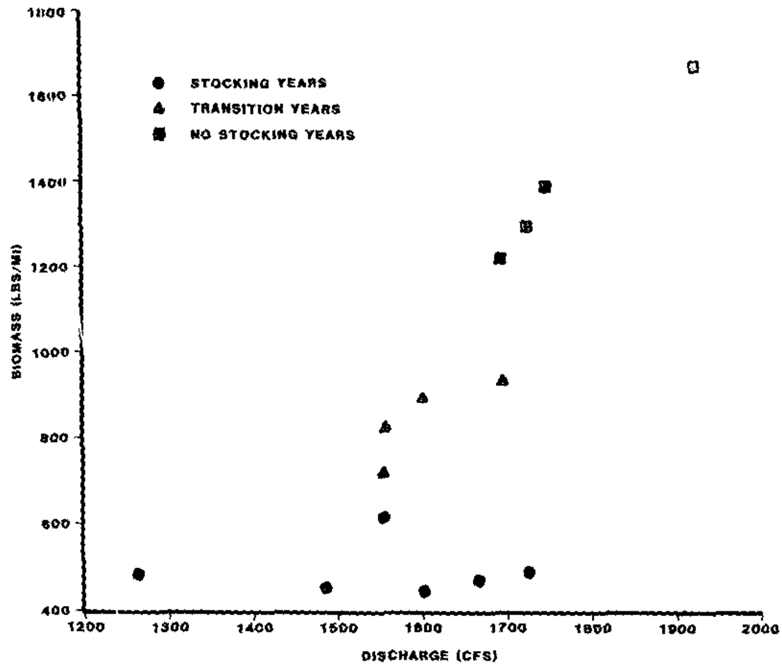

FIGURE 4.—Total biomass (lb/mi) estimates for all 2-year-old and older wild brown and rainbow trout during stocking, transition, and poststocking years in the Madison River in relation to mean winter (December 1–April 30) flow (cubic feet per second) at the McAllister gage.

size groups between stocking and nonstocking years illustrates the changes in the population structure better than age-groups (Table 7). Brown trout smaller than 10 in showed no significant difference in numbers between stocking and nonstocking years. Spring 2-year-old brown trout ranged in size from 8.0 to 11.9 in. During the prestocking years 1967–1970, 10-in and longer brown trout composed 56% of this age-group, 24% during the stocking years 1971–1973, and back to 50% for the nonstocking year 1974, indicating the effect of stocking was keyed more to size than age. All inch-groups from 10.0 to 17.9 showed decreases in mean numbers from nonstocking to stocking years; the

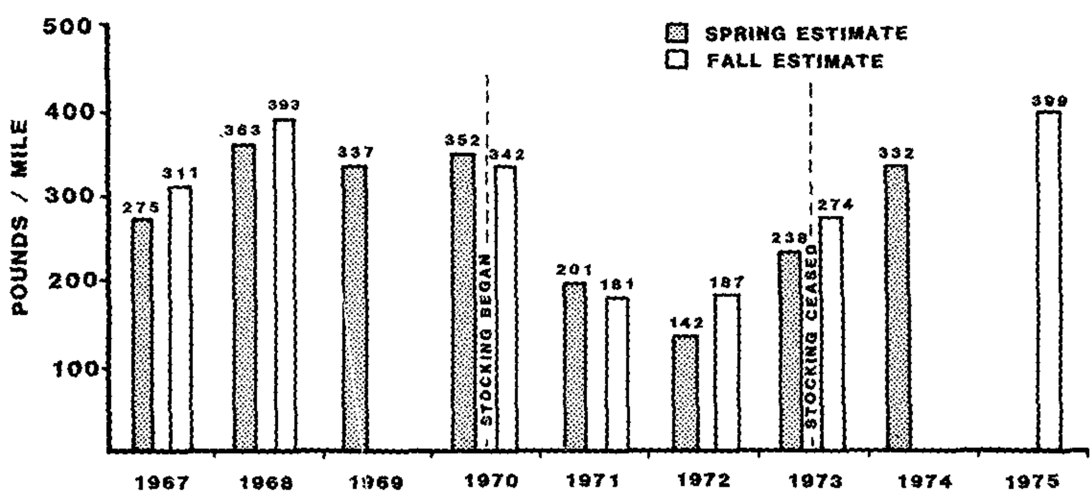

FIGURE 5.—Spring and fall biomass estimates (lb/mi) for 2-year-old and older wild brown trout before, during, and after stocking of rainbow trout in the lower section of O'Dell Creek (1967–1975).

TABLE 6.—Spring population and biomass estimates for wild brown trout for years after rainbow trout were and were not stocked in the lower study section of O'Dell Creek. Confidence intervals (95%) are shown in parentheses. Values of t above 2.45 are significant ($P < 0.05$).

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Nonstocking years			
1967	669	311	112	34	457 (±76)	275 (±46)
1968	652	339	148	48	535 (±76)	363 (±51)
1969	660	323	135	44	502 (±70)	337 (±50)
1970	1,116	322	193	52	567 (±73)	352 (±45)
1974	1,008	402	153	58	613 (±104)	332 (±56)
Average	821	339	148	47	535	332
			Stocking years			
1971	857	244	99	40	383 (±84)	201 (±44)
1972	772	188	61	31	280 (±43)	142 (±22)
1973	1,128	431	75	37	543 (±60)	238 (±27)
Average	919	288	78	36	402	194
			t-value			
	0.63	0.88	3.60	1.93	2.01	4.79

totals were significantly different. The numbers of 18.0-in and larger brown trout declined 78% from nonstocking to stocking years, but statistical differences were not calculated due to heterogeneous variances caused by the 1974 estimate. The 1974 estimate of 18.0-in and larger brown trout was not representative of a nonstocking year because insufficient time had elapsed for fish to grow to this size. If the 1974 data for this size group are omitted from the data, the difference between stocking and nonstocking years is significant ($t = 3.46$). In fact, numbers of brown trout in the 16.0–17.9-in size groups had not returned to prestocking levels by 1974.

TABLE 7.—Spring population estimates (number of fish/mi) for three size groups of wild brown trout for years after rainbow were and were not stocked in the lower study section of O'Dell Creek.

Year	Size group (in)		
	3.5–9.9	10.0–17.9	18.0 and larger
	Nonstocking years		
1967	784	331	11
1968	778	384	15
1969	810	343	9
1970	1,273	391	9
1974	1,215	405	1
Average	972	371	9
	Stocking years		
1971	1,053	184	2
1972	903	140	2
1973	1,341	262	3
Average	1,099	195	2
	t-value		
	0.72	4.34[a]	

[a] Difference between stocking and nonstocking years was significant ($P < 0.05$).

Mean fall estimates of 2-year-old and older wild brown trout during the rainbow trout stocking years decreased 52% in number and 50% in biomass when compared to the means from the pre- and poststocking years (Table 8). Linear regression data for pre- and poststocking, transitional, and stocking years showed a significant correlation between stocking of hatchery rainbow trout and the decline of wild trout biomass levels ($r = 0.9055$; $t = 4.77$). When mean numbers for various age-groups were compared, the 1-, 2-, 3-, and 4-year-old and older age-groups were 13, 57, 56, and 7% smaller, respectively, in the stocking years; differences were statistically significant for the 2- and 3-year-old age groups.

Wild brown trout estimates (age II+) for the upper section of O'Dell Creek were used as controls because there were no significant differences in spring or fall estimates ($t = 0.43$ and $t = 0.043$, respectively) between the upper and lower sections during years of no stocking (Table 9). When mean spring biomass estimates from the unstocked upper section (1970–1974) were compared with the stocked lower section (1971–1973), the stocked lower section had a significantly lower (45%) biomass estimate ($t = 4.26$). A similar comparison of

TABLE 8.—Fall population and biomass estimates of wild brown trout during years rainbow trout were and were not stocked in the lower study section of O'Dell Creek. Confidence intervals (95%) are shown in parentheses.

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Pre- and poststocking years[a]			
1967	427	228	69	32	329 (±99)	311 (±59)
1968	450	271	107	43	421 (±82)	393 (±69)
1969	[b]	[b]	119	22	[b]	[b]
1975	837	277	144	80	501 (±94)	399 (±75)
Average	571	259	110	44	417	368
			Transition years[c]			
1970	698	214	133	39	386 (±123)	342 (±53)
1973	521	229	57	49	335 (±59)	274 (±67)
Average	610	222	95	44	361	308
			Stocking years[d]			
1971	496	78	61	46	185 (±42)	181 (±31)
1972	499	143	35	36	214 (±57)	187 (±41)
Average	498	111	48	41	200	184

[a] Estimates made in years preceded by two or more summers of no stocking.
[b] Due to poor sample size, estimates were not made.
[c] Estimates made in years preceded by one summer of stocking or no stocking.
[d] Estimates made in years preceded by two or more summers of stocking.

mean fall biomass estimates between the unstocked upper section (1970–1972) and the stocked lower section (1971–1972) showed a 50% lower estimate; although this difference was not significant by the t-test ($t = 2.59$), nonoverlapping 95% confidence intervals for individual comparisons suggest significant differences.

Rainbow trout.—No population estimates were made for wild rainbow trout in either the upper or lower sections due to their extremely low numbers. Fall estimates of hatchery rainbow trout in the lower section, made after the first two summers (June–July) of stocking, averaged 198/mi with a biomass of 104 lb/mi. A third fall estimate (1972) showed 58 fish/mi (60 lb/mi). Small numbers of hatchery rainbow trout were captured in the upper section during electrofishing and probably came from sites in the lower section.

Growth.—Mean annual growth of all age-groups of brown trout, yearling through 4-year-olds, decreased during the stocking years from levels found in the nonstocking years (Table 10). No significant change was found in the summer growth rate for any age-group. All age-groups examined had lower winter growth rates in the stocking years, significantly lower for yearlings and 2-year-olds. The net result of this lower winter growth rate was a reduction in the average spring size of all age-groups older than yearlings; 2-, 3-, and 4-year-olds averaged 1.0, 1.2, and 2.0 in smaller, respectively, in the stocking years. No significant difference in average size of spring yearlings was found between stocking and nonstocking years.

Mortality.—A comparison of annual mortality rates between prestocking years and the first two

TABLE 9.—Spring and fall biomass estimates (lb/mi) of age-II+ wild brown trout during years rainbow trout were and were not stocked in the upper and lower sections of O'Dell Creek. Confidence intervals (95%) are in parentheses.

Year	Upper section, no stocking	Lower section	
		Stocking	No stocking
	April		
1967			275 (±46)
1968			363 (±51)
1969			337 (±50)
1970	367 (±21)		352 (±29)
1971	345 (±44)	201 (±28)	
1972	262 (±32)	142 (±14)	
1973	354 (±43)	238 (±17)	
1974	423 (±31)		332 (±36)
Average	350	194	332
	September		
1967			311 (±38)
1968			393 (±44)
1970	412 (±44)		
1971	398 (±61)	181 (±20)	
1972	285 (±43)	187 (±26)	
1975			399 (±84)
Average	365	184	368

TABLE 8.—Fall population and biomass estimates of wild brown trout during years rainbow trout were and were not stocked in the lower study section of O'Dell Creek. Confidence intervals (95%) are shown in parentheses.

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Pre- and poststocking years[a]			
1967	427	228	69	32	329 (±99)	311 (±59)
1968	450	271	107	43	421 (±82)	393 (±69)
1969	b	b	119	22	b	b
1975	837	277	144	80	501 (±94)	399 (±75)
Average	571	259	110	44	417	368
			Transition years[c]			
1970	698	214	133	39	386 (±123)	342 (±53)
1973	521	229	57	49	335 (±59)	274 (±67)
Average	610	222	95	44	361	308
			Stocking years[d]			
1971	496	78	61	46	185 (±42)	181 (±31)
1972	499	143	35	36	214 (±57)	187 (±41)
Average	498	111	48	41	200	184

[a] Estimates made in years preceded by two or more summers of no stocking.
[b] Due to poor sample size, estimates were not made.
[c] Estimates made in years preceded by one summer of stocking or no stocking.
[d] Estimates made in years preceded by two or more summers of stocking.

mean fall biomass estimates between the unstocked upper section (1970–1972) and the stocked lower section (1971–1972) showed a 50% lower estimate; although this difference was not significant by the t-test ($t = 2.59$), nonoverlapping 95% confidence intervals for individual comparisons suggest significant differences.

Rainbow trout.—No population estimates were made for wild rainbow trout in either the upper or lower sections due to their extremely low numbers. Fall estimates of hatchery rainbow trout in the lower section, made after the first two summers (June–July) of stocking, averaged 198/mi with a biomass of 104 lb/mi. A third fall estimate (1972) showed 58 fish/mi (60 lb/mi). Small numbers of hatchery rainbow trout were captured in the upper section during electrofishing and probably came from sites in the lower section.

Growth.—Mean annual growth of all age-groups ıf brown trout, yearling through 4-year-olds, dereased during the stocking years from levels found the nonstocking years (Table 10). No significant ange was found in the summer growth rate for age-group. All age-groups examined had lower ter growth rates in the stocking years, signifily lower for yearlings and 2-year-olds. The net t of this lower winter growth rate was a reon in the average spring size of all age-groups than yearlings; 2-, 3-, and 4-year-olds av- 1.0, 1.2, and 2.0 in smaller, respectively, in the stocking years. No significant difference in average size of spring yearlings was found between stocking and nonstocking years.

Mortality.—A comparison of annual mortality rates between prestocking years and the first two

TABLE 9.—Spring and fall biomass estimates (lb/mi) of age-II+ wild brown trout during years rainbow trout were and were not stocked in the upper and lower sections of O'Dell Creek. Confidence intervals (95%) are in parentheses.

Year	Upper section, no stocking	Lower section	
		Stocking	No stocking
		April	
1967			275 (±46)
1968			363 (±51)
1969			337 (±50)
1970	367 (±21)		352 (±29)
1971	345 (±44)	201 (±28)	
1972	262 (±32)	142 (±14)	
1973	354 (±43)	238 (±17)	
1974	423 (±31)		332 (±36)
Average	350	194	332
		September	
1967			311 (±38)
1968			393 (±44)
1970	412 (±44)		
1971	398 (±61)	181 (±20)	
1972	285 (±43)	187 (±26)	
1975			399 (±84)
Average	365	184	368

TABLE 10.—Average summer (April–September), winter (September–April) and annual increases in length (in) of four age-groups of wild brown trout during nonstocking and stocking years for lower O'Dell Creek. Values of $t > 2.57$ are significant ($P < 0.05$).

Time period	Age-group I	II	III	IV
Nonstocking years				
Summer	2.8	1.4	1.3	1.2
Winter	1.5	1.9	1.6	0.6
Annual	4.3	3.3	2.9	1.8
Stocking years				
Summer	3.1	1.4	1.2	1.0
Winter	0.9	1.3	1.1	0.4
Annual	4.0	2.7	2.3	1.4
***t*-value**				
Summer[a]	0.94	0.00	0.23	0.38
Winter[b]	3.52	2.64	0.75	0.63

[a] Comparisons of summer growth between stocking and nonstocking years.

[b] Comparisons of winter growth between stocking and nonstocking years.

stocking years showed an increase from 58% to an average of 76%. When the wild brown trout populations stabilized at a lower level, the annual mortality rate dropped to a rate similar to prestocking years (60%) even though stocking continued. Stocking tended to raise the summer mortality of 2-year-old and older brown trout from an average of 25% during prestocking years to 42% for the first two stocking years. Yearling brown trout mortality rates in the lower section of O'Dell Creek were 47% for the stocking years and 24% for the nonstocking years.

Movement.—Based on electrofishing returns of tagged wild trout, the rate of movement within O'Dell Creek accelerated during the stocking years. The number of brown trout moving more than 1,320 ft increased from an average of 2% in nonstocking years to 10% in stocking years. Those brown trout showing detectable movement (but moving less than 1,320 ft) increased from 19% in nonstocking years to 33% in stocking years. Based on angler tag returns an average of one tagged O'Dell Creek wild trout was caught per year in the Madison River in nonstocking years versus an average of 12/year during stocking years. Tag returns were based only on fish tagged during spring electrofishing, with an average of 240 being tagged in nonstocking years and 215 in stocked years.

Angling pressure.—There were no direct measurements of angling pressure on this stream during the period of study, but mail surveys in 1968 and 1975 estimated there were 56 angler-days per mile in 1968 and 69 per mile in 1975. Tag returns from the lower section also confirmed this low angler use—the return rate averaged only 8% for nonstocking years and 6% for stocking years.

Discussion

Populations of 2-year-old and older wild brown and rainbow trout in these two Montana streams declined significantly in numbers and total weight following the introduction of hatchery-reared, catchable-size rainbow trout. The degree of decline varied with the species, age or size, the stream being stocked, and the number of consecutive years of stocking. Other investigations also have shown decreases in wild fish populations in streams when hatchery fish were stocked. Bachman (1982) found that when hatchery brown trout were stocked into a section of Spruce Creek, Pennsylvania, wild brown trout numbers decreased below any previously measured level. Thuember (1975) found that the number of wild brook trout nearly doubled in the North Branch of the Pike River and K. C. Creek, Wisconsin, when stocking of hatchery brook trout ceased. Snow (1974) reported that when hatchery northern pike (*Esox lucius*) were stocked in Murphy's Flow, where native northern pike populations existed, wild pike numbers declined 76%. McMullian (1982) found that 7 years after rainbow trout stocking had been discontinued in the Melrose section of the Big Hole River, Montana, wild brown trout and rainbow trout increased 83 and 325%, respectively. In Big Springs Creek, Idaho, Petrosky (1984) concluded that experimental stocking rates of 2.5–5.0 catchable fish per meter had little effect on the number of wild rainbow trout present. However, further analysis of the data showed summer mortality of wild rainbow trout increased with an increase in the stocking rate of catchable-size rainbow trout. This resulted in a decline of 2-year-old and older wild rainbow trout in the fall, the degree of decline being related to the stocking rate.

Two major physical factors that can alter trou biomass in Montana streams are variations in hab itat and volume of flow. During the period of stud few obvious changes were noted in the conditi of the banks in either the Madison River or O'D Creek study sections, but some variations (b increase and decrease) in streamflow were sured in the Madison River. Nelson and Vi (1978) found that total wild trout biomass (l in the Gallatin River, Montana, was higher i sections which experienced the smallest s

(July–September) dewatering from irrigation withdrawals. In the Madison River, the low-flow period usually occurred during the winter (December 1–April 30). During the first years of this study (1967–1971), higher winter flow levels resulted in higher biomasses of 2-year-old and older wild brown and rainbow trout in the nonstocked Norris section, whereas the wild trout biomass in the stocked Varney section did not increase under the same flow regimes. The Varney and Burnt Tree sections, each having similar habitat conditions and similar flow volumes and regimes, were used to determine if mean winter flow levels had an influence on wild brown trout and rainbow trout biomasses during stocking and nonstocking years. This analysis was based on the assumption that minor differences in habitat may alter the relative number of certain size groups but that total biomasses (lb/mi) should be similar. When only data from stocking years were used, no appreciable change in the 2-year-old and older wild brown and rainbow trout biomass level was noted under any observed winter flow regime. However, during nonstocking years increases in mean winter flows resulted in significant increases in the 2-year-old and older wild trout biomasses. Under the observed fluctuations in winter flow, the total 2-year-old and older wild trout biomasses were lowered significantly by the stocking of catchable-size rainbow trout and biomasses did not increase even during more favorable winter flows.

Stable flow regimes at O'Dell Creek were interrupted by severe winter flooding in the winter of 1971–1972. The following spring (1972), estimates of 2-year-old and older brown trout in both study sections showed a decline from previous spring estimates. In the nonstocked upper section, the brown trout biomass estimate was 30% lower than the mean of other nonstocked years. In the lower, stocked section, the spring 1972 estimate was 36% below the mean of other stocked years and 57% below the mean of unstocked years. By 1973, the spring biomass estimate for the upper section had returned to previous spring levels, while the lower, stocked section returned to levels found in the stocking year 1971 but not the levels in nonstocked years.

Rainbow trout showed a more substantial increase in 2-year-old and older total numbers and total biomass than brown trout when the stocking of catchable-size rainbow trout ceased. After four consecutive years of nonstocking in the Madison River, 2-year-old and older brown trout increased 162% in number and 133% in total biomass versus eight- and 10-fold increases in number and biomass, respectively, for wild rainbow trout. Because wild rainbow trout are more severely affected by stocking than brown trout, their recovery time was longer. Wild rainbow trout biomass was still increasing 4 years after stocking ceased, while brown trout biomass peaked after 2 years. McMullian (1982) also found the wild brown trout recovery rate to be faster than that of wild rainbow trout in the Big Hole River, Montana.

The adverse impact of stocking hatchery rainbow trout on the wild brown trout population was associated more with size than age. Brown trout in O'Dell Creek smaller than 10.0 in showed no significant changes in number between stocking and nonstocking years, while numbers of those exceeding 10 in long decreased significantly during stocking years. To further illustrate this size versus age factor, numbers of fall yearling brown trout (age I+) were not significantly different between stocking and nonstocking years in lower O'Dell Creek. During this fall period, none of the yearling brown trout were longer than 10 in, but between the September and April (spring) estimates, an average of 56% of the yearlings had grown enough to exceed 10 in during nonstocking years and are represented as 2-year-olds. In stocking years, only an average of 24% of the 2-year-old brown trout were longer than 10 in, but those 2-year-olds smaller than 10.0 in showed no decrease in numbers from nonstocking years. In fact, the large number of 2-year-old brown trout shown in the spring 1973 estimate was comprised mostly of fish smaller than 10 in. The percent of 2-year-olds exceeding 10 in long returned to prestocking levels (50%) when stocking was discontinued in 1973. In the Madison River, numbers of fall yearling brown trout were not significantly different between stocking and nonstocking years, but they increased significantly with river flows and in both stocking and nonstocking years. Again, like O'Dell Creek, the numbers of brown trout between 10.0 and 17.9 in long showed significant increases when stocking was discontinued. Impacts on wild rainbow trout smaller than 10 in long were not well documented in the Madison River sections due to poor fall yearling estimates, although there is some indication stocking may adversely affect smaller rainbow trout because the average yearling numbers during nonstocking years were over four times larger than the number for the only stocking year estimate (1967). Numbers of rainbow trout in the 10.0–17.9-in size group also showed a significant increase when stocking was discontinued.

Stocking of hatchery rainbow trout did alter existing natural mortality rates of wild trout. With the cessation of stocking in the Varney section of the Madison River in 1970, the annual mortality decreased dramatically, then rose in subsequent years as wild populations increased. In the lower O'Dell Creek section, annual mortality increased during the first 2 years of stocking. When the abundance of brown trout decreased to levels in equilibrium with existing stocking levels, mortality rates dropped to prestocking levels. Petrosky (1984) also found an increase in the summer mortality rates of 2-year-old and older wild rainbow trout when catchable-size hatchery rainbow trout were stocked; mortality was highest in sections receiving the highest stocking rate.

In lower O'Dell Creek, annual growth rates of brown trout decreased when stocking was initiated. This decrease in growth was evident primarily during the winter period (September–April), at the time of mortality rate increases. This decrease in growth was another indicator of population stress.

Stresses resulting from stocking also may increase wild trout susceptibility to angling. McLaren (1979) found that the introduction of hatchery trout increased the activity of wild trout and altered their activity patterns to coincide with those of hatchery trout. This may explain the findings of Butler and Borgeson (1965) that showed wild brown and rainbow trout were more catchable during periods of stocking. During stocking years in the Madison River, there was a 40% higher angler return of tags than in unstocked years for the larger wild trout (3 years old and older), even though there were fewer anglers. This did not occur in lower O'Dell Creek, where angling pressure was extremely low. Therefore, angling does not explain the high losses of wild trout but does point out their stressed condition.

The actual mechanisms that cause declines in wild fish numbers when hatchery fish are stocked is not totally understood, but disruption of existing social behavior may be a major factor. A number of investigators have observed a relatively stable social hierarchy in wild trout populations based on size of the fish. Jenkins (1969) and Newman (1956) found adult brown trout and rainbow trout showed aggressive behavior between individuals at drift feeding sites. These aggressive interactions were relatively stable in wild trout, minimized by ranking of trout according to size. Bachman (1982) suggested that, because significant social interaction occurred during feeding, the number of available feeding sites may determine the carrying capacity of a stream. If this were true, any significant disruption of the stable social hierarchy may lead to stresses which could significantly reduce the stream's natural carrying capacity.

Other investigators have studied changes in resident wild populations when alien fish or animals are introduced. McLaren (1979) found that hatchery-reared brown trout, when placed in a seminatural stream environment, were more active, fed more frequently, and exhibited greater antagonistic behavior than their wild counterparts. Bachman (1982) found hatchery brown trout disrupted the stable social structure that existed in wild trout populations prior to stocking, and they engaged in frequent long antagonistic encounters with the wild trout that resulted in some wild trout becoming exhausted. Butler (1975) suggested that imposing hatchery trout upon wild trout resulted in a condition similar to Selye's (1973) general adaptation syndrome, in which an animal placed in a high density situation suffers physiological changes resulting in the death of the individual. Davis (1949) observed that when alien rats were introduced into stable rat populations, the native rats actually decreased due to the stresses of accelerated social turmoil and competition.

Management Implications

The practice of stocking catchable-size hatchery trout into most self-sustaining wild trout streams has some serious management implications. Stocking catchables can reduce the number of wild trout available to anglers, can be an expensive program for wildlife agencies to carry out over the years, and may cause some genetic alteration of the wild stocks. Kruger and Menzel (1978) found that long-term stocking of hatchery brook trout in nine brook trout streams in Wisconsin altered certain alleles in wild brook trout. Correlations were noted between the number of years a stream was stocked and the degree of genetic alteration. Changes in genetics were not attributed to interbreeding but to the selection of wild brook trout compatible with the hatchery brook trout in that environment. These genetic alterations may cause more long-term problems to wild trout than the direct losses described in this study. Use of hatchery plants in self-sustaining wild trout fisheries should be avoided, but there are other desirable stocking possibilities such as in lakes, ponds, and streams where no natural reproduction is possible and where angler use is high enough to quickly remove hatchery trout. There would be no serious impact on wild fisheries in put-and-take situations where high harvest rates make the economics more favorable and eliminate any change of genetic degradation of wild trout strains. Management of self-sustaining wild trout streams would be better directed to maintaining or enhancing riparian habitat, maintaining adequate water flows, and applying appropriate catch regulations.

Acknowledgments

This study was funded in part through Federal Aid in Fish Restoration, Project F-9-R. I would like to acknowledge the help of John "Bud" Gaffney, LeRoy Ellig, Art Whitney, Ron Marcoux, and George Holton, without whose assistance the study could not have been done. Special thanks go to Bob White, Jerry Wells, and Fred Nelson for their editing and review of the manuscript. Bob McFarland and Burwell Gooch assisted with the statistical analyses. Also thanks go to Wayne Black and Jeff Bagdanov, who did the graphics.

References

Bachman, R. A. 1982. Foraging behavior of free ranging wild brown trout (*Salmo trutta*) in a stream. Doctoral dissertation. Pennsylvania State University, University Park.

Brynildson, D. M., and L. M. Christenson. 1961. Survival, yield, and coefficient of condition of hatchery-reared trout stocked in Wisconsin waters. Wisconsin Department of Conservation, Miscellaneous Report 3 (Fisheries), Madison.

Butler, R. L. 1975. Some thoughts on the effects of stocking hatchery trout on wild trout populations. Pages 83–87 *in* W. King, editor. Proceedings of the wild trout management symposium, Trout Unlimited, Washington, D.C.

Butler, R. L., and D. P. Borgeson. 1965. California "catchable" trout fisheries. California Department of Fish and Game, Fish Bulletin 127.

Davis, D. E. 1949. The role of intraspecific competition in game management. Proceedings of the North American Wildlife Conference 14:225–231.

Jenkins, T. M. 1969. Social structure, position choice and microdistribution of two trout species (*Salmo trutta* and *Salmo gairdneri*) resident in mountain streams. Animal Behavior Monographs 2:57–123.

Kruger, C. C., and B. W. Menzel. 1978. Genetic impacts of stocking upon wild brook trout populations in Wisconsin. Pages 169–179 *in* J. R. Moring, editor. Proceedings of the wild trout–catchable trout symposium. Oregon Department of Fish and Game, Corvallis.

Mason, J. W., D. M. Brynildson, and P. E. Degurse. 1967. Comparative survival of wild and domestic strains of brook trout in streams. Transactions of the American Fisheries Society 96:313–319.

McLaren, J. B. 1979. Comparative behavior of hatchery-reared and wild brown trout and its relation to intergroup competition in a stream. Doctoral dissertation. Pennsylvania State University, University Park.

McMullan, S. L. 1982. Inventory and survey of the waters of the Big Hole and Beaverhead drainage. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-30, Job Ib, Helena.

Miller, R. B. 1958. The role of competitors on the mortality of hatchery trout. Journal of the Fisheries Research Board of Canada 15:27–45.

Nelson, R. A., and E. R. Vincent. 1978. Inventory and survey of the project area. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-26, Job Ia, Helena.

Newman, M. A. 1956. Social behavior and interspecific competition in two trout species. Physiological Zoology 29:64–81.

Petrosky, C. E. 1984. Competitive efforts from stocked catchable-size rainbow trout on the wild trout population dynamics. Doctoral dissertation. University of Idaho, Moscow.

Ricker, W. R. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 119.

Seber, G. A. F. 1973. Estimation of animal abundance and related parameters. Griffin, London.

Selye, H. 1973. The evolution of the stress concept. American Scientist 61:692–699.

Shetter, D. S. 1947. Further results from spring and fall plantings of legal-sized, hatchery-reared trout in streams and lakes of Michigan. Transactions of the American Fisheries Society 74:35–58.

Snedecor, G. W. 1956. Statistical methods applied to experiments in agriculture and biology. Iowa State College Press, Ames.

Snow, H. E. 1974. Effects of stocking northern pike in Murphy's Flowage. Wisconsin Department of Natural Resources Technical Bulletin 79.

Thuember, T. 1975. Fish and the blue ribbon streams. Wisconsin Conservation Bulletin 40:16–17.

U.S. Geological Survey. 1966–1976. Water survey data for Montana. Helena, Montana.

Vincent, E. R. 1969a. Evaluation of river fish populations. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-17, Job 7, Helena.

Vincent, E. R. 1969b. Madison River creel census. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-16, Job Ia, Helena.

Vincent, E. R. 1970. Evaluation of river fish populations. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-18, Job 7, Helena.

Vincent, E. R. 1971. River electrofishing and fish population estimates. Progressive Fish-Culturist 33: 163–169.

Vincent, E. R. 1982. Fish population estimate techniques in Montana. Proceedings of the Annual Conference Western Association of Fish and Wildlife Agencies 62:109–115.

F-13-J

North American Journal of Fisheries Management 7:91–105, 1987

Effects of Stocking Catchable-Size Hatchery Rainbow Trout on Two Wild Trout Species in the Madison River and O'Dell Creek, Montana

E. RICHARD VINCENT

Montana Department of Fish, Wildlife and Parks, 8695 Huffine Lane Bozeman, Montana 59715, USA

Abstract.—The fall population of 2-year-old and older wild brown trout (*Salmo trutta*) more than doubled (160% increase), in both total numbers and biomass, 4 years after the last catchable-size hatchery rainbow trout were stocked in the Varney section of the Madison River, Montana; wild rainbow trout (*Salmo gairdneri*) numbers increased eight times (868%) and their biomass increased 10 times (1,016%) during the same period. Brown trout biomass peaked within 2 years after stocking ceased, whereas wild rainbow trout biomass continued to increase for 4 years. Numbers of wild brown and rainbow trout 10.0–17.9 in long showed the greatest increases after stocking ceased. Flow variations had little effect on the total biomass of 2-year-old and older wild trout during stocking years ($t = 1.24$), but stocking had a significant negative correlation ($r = -0.953$) with total biomass. When catchable-size hatchery rainbow trout were stocked for three consecutive years into a previously unstocked section of O'Dell Creek, Montana, the 2-year-old and older wild brown trout population was reduced 49% in total number and biomass. Wild brown trout 10.0–17.9 in long showed significant declines in numbers after stocking was initiated, whereas those smaller than 10.0 in showed no significant change in numbers. A temporary decline in growth rates of yearling through 4-year-old brown trout was observed in O'Dell Creek during the first 2 years of stocking. Measurable movement of marked wild trout in the lower (stocked) section of O'Dell Creek accelerated during years of stocking. Stocking of catchable-size hatchery rainbow trout had no detectable adverse effect on wild brown trout through their first 18 months of life in either lower O'Dell Creek or the Varney section of the Madison River.

The use of hatchery-reared, catchable-size trout to supplement existing wild stream-dwelling trout populations has been an accepted fisheries management practice. However, little attention has been given to any effects stocking had on the wild trout. Some studies have examined stresses on hatchery trout stocked in trout streams. Miller (1958) found that hatchery trout lost weight and had high initial mortality when stocked in sections of George Creek, Alberta, with resident wild cutthroat trout (*Salmo clarki*). He attributed these losses to stress from social struggles between hatchery and resident wild trout. Shetter (1947), Brynildson and Christenson (1961), and Mason et al. (1967) found higher survival of stocked hatchery trout in streams with the lowest numbers of wild trout, which suggested detrimental social interaction with wild trout.

This study was conducted in 1967–1976 to evaluate the effect of stocking catchable-size, hatchery-reared rainbow trout (*Salmo gairdneri*) into two Montana streams supporting self-sustaining wild brown trout (*Salmo trutta*) and wild rainbow trout populations. The primary objectives of the study were to determine: (1) if wild trout populations were affected by stocking; (2) what size or age-groups, if any, were affected; and (3) if stocking did have adverse effects, what the length of the recovery period was after stocking was discontinued. Other factors examined were growth, mortality, movement, angling pressure, and flow levels.

Prior to 1948, little annual stocking of hatchery-raised trout occurred in the Madison River and O'Dell Creek because wild brown and rainbow trout were able to sustain a fishery via natural reproduction. From 1948 to 1954, stocking was limited to small (2–5-in-long) brown and rainbow trout in both the Madison River and O'Dell Creek. The first catchable-size (8–12-in) rainbow trout were stocked in 1955. By 1969, annual stocking had increased to an average of 1,600 fish/mi for the 51-mi section of the Madison River from Quake Lake to Ennis Reservoir (Figure 1). Catchable-size fish were stocked monthly from April through August with some stream reaches receiving more fish than others due to more favorable access. Stocking was discontinued in the 6-mi section from Varney bridge to Burnt Tree in 1970 and in the remaining 45 mi of the middle Madison River in 1974. From 1955 to 1964, O'Dell Creek received a small number of catchable-size rainbow trout.

From wild trout population estimates for the Norris and Varney study sections, estimated total

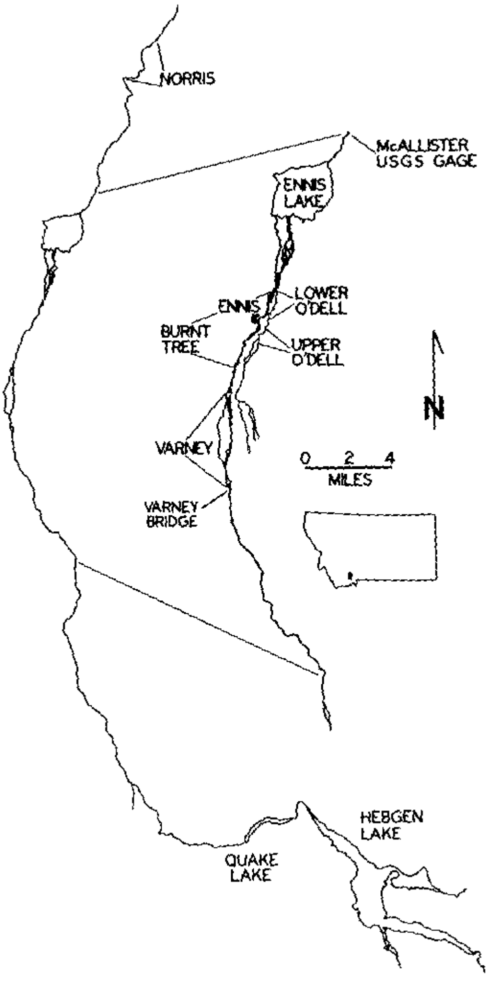

FIGURE 1.—Map of the Madison River and O'Dell Creek study areas.

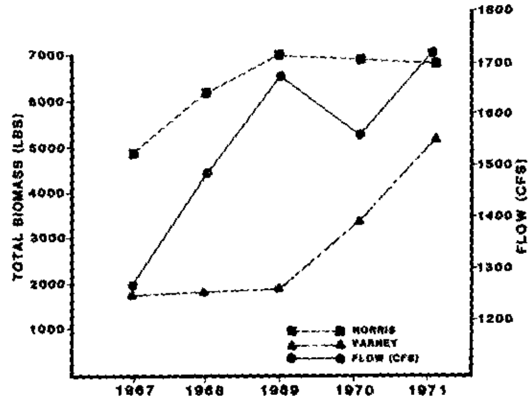

FIGURE 2.—Comparison of mean winter (December 1–April 30) flow (cubic feet per second) to estimated total biomass (lb) of 2-year-old and older wild brown and rainbow trout in each of two sections of the Madison River, 1967–1971. Norris estimates were made in April, Varney estimates in September.

biomasses (lb/4-mi section) of 2-year-old and older wild brown and rainbow trout were compared with mean winter flows (December 1–April 30) preceding the estimates (Figure 2). April estimates for the Norris section showed that, as the mean winter flow increased from 1967 to 1969, the total pounds of wild trout increased. However, September estimates of wild trout biomass from the Varney section showed no appreciable change. A correlation between mean winter flow and total biomass (lb/mi) showed that mean winter flow fluctuations accounted for 87% ($r = 0.9347$) of the variation in wild trout biomass in the Norris section, but only 34% ($r = 0.583$) of the variation in the Varney section. The correlation was significant ($P < 0.05$) for the Norris section ($t = 4.55$), but not significant for the Varney section ($t = 1.25$). Some factors other than flow must have been controlling wild trout biomass in the Varney section. Overharvest of larger trout by anglers was ruled out as one of the factors due to lower (18%) angler use in the Varney section (Vincent 1969a). One major difference between the sections was that the Varney section had been stocked annually since 1955 with catchable-size rainbow trout, whereas the Norris section had received none after 1960.

Study Area

Madison River.—The Madison River originates in Yellowstone National Park with the junction of the Gibbon and Firehole rivers in Wyoming. It enters Montana via the northwestern corner of the park, then flows 120 mi in a northerly direction before joining the Gallatin and Jefferson rivers to form the Missouri River. Its total drainage area is approximately 2,500 mi^2.

Fish native to the Madison River are cutthroat trout, Arctic grayling (*Thymallus arcticus*), mountain whitefish (*Prosopium williamsoni*), mountain sucker (*Catostomus platyrhynchus*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), longnose dace (*Rhinichthys cataractae*), and mottled sculpin (*Cottus bairdi*). Brown trout, rainbow trout, and brook trout (*Salvelinus fontinalis*) were introduced into the Madison River during the late 1800s. Utah chub (*Gila atraria*) was introduced into Hebgen Reservoir by fishermen in the 1930s and subsequently gained access to the Madison River.

Two 4-mi-long study sections were established on the Madison River: Varney, 41 mi downstream from Quake Lake; and Burnt Tree, 1.5 mi downstream from the lower boundary of the Varney section (Figure 1). These two study sections were located within a reach of river characterized by a braided channel with long riffles interspersed with fast runs and a few pools having maximum depths of 7 ft. The average stream width was approximately 200 ft and the average stream gradient was 30 ft/mi. Woody vegetation covered much of the banks and undercut areas provided good cover for trout. The streambed consisted of large- to medium-size rocks with ample areas of smaller spawning-size gravel. The average annual discharge at the U.S. Geological Survey McAllister gage (9.7 mi below the end of the Burnt Tree section) was 1,400 ft^3/s, with peak flows near 5,000 ft^3/s in June and a low flow of about 1,000 ft^3/s for the winter months of December–March (U.S. Geological Survey 1966–1975).

O'Dell Creek.—O'Dell Creek, a tributary to the Madison River, originates near Varney bridge and flows northward, parallel to the Madison, for approximately 10 mi. The primary water source is a series of springs emerging along the east side of the Madison River. It has a very sinuous riffle–pool channel that flows through the brushy Madison River floodplain. Flows are usually very stable (approximately 100 ft^3/s) except during some winter periods when ice gorging on the Madison River diverts some water into the O'Dell channel. Because of its more stable flows and lower gradient (20 ft/mi), the streambed has a much finer substrate than the Madison River.

Fish native to O'Dell Creek are the same as those found in the Madison River. Nonnative game fish found in O'Dell Creek include brown, rainbow, cutthroat, and brook trout. The bushy undercut banks and overhanging vegetation provide ideal habitat for brown trout, the predominant species.

Two study sections were established on O'Dell Creek. The lower section, ending 0.5 mi from the mouth, was 1.8 mi long; the upper section was 1.0 mi long. The average channel width was 25 ft for the upper section and 35 ft for the lower section; maximum depths reached 8 ft.

Methods

Population estimates were made in the spring (April–May) and fall (September) for each study section when possible. Fish were sampled from an electrofishing boat floating through the study section. The boat contained a stationary negative electrode, a mobile positive electrode, a portable 2,500-W AC generator with a rectifying unit, and a live box to retain captured fish. Captured fish were weighed periodically to the nearest 0.02 lb, measured to the nearest 0.1 in, marked, and released within the study section. Fish were marked either with a partial fin clip or tagged with a numbered Floy anchor tag.

Population estimates were made by the Peterson mark-and-recapture method with an adaptation of formula 4 of Ricker (1958). The multiple mark-and-recapture method was used in the Madison River estimates, where the daily trip capture efficiencies ranged from 5 to 7%. The single mark-and-recapture method was used in O'Dell Creek where daily trip capture efficiencies ranged from 25 to 35%. A 7–14-d interval was allowed between marking and recapture periods to allow sufficient time for marked trout to randomly mix with unmarked trout. Estimates of total numbers, total weight, numbers per size group, numbers per age-group, and mortality rates were made by methods described by Vincent (1971, 1982). Variances for total number and weight were obtained by using Seber's (1973) formula. Confidence intervals were calculated at the 95% level.

Student's t-test was used to test the null hypotheses of no difference between the mean weight or numbers of wild fish in stocking years versus nonstocking years. A normal distribution was assumed in all comparisons. In no instances were t-tests used where a heterogeneous variance was detected, as determined by an F-test (Snedecor 1956). When two or more population estimates were averaged to make stocking and nonstocking comparisons, the variances for each estimate were incorporated into the statistical t-test analysis. All levels of significance were at the 5% level or less. A linear regression was used to determine correlations of mean winter flow with total biomass of 2-year-old and older wild trout in the Madison River and of stocking with total biomass.

The Varney section was set up as the primary study section, where stocking of catchable fish had been continuous from 1955 through 1969. With the end of stocking in this section in 1970, a comparison of wild trout populations during stocking (1967–1969) and nonstocking periods (1970–1976) could be made. However, an unscheduled stocking of catchable fish during the summer of 1972 somewhat altered this approach.

The Burnt Tree section was used as a control, where stocking of catchable fish would continue through 1973. Any population change occurring

TABLE 1.—Spring estimates of total numbers and biomasses of 3-year-old and older wild brown trout in the Varney section of the Madison River after years rainbow trout were and were not stocked. Confidence intervals (95%) are in parentheses; values of t above 2.78 are significant ($P \leq 0.05$).

	Year after stocking					Year after nonstocking			
Total	1967	1968	1969	1970	Aver-age	1971	1972	Aver-age	t-value
Number (fish/mi)	261 (±123)	247 (±172)	300 (±114)	255 (±96)	266	354 (±137)	432 (±198)	393	4.25
Biomass (lb/mi)	365 (±153)	408 (±110)	417 (±147)	377 (±108)	392	478 (±169)	570 (±293)	524	3.92

in the Varney section after stocking ceased was compared with population changes in the stocked Burnt Tree section to rule out or confirm that factors other than stocking could have caused any change. This section had very similar habitat conditions to the Varney section. Even if each section had some natural differences in total wild trout biomass, both sections were exposed to the same flow levels, water temperatures, and other climatic trends.

O'Dell Creek had not experienced any appreciable stocking of catchable fish prior to this study; the last stocking had occurred in 1964. The lower O'Dell Creek section was monitored for 3 years (1967–1969) under a nonstocking sequence, followed by three consecutive years of stocking (1970–1972), then three additional years of nonstocking (1973–1975). Approximately 4,000–4,500 catchable-size rainbow trout were stocked in each of the planting years over a lower 1.8-mi section. An upper section was maintained as a field control where a nonstocking policy was in effect (1970–1974). Both the upper and lower study sections had very similar habitat conditions, although water flows were 20–30% higher in the lower section.

Each major study section was divided into smaller subsections 1,250–2,500 ft long in order to study fish movement. Wild trout from each subsection were marked with a Floy anchor tag. Recapture information was gathered either from subsequent electrofishing operations or from angler tag returns. Angler tag returns also were used to estimate a relative yearly angling pressure or harvest. It was assumed that the ratio of tags returned to the number of fish actually caught by anglers was constant throughout the study period. Identification of hatchery rainbow trout in the stream was based on the degree of eroded and deformed fins, especially the dorsal. Hatchery trout examined prior to stocking exhibited such extreme erosion of the dorsal and pectoral fins that no appreciable portion of these fins remained. The average size of the catchable rainbow trout was 12 in long when planted. Since few wild rainbow trout in O'Dell Creek exceeded 8 in, identification of hatchery rainbow trout was even more accurate there.

Wild trout responses to stocking or nonstocking carried beyond 1 year and it was necessary to place fall trout estimates into categories based on the length of time from the last stocking or nonstocking date. These categories for brown trout and rainbow trout were: (1) "stocking" years—stocking had occurred for at least two consecutive summers prior to the estimates; (2) "transition" years—the estimate had been preceded by only one summer of stocking or nonstocking; and (3) "post-stocking" years—at least two consecutive summers of no stocking preceded the estimate. These categories were not used for spring estimates due to insufficient numbers of spring estimates after stocking ceased in the Madison River and lower O'Dell Creek.

Mean winter discharge rates (ft^3/s) were computed from December 1–April 30 discharge rates at the McAllister water-level gage located 1.5 mi below Ennis Dam. The winter flow period was selected because it is the low-flow period each year. If flows were controlling population changes, some correlation between these variables could be expected.

Results

Madison River

Brown trout.—Spring estimates of number and biomass of 3-year-old and older brown trout in the Varney section showed immediate increases in 1971 following the first summer (1970) of no stocking (Table 1). By the second spring (1972), total biomass had increased 34% over the 1967–1969 average. Statistically significant differences were found in both biomass and number of fish between stocking and nonstocking years.

Fall biomass estimates of 2-year-old and older

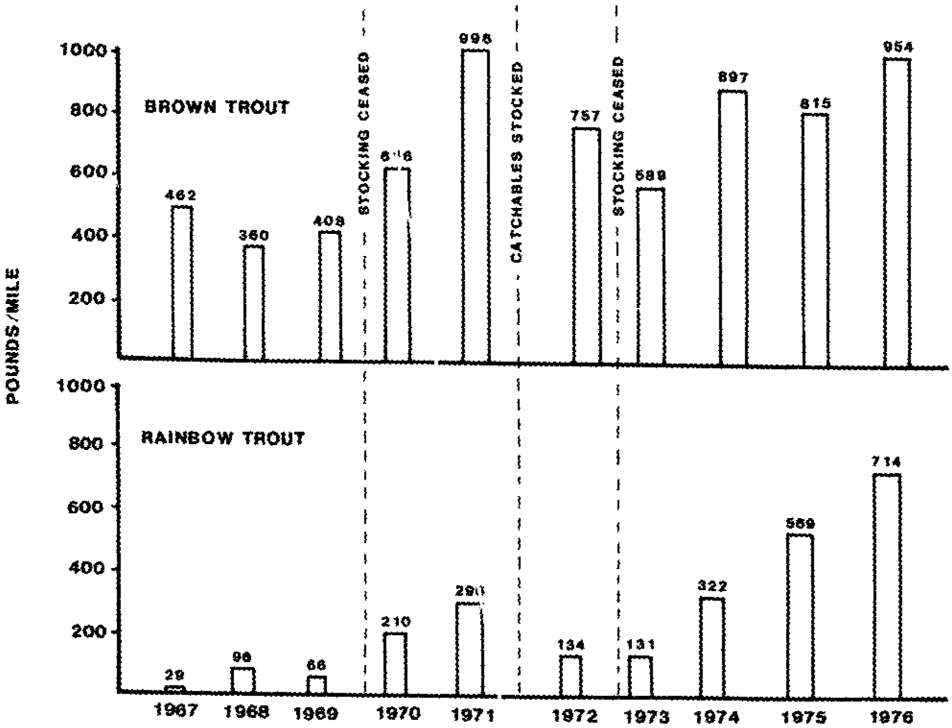

FIGURE 3.—Fall biomass (lb/mi) estimates for 2-year-old and older wild brown and rainbow trout in the Varney section of the Madison River during years when rainbow trout were and were not stocked.

brown trout also showed immediate increases following the 1970 cessation of stocking. By September 1971, the total biomass had increased 143% from the 1967–1969 average (Figure 3). Following an unscheduled stocking of catchable rainbow trout during the summer of 1972, the brown trout biomass declined 24% from its September 1971 level. After two more years of no stocking (1973–1974), the September 1974 brown trout biomass estimate was within 11% of the 1971 levels. Comparisons of mean numbers and biomasses for 2-year-old and older brown trout between stocking (1967–1969) and poststocking years (1971, 1974–1976) showed values in the latter years to be 153 and 123% higher, respectively, the differences being statistically significant (Table 2). Mean numbers and biomasses for the transitional years (1970, 1972, and 1973) were between means for stocking and poststocking years, and were significantly greater than those for stocking years.

All age-groups of brown trout increased in numbers when stocking ceased. Mean numbers and biomasses of 2- and 3-year-olds showed significant increases of 169 and 142%, respectively between stocking and poststocking periods. Four-year-old and older brown trout also showed large increases in mean numbers in two of the four poststocking years, but the overall increase of 120% was not statistically significant (Table 2).

To determine whether or not certain sizes of brown trout were more affected by stocking than others, fish from the fall numerical estimates were separated into three size categories (Table 3). Only the brown trout 10.0–17.9-in size group showed a significant increase in numbers following the cessation of stocking.

When stocking years for the Varney section (1967–1969) and the Burnt Tree control section (1971–1973) were compared, no significant difference in the biomasses of 2-year-olds and older was found. This would suggest similar populations for brown trout in the two sections. In 1971, the poststocking biomass of 2-year-old and older brown trout in the Varney section was 122% greater than the biomass in the stocked Burnt Tree section (Table 4). Since the 95% confidence intervals do not overlap between the two estimates, the difference is considered significant. The 1972 and 1973 comparisons between the two sections are comparisons of stocking years (Burnt Tree) versus transition years (Varney), when the Varney section showed a significant 39% increase over the Burnt Tree

TABLE 2.—Fall population and biomass estimates of wild brown trout for the Varney section of the Madison River during years rainbow trout were and were not stocked. Confidence intervals (95%) are in parentheses; t-values are shown for comparisons between stocking and poststocking years, and values of t greater than 2.57 are significant ($P < 0.05$).

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Stocking years[a]			
1967	395	201	99	55	355 (±129)	462 (±168)
1968	1,060	154	95	38	287 (±75)	360 (±96)
1969	788	171	102	44	317 (±117)	408 (±150)
Average	748	175	99	46	320	410
			Transition years[b]			
1970	997	231	139	69	439 (±113)	616 (±158)
1972	753	386	189	95	670 (±248)	757 (±280)
1973	902	426	89	72	587 (±153)	589 (±154)
Average	884	348	139	79	565	654
			Poststocking years[c]			
1971	924	407	192	165	764 (±229)	996 (±298)
1974	1,003	542	258	51	851 (±230)	897 (±242)
1975	1,209	465	256	78	799 (±124)	815 (±126)
1976	1,969	468	254	109	831 (±220)	954 (±253)
Average	1,276	471	240	101	811	916
			t-value			
	1.69	8.92	7.75	1.88	17.90	10.08

[a] Estimates made in years preceded by two or more summers of stocking.
[b] Estimates made in years preceded by one summer of stocking or no stocking.
[c] Estimates made in years preceded by two or more summers of no stocking.

section (Table 4). The first fall estimates following cessation of stocking in the Burnt Tree section showed a 74% increase in the 2-year-old and older brown trout biomass over the average for 1971–1973.

Rainbow trout.—Following the cessation of stocking after 1969, there was an immediate increase in the fall population of 2-year-old and older wild rainbow trout in 1970 in the Varney section (Figure 3) and, by September 1971, the rainbow trout biomass had increased three-fold (363%) over the average during the 1967–1969 stocking period. After the unscheduled summer 1972 stocking, the biomass decreased 55% in 1972 and 1973 from that of September 1971, then proceeded to increase dramatically. By 1976, after four consecutive years of no stocking, the total biomass had increased 11-fold over the mean during the stocking years. Similar comparisons by age-group showed that yearlings increased 474%, 2-year-olds 640%, and 3-year-old and older fish 942% over the 1967–1969 means (Table 5). The differences were not statistically evaluated due to heterogeneous variances caused by the large annual increases in numbers. However, comparisons of mean numbers and biomass of all 2-year-old and older wild rainbow trout between stocking and poststocking years showed the latter values to be 733 and 642% higher, respectively, the differences being statistically significant.

Fall wild rainbow trout population estimates also were separated into two size groups to determine if there was a size-related response to stocking in the Varney section (Table 3). Both the 10.0–17.9-in and the larger size groups showed large increases in numbers after stocking ceased. The mean number of 18-in and larger rainbow trout quadrupled after stocking ceased. There was a statistically significant increase in the 10.0–17.9-in group also. In the Burnt Tree section, the first fall estimate of 2-year-old and older wild rainbow trout (1974) following the cessation of stocking showed a 317% increase in numbers and a 145% increase in biomass over the mean for the 1971–1973 stocking years.

Population estimates of hatchery-reared fish in the Varney section were made each fall during the stocking years to evaluate their survival rates. These numerical estimates ranged from 32/mi in 1972 to 151/mi in 1969. The average biomass estimate

TABLE 3.—Fall population estimates (number/mi) for various size groups of wild brown and rainbow trout during stocking and poststocking years for the Varney section of the Madison River. Values of t greater than 2.57 are significant ($P < 0.05$).

Year	5.0–9.9[a] Brown trout	10–17.9 Brown trout	10–17.9 Rainbow trout	18.0 and larger Brown trout	18.0 and larger Rainbow trout
		Stocking years[b]			
1967	381	328	32	40	1
1968	1,019	303	96	25	2
1969	776	300	67	29	5
Average	725	310	65	31	3
		Poststocking years[c]			
1971	925	669	262	93	16
1974	1,040	791	417	19	7
1975	1,256	730	714	18	4
1976	1,962	795	552	37	20
Average	1,296	746	486	42	12
		t-value			
	1.89	9.30	2.82	0.54	

[a] No estimates for rainbow trout due to insufficient sample sizes.

[b] Estimates made in years preceded by two or more summers of stocking.

[c] Estimates made in years preceded by at least two summers of no stocking.

for these surviving hatchery fish was 40 lb/mi. Spring electrofishing yielded too few hatchery fish to make estimates. Estimates of the number and biomass of hatchery rainbow trout in the Burnt Tree section averaged 128/mi and 91 lb/mi, respectively, for the 1971–1973 period.

Effect of flow rates.—Total biomass of 2-year-old and older wild brown and rainbow trout was compared with mean winter flow for both stocking and nonstocking years in the Madison River (Figure 4). When total biomasses in stocking years were compared to mean winter flows, no significant correlation was found ($r = 0.538$, $t = 1.24$), whereas a correlation was significant for poststocking years ($r = 0.740$; $t = 2.69$). This indicates that stocking was limiting the numbers of 2-year-old and older wild trout. Numbers of yearling brown trout increased significantly with increased flow levels during both stocking ($r = 0.8949$, $t = 4.48$) and poststocking ($r = 0.9302$, $t = 5.78$) years.

Mortality.—Annual mortality of 2-year-old and older wild brown trout was similar between stocking and poststocking years—55 and 58%, respectively. During transitional periods following cessation or initiation of stocking, however, mortality rates deviated from the norm. After stocking ceased, the average annual mortality was 33%, whereas it was 70% following the 1972 stocking. Summer mortality rates of wild trout averaged 43% for the stocking years versus less than 20% for poststocking years. Winter mortality rates for yearling brown trout were highest in the stocking years (68%) and lowest in poststocking years (16%).

Movement.—No comparisons were made of differential movement between stocking and nonstocking years. To determine if movement could explain some of the changes in the Varney study section, tag returns from electrofishing of wild trout were used. Twenty-five percent of the brown trout and 29% of the rainbow trout sampled moved more than 2,000 ft. Seven percent of the brown trout and 8% of the rainbow trout moved distances greater than 1.5 mi. No substantial directional movement was detected—45% of the tag returns showed movement upstream and 55% downstream. Hatchery rainbow trout that were stocked either in the lower 1 mi or upper 0.5 mi of the Varney section dispersed throughout the Varney area.

Angling pressure.—Angling pressure was not measured directly in the study sections but some

TABLE 4.—Fall biomass estimates of 2-year-old and older wild brown trout in the Varney and Burnt Tree sections of the Madison River (1971–1973). Confidence intervals (95%) are in parentheses.

Year	Biomass (lb/mi): Burnt Tree, stocking[a]	Varney: Poststocking[b]	Varney: Transitional[c]	Difference (%)
1971	448 (±123)	996 (±298)		122
1972	405 (±101)		756 (±280)	87
1973	565 (±120)		589 (±154)	4
Average (1972–1973)	485		673	39

[a] Estimates made in years preceded by two or more summers of stocking.

[b] Estimate made in year preceded by two summers of no stocking.

[c] Estimates made in years preceded by one summer of stocking or no stocking.

TABLE 5.—Fall population and biomass estimates of wild rainbow trout for the Varney section of the Madison River during stocking and nonstocking years. Confidence intervals (95%) are in parentheses; t-values are shown for comparison of stocking and poststocking years, and are significant ($P < 0.05$).

Year	Number of fish/mi			Age II+ and older fish	
	Age I+	Age II+	Age III and older	Number/mi	Biomass (lb/mi)
			Stocking years[a]		
1967	82	30	5	35 (±22)	29 (±18)
1968	[b]	64	28	92 (±65)	96 (±68)
1969	[b]	32	25	57 (±40)	66 (±47)
Average	82	42	19	61	64
			Transition years[c]		
1970	217	186	45	231 (±95)	210 (±104)
1972		26	79	105 (±43)	135 (±58)
1973	644	74	40	114 (±47)	131 (±108)
Average	431	95	55	150	159
			Poststocking years[d]		
1971		184	97	281 (±104)	296 (±104)
1974	622	389	45	434 (±166)	322 (±107)
1975	350	471	256	727 (±174)	569 (±136)
1976	440	198	393	591 (±269)	714 (±325)
Average	471	311	198	508	475
			t-value		
				3.00	2.64

[a] Estimates made in years preceded by two or more summers of stocking.
[b] No estimates due to insufficient sample size.
[c] Estimates made in years preceded by one summer of stocking or no stocking.
[d] Estimates made in years preceded by two or more summers of no stocking.

information on angler use was available. Vincent (1969b) estimated that fishing pressure on the 51 mi of the Madison River between Quake and Ennis lakes averaged 680 angler-days per mile in 1969. A statewide survey estimated angling pressure for this reach to be 953 angler-days per mile in 1975. This was an increase in angling pressure of 40%, so there was much more angling pressure in nonstocking years than in stocking years. Tag returns from 3-year-old and older trout caught by anglers were used as an indicator of relative harvest between study years. Tag returns declined from 12% in stocking years (1967–1969) to 8% in nonstocking years (1970–1971) for brown trout; there was a 4% drop for wild rainbow trout as well. Although the percent harvest decreased for brown trout and wild rainbow trout in the nonstocking years, the larger populations present in the nonstocking year 1971 made the total harvests similar between stocked and unstocked years.

O'Dell Creek

Brown trout.—Little change between 1970 spring and fall biomasses of 2-year-old and older wild brown trout was noted following the June–July stocking of 4,000 hatchery-reared, catchable-size rainbow trout that year (Figure 5). However, biomass estimates made the following spring (1971) showed a 39% decrease from the 1967–1969 prestocking average. With continued stocking in 1971, a further decline was observed, the spring 1972 biomass estimate being 57% below the 1967–1970 average. Stocking continued in 1972, but further declines were not measured. After stocking ceased in 1973, the spring 1974 biomass estimate returned to the prestocking average of 332 lb/mi.

Mean spring biomasses of 2-year-old and older brown trout were significantly higher (42%) in nonstocking than in stocking years ($t = 4.79$; Table 6). No significant difference was found in the mean numbers of 2-year-old and older fish, although there was an estimated 25% reduction in mean numbers during the stocking years, due to the large number of 2-year-olds found in the spring 1973 estimate. Spring yearling numbers were not significantly different between stocking and nonstocking years. Only 3-year-old brown trout showed a significant (47%) decline in mean numbers during the stocking years. However, 2- and 4-year-old fish declined 15 and 23%, respectively. Comparison of

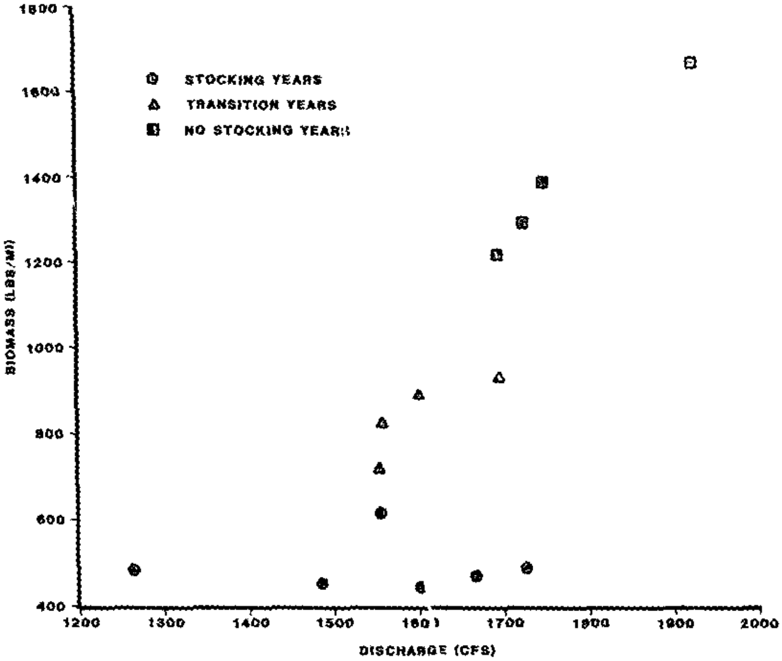

FIGURE 4.—Total biomass (lb/mi) estimates for all 2-year-old and older wild brown and rainbow trout during stocking, transition, and poststocking years in the Madison River in relation to mean winter (December 1–April 30) flow (cubic feet per second) at the McAllister gage.

size groups between stocking and nonstocking years illustrates the changes in the population structure better than age-groups (Table 7). Brown trout smaller than 10 in showed no significant difference in numbers between stocking and nonstocking years. Spring 2-year-old brown trout ranged in size from 8.0 to 11.9 in. During the prestocking years 1967–1970, 10-in and longer brown trout composed 56% of this age-group, 24% during the stocking years 1971–1973, and back to 50% for the nonstocking year 1974, indicating the effect of stocking was keyed more to size than age. All inch-groups from 10.0 to 17.9 showed decreases in mean numbers from nonstocking to stocking years; the

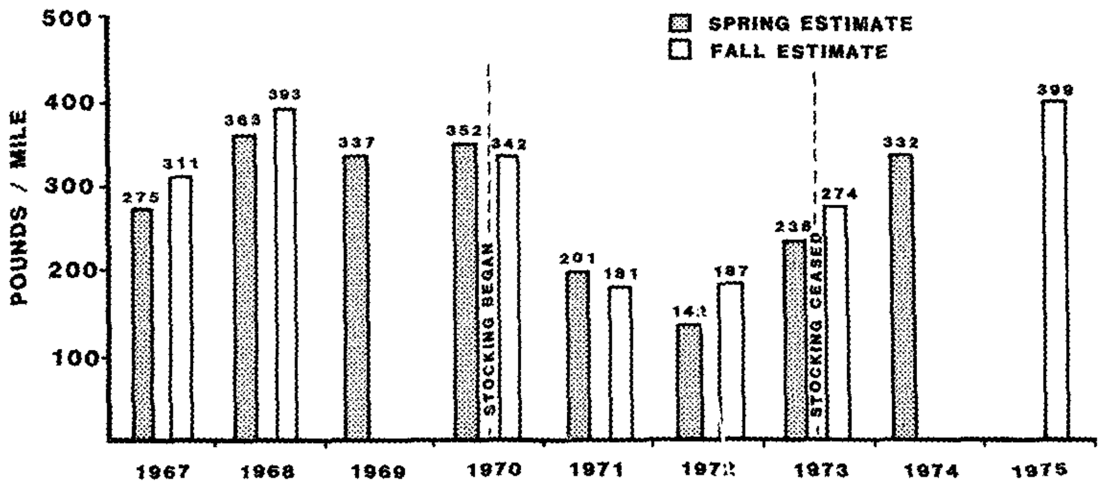

FIGURE 5.—Spring and fall biomass estimates (lb/mi) for 2-year-old and older wild brown trout before, during, and after stocking of rainbow trout in the lower section of O'Dell Creek (1967–1975).

TABLE 6.—Spring population and biomass estimates for wild brown trout for years after rainbow trout were and were not stocked in the lower study section of O'Dell Creek. Confidence intervals (95%) are shown in parentheses. Values of t above 2.45 are significant ($P < 0.05$).

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Nonstocking years			
1967	669	311	112	34	457 (±76)	275 (±46)
1968	652	339	148	48	535 (±76)	363 (±51)
1969	660	323	135	44	502 (±70)	337 (±50)
1970	1,116	322	193	52	567 (±73)	352 (±45)
1974	1,008	402	153	58	613 (±104)	332 (±56)
Average	821	339	148	47	535	332
			Stocking years			
1971	857	244	99	40	383 (±84)	201 (±44)
1972	772	188	61	31	280 (±43)	142 (±22)
1973	1,128	431	75	37	543 (±60)	238 (±27)
Average	919	288	78	36	402	194
			***t*-value**			
	0.63	0.88	3.60	1.93	2.01	4.79

totals were significantly different. The numbers of 18.0-in and larger brown trout declined 78% from nonstocking to stocking years, but statistical differences were not calculated due to heterogeneous variances caused by the 1974 estimate. The 1974 estimate of 18.0-in and larger brown trout was not representative of a nonstocking year because insufficient time had elapsed for fish to grow to this size. If the 1974 data for this size group are omitted from the data, the difference between stocking and nonstocking years is significant ($t = 3.46$). In fact, numbers of brown trout in the 16.0–17.9-in size groups had not returned to prestocking levels by 1974.

TABLE 7.—Spring population estimates (number of fish/mi) for three size groups of wild brown trout for years after rainbow were and were not stocked in the lower study section of O'Dell Creek.

Year	Size group (in)		
	3.5–9.9	10.0–17.9	18.0 and larger
	Nonstocking years		
1967	784	331	11
1968	778	384	15
1969	810	343	9
1970	1,273	391	9
1974	1,215	405	1
Average	972	371	9
	Stocking years		
1971	1,053	184	2
1972	903	140	2
1973	1,341	262	3
Average	1,099	195	2
	***t*-value**		
	0.72	4.34[a]	

[a] Difference between stocking and nonstocking years was significant ($P < 0.05$).

Mean fall estimates of 2-year-old and older wild brown trout during the rainbow trout stocking years decreased 52% in number and 50% in biomass when compared to the means from the pre- and poststocking years (Table 8). Linear regression data for pre- and poststocking, transitional, and stocking years showed a significant correlation between stocking of hatchery rainbow trout and the decline of wild trout biomass levels ($r = 0.9055$; $t = 4.77$). When mean numbers for various age-groups were compared, the 1-, 2-, 3-, and 4-year-old and older age-groups were 13, 57, 56, and 7% smaller, respectively, in the stocking years; differences were statistically significant for the 2- and 3-year-old age groups.

Wild brown trout estimates (age II+) for the upper section of O'Dell Creek were used as controls because there were no significant differences in spring or fall estimates ($t = 0.43$ and $t = 0.043$, respectively) between the upper and lower sections during years of no stocking (Table 9). When mean spring biomass estimates from the unstocked upper section (1970–1974) were compared with the stocked lower section (1971–1973), the stocked lower section had a significantly lower (45%) biomass estimate ($t = 4.26$). A similar comparison of

TABLE 8.—Fall population and biomass estimates of wild brown trout during years rainbow trout were and were not stocked in the lower study section of O'Dell Creek. Confidence intervals (95%) are shown in parentheses.

Year	Number of fish/mi				Age II and older fish	
	Age I	Age II	Age III	Age IV and older	Number/mi	Biomass (lb/mi)
			Pre- and poststocking years[a]			
1967	427	228	69	32	329 (±99)	311 (±59)
1968	450	271	107	43	421 (±82)	393 (±69)
1969	b	b	119	22	b	b
1975	837	277	144	80	501 (±94)	399 (±75)
Average	571	259	110	44	417	368
			Transition years[c]			
1970	698	214	133	39	386 (±123)	342 (±53)
1973	521	229	57	49	335 (±59)	274 (±67)
Average	610	222	95	44	361	308
			Stocking years[d]			
1971	496	78	61	46	185 (±42)	181 (±31)
1972	499	143	35	36	214 (±57)	187 (±41)
Average	498	111	48	41	200	184

[a] Estimates made in years preceded by two or more summers of no stocking.
[b] Due to poor sample size, estimates were not made.
[c] Estimates made in years preceded by one summer of stocking or no stocking.
[d] Estimates made in years preceded by two or more summers of stocking.

mean fall biomass estimates between the unstocked upper section (1970–1972) and the stocked lower section (1971–1972) showed a 50% lower estimate; although this difference was not significant by the t-test ($t = 2.59$), nonoverlapping 95% confidence intervals for individual comparisons suggest significant differences.

Rainbow trout.—No population estimates were made for wild rainbow trout in either the upper or lower sections due to their extremely low numbers. Fall estimates of hatchery rainbow trout in the lower section, made after the first two summers (June–July) of stocking, averaged 198/mi with a biomass of 104 lb/mi. A third fall estimate (1972) showed 58 fish/mi (60 lb/mi). Small numbers of hatchery rainbow trout were captured in the upper section during electrofishing and probably came from sites in the lower section.

Growth.—Mean annual growth of all age-groups of brown trout, yearling through 4-year-olds, decreased during the stocking years from levels found in the nonstocking years (Table 10). No significant change was found in the summer growth rate for any age-group. All age-groups examined had lower winter growth rates in the stocking years, significantly lower for yearlings and 2-year-olds. The net result of this lower winter growth rate was a reduction in the average spring size of all age-groups older than yearlings; 2-, 3-, and 4-year-olds averaged 1.0, 1.2, and 2.0 in smaller, respectively, in the stocking years. No significant difference in average size of spring yearlings was found between stocking and nonstocking years.

Mortality.—A comparison of annual mortality rates between prestocking years and the first two

TABLE 9.—Spring and fall biomass estimates (lb/mi) of age-II+ wild brown trout during years rainbow trout were and were not stocked in the upper and lower sections of O'Dell Creek. Confidence intervals (95%) are in parentheses.

Year	Upper section, no stocking	Lower section	
		Stocking	No stocking
		April	
1967			275 (±46)
1968			363 (±51)
1969			337 (±50)
1970	367 (±21)		352 (±29)
1971	345 (±44)	201 (±28)	
1972	262 (±32)	142 (±14)	
1973	354 (±43)	238 (±17)	
1974	423 (±31)		332 (±36)
Average	350	194	332
		September	
1967			311 (±38)
1968			393 (±44)
1970	412 (±44)		
1971	398 (±61)	181 (±20)	
1972	285 (±43)	187 (±26)	
1975			399 (±84)
Average	365	184	368

TABLE 10.—Average summer (April–September), winter (September–April) and annual increases in length (in) of four age-groups of wild brown trout during nonstocking and stocking years for lower O'Dell Creek. Values of $t > 2.57$ are significant ($P < 0.05$).

Time period	Age-group I	II	III	IV
	Nonstocking years			
Summer	2.8	1.4	1.3	1.2
Winter	1.5	1.9	1.6	0.6
Annual	4.3	3.3	2.9	1.8
	Stocking years			
Summer	3.1	1.4	1.2	1.0
Winter	0.9	1.3	1.1	0.4
Annual	4.0	2.7	2.3	1.4
	***t*-value**			
Summer[a]	0.94	0.00	0.23	0.38
Winter[b]	3.52	2.64	0.75	0.63

[a] Comparisons of summer growth between stocking and nonstocking years.
[b] Comparisons of winter growth between stocking and nonstocking years.

stocking years showed an increase from 58% to an average of 76%. When the wild brown trout populations stabilized at a lower level, the annual mortality rate dropped to a rate similar to prestocking years (60%) even though stocking continued. Stocking tended to raise the summer mortality of 2-year-old and older brown trout from an average of 25% during prestocking years to 42% for the first two stocking years. Yearling brown trout mortality rates in the lower section of O'Dell Creek were 47% for the stocking years and 24% for the nonstocking years.

Movement.—Based on electrofishing returns of tagged wild trout, the rate of movement within O'Dell Creek accelerated during the stocking years. The number of brown trout moving more than 1,320 ft increased from an average of 2% in nonstocking years to 10% in stocking years. Those brown trout showing detectable movement (but moving less than 1,320 ft) increased from 19% in nonstocking years to 33% in stocking years. Based on angler tag returns an average of one tagged O'Dell Creek wild trout was caught per year in the Madison River in nonstocking years versus an average of 12/year during stocking years. Tag returns were based only on fish tagged during spring electrofishing, with an average of 240 being tagged in nonstocking years and 215 in stocked years.

Angling pressure.—There were no direct measurements of angling pressure on this stream during the period of study, but mail surveys in 1968 and 1975 estimated there were 56 angler-days per mile in 1968 and 69 per mile in 1975. Tag returns from the lower section also confirmed this low angler use—the return rate averaged only 8% for nonstocking years and 6% for stocking years.

Discussion

Populations of 2-year-old and older wild brown and rainbow trout in these two Montana streams declined significantly in numbers and total weight following the introduction of hatchery-reared, catchable-size rainbow trout. The degree of decline varied with the species, age or size, the stream being stocked, and the number of consecutive years of stocking. Other investigations also have shown decreases in wild fish populations in streams when hatchery fish were stocked. Bachman (1982) found that when hatchery brown trout were stocked into a section of Spruce Creek, Pennsylvania, wild brown trout numbers decreased below any previously measured level. Thuember (1975) found that the number of wild brook trout nearly doubled in the North Branch of the Pike River and K. C. Creek, Wisconsin, when stocking of hatchery brook trout ceased. Snow (1974) reported that when hatchery northern pike (*Esox lucius*) were stocked in Murphy's Flow, where native northern pike populations existed, wild pike numbers declined 76%. McMullian (1982) found that 7 years after rainbow trout stocking had been discontinued in the Melrose section of the Big Hole River, Montana, wild brown trout and rainbow trout increased 83 and 325%, respectively. In Big Springs Creek, Idaho, Petrosky (1984) concluded that experimental stocking rates of 2.5–5.0 catchable fish per meter had little effect on the number of wild rainbow trout present. However, further analysis of the data showed summer mortality of wild rainbow trout increased with an increase in the stocking rate of catchable-size rainbow trout. This resulted in a decline of 2-year-old and older wild rainbow trout in the fall, the degree of decline being related to the stocking rate.

Two major physical factors that can alter trout biomass in Montana streams are variations in habitat and volume of flow. During the period of study, few obvious changes were noted in the condition of the banks in either the Madison River or O'Dell Creek study sections, but some variations (both increase and decrease) in streamflow were measured in the Madison River. Nelson and Vincent (1978) found that total wild trout biomass (lb/mi) in the Gallatin River, Montana, was higher in those sections which experienced the smallest summer

(July–September) dewatering from irrigation withdrawals. In the Madison River, the low-flow period usually occurred during the winter (December 1–April 30). During the first years of this study (1967–1971), higher winter flow levels resulted in higher biomasses of 2-year-old and older wild brown and rainbow trout in the nonstocked Norris section, whereas the wild trout biomass in the stocked Varney section did not increase under the same flow regimes. The Varney and Burnt Tree sections, each having similar habitat conditions and similar flow volumes and regimes, were used to determine if mean winter flow levels had an influence on wild brown trout and rainbow trout biomasses during stocking and nonstocking years. This analysis was based on the assumption that minor differences in habitat may alter the relative number of certain size groups but that total biomasses (lb/mi) should be similar. When only data from stocking years were used, no appreciable change in the 2-year-old and older wild brown and rainbow trout biomass level was noted under any observed winter flow regime. However, during nonstocking years increases in mean winter flows resulted in significant increases in the 2-year-old and older wild trout biomasses. Under the observed fluctuations in winter flow, the total 2-year-old and older wild trout biomasses were lowered significantly by the stocking of catchable-size rainbow trout and biomasses did not increase even during more favorable winter flows.

Stable flow regimes at O'Dell Creek were interrupted by severe winter flooding in the winter of 1971–1972. The following spring (1972), estimates of 2-year-old and older brown trout in both study sections showed a decline from previous spring estimates. In the nonstocked upper section, the brown trout biomass estimate was 30% lower than the mean of other nonstocked years. In the lower, stocked section, the spring 1972 estimate was 36% below the mean of other stocked years and 57% below the mean of unstocked years. By 1973, the spring biomass estimate for the upper section had returned to previous spring levels, while the lower, stocked section returned to levels found in the stocking year 1971 but not the levels in nonstocked years.

Rainbow trout showed a more substantial increase in 2-year-old and older total numbers and total biomass than brown trout when the stocking of catchable-size rainbow trout ceased. After four consecutive years of nonstocking in the Madison River, 2-year-old and older brown trout increased 162% in number and 133% in total biomass versus eight- and 10-fold increases in number and biomass, respectively, for wild rainbow trout. Because wild rainbow trout are more severely affected by stocking than brown trout, their recovery time was longer. Wild rainbow trout biomass was still increasing 4 years after stocking ceased, while brown trout biomass peaked after 2 years. McMullian (1982) also found the wild brown trout recovery rate to be faster than that of wild rainbow trout in the Big Hole River, Montana.

The adverse impact of stocking hatchery rainbow trout on the wild brown trout population was associated more with size than age. Brown trout in O'Dell Creek smaller than 10.0 in showed no significant changes in number between stocking and nonstocking years, while numbers of those exceeding 10 in long decreased significantly during stocking years. To further illustrate this size versus age factor, numbers of fall yearling brown trout (age I+) were not significantly different between stocking and nonstocking years in lower O'Dell Creek. During this fall period, none of the yearling brown trout were longer than 10 in, but between the September and April (spring) estimates, an average of 56% of the yearlings had grown enough to exceed 10 in during nonstocking years and are represented as 2-year-olds. In stocking years, only an average of 24% of the 2-year-old brown trout were longer than 10 in, but those 2-year-olds smaller than 10.0 in showed no decrease in numbers from nonstocking years. In fact, the large number of 2-year-old brown trout shown in the spring 1973 estimate was comprised mostly of fish smaller than 10 in. The percent of 2-year-olds exceeding 10 in long returned to prestocking levels (50%) when stocking was discontinued in 1973. In the Madison River, numbers of fall yearling brown trout were not significantly different between stocking and nonstocking years, but they increased significantly with river flows and in both stocking and nonstocking years. Again, like O'Dell Creek, the numbers of brown trout between 10.0 and 17.9 in long showed significant increases when stocking was discontinued. Impacts on wild rainbow trout smaller than 10 in long were not well documented in the Madison River sections due to poor fall yearling estimates, although there is some indication stocking may adversely affect smaller rainbow trout because the average yearling numbers during nonstocking years were over four times larger than the number for the only stocking year estimate (1967). Numbers of rainbow trout in the 10.0–17.9-in size group also showed a significant increase when stocking was discontinued.

Stocking of hatchery rainbow trout did alter existing natural mortality rates of wild trout. With the cessation of stocking in the Varney section of the Madison River in 1970, the annual mortality decreased dramatically, then rose in subsequent years as wild populations increased. In the lower O'Dell Creek section, annual mortality increased during the first 2 years of stocking. When the abundance of brown trout decreased to levels in equilibrium with existing stocking levels, mortality rates dropped to prestocking levels. Petrosky (1984) also found an increase in the summer mortality rates of 2-year-old and older wild rainbow trout when catchable-size hatchery rainbow trout were stocked; mortality was highest in sections receiving the highest stocking rate.

In lower O'Dell Creek, annual growth rates of brown trout decreased when stocking was initiated. This decrease in growth was evident primarily during the winter period (September–April), at the time of mortality rate increases. This decrease in growth was another indicator of population stress.

Stresses resulting from stocking also may increase wild trout susceptibility to angling. McLaren (1979) found that the introduction of hatchery trout increased the activity of wild trout and altered their activity patterns to coincide with those of hatchery trout. This may explain the findings of Butler and Borgeson (1965) that showed wild brown and rainbow trout were more catchable during periods of stocking. During stocking years in the Madison River, there was a 40% higher angler return of tags than in unstocked years for the larger wild trout (3 years old and older), even though there were fewer anglers. This did not occur in lower O'Dell Creek, where angling pressure was extremely low. Therefore, angling does not explain the high losses of wild trout but does point out their stressed condition.

The actual mechanisms that cause declines in wild fish numbers when hatchery fish are stocked is not totally understood, but disruption of existing social behavior may be a major factor. A number of investigators have observed a relatively stable social hierarchy in wild trout populations based on size of the fish. Jenkins (1969) and Newman (1956) found adult brown trout and rainbow trout showed aggressive behavior between individuals at drift feeding sites. These aggressive interactions were relatively stable in wild trout, minimized by ranking of trout according to size. Bachman (1982) suggested that, because significant social interaction occurred during feeding, the number of available feeding sites may determine the carrying capacity of a stream. If this were true, any significant disruption of the stable social hierarchy may lead to stresses which could significantly reduce the stream's natural carrying capacity.

Other investigators have studied changes in resident wild populations when alien fish or animals are introduced. McLaren (1979) found that hatchery-reared brown trout, when placed in a seminatural stream environment, were more active, fed more frequently, and exhibited greater antagonistic behavior than their wild counterparts. Bachman (1982) found hatchery brown trout disrupted the stable social structure that existed in wild trout populations prior to stocking, and they engaged in frequent long antagonistic encounters with the wild trout that resulted in some wild trout becoming exhausted. Butler (1975) suggested that imposing hatchery trout upon wild trout resulted in a condition similar to Selye's (1973) general adaptation syndrome, in which an animal placed in a high density situation suffers physiological changes resulting in the death of the individual. Davis (1949) observed that when alien rats were introduced into stable rat populations, the native rats actually decreased due to the stresses of accelerated social turmoil and competition.

Management Implications

The practice of stocking catchable-size hatchery trout into most self-sustaining wild trout streams has some serious management implications. Stocking catchables can reduce the number of wild trout available to anglers, can be an expensive program for wildlife agencies to carry out over the years, and may cause some genetic alteration of the wild stocks. Kruger and Menzel (1978) found that long-term stocking of hatchery brook trout in nine brook trout streams in Wisconsin altered certain alleles in wild brook trout. Correlations were noted between the number of years a stream was stocked and the degree of genetic alteration. Changes in genetics were not attributed to interbreeding but to the selection of wild brook trout compatible with the hatchery brook trout in that environment. These genetic alterations may cause more long-term problems to wild trout than the direct losses described in this study. Use of hatchery plants in self-sustaining wild trout fisheries should be avoided, but there are other desirable stocking possibilities such as in lakes, ponds, and streams where no natural reproduction is possible and where angler use is high enough to quickly remove hatchery trout. There would be no serious impact on wild fisheries in put-and-take situations where high harvest rates make the economics more favorable and eliminate any change of genetic degradation of wild trout strains. Management of self-sustaining wild trout streams would be better directed to maintaining or enhancing riparian habitat, maintaining adequate water flows, and applying appropriate catch regulations.

Acknowledgments

This study was funded in part through Federal Aid in Fish Restoration, Project F-9-R. I would like to acknowledge the help of John "Bud" Gaffney, LeRoy Ellig, Art Whitney, Ron Marcoux, and George Holton, without whose assistance the study could not have been done. Special thanks go to Bob White, Jerry Wells, and Fred Nelson for their editing and review of the manuscript. Bob McFarland and Burwell Gooch assisted with the statistical analyses. Also thanks go to Wayne Black and Jeff Bagdanov, who did the graphics.

References

Bachman, R. A. 1982. Foraging behavior of free ranging wild brown trout (*Salmo trutta*) in a stream. Doctoral dissertation. Pennsylvania State University, University Park.

Brynildson, D. M., and L. M. Christenson. 1961. Survival, yield, and coefficient of condition of hatchery-reared trout stocked in Wisconsin waters. Wisconsin Department of Conservation, Miscellaneous Report 3 (Fisheries), Madison.

Butler, R. L. 1975. Some thoughts on the effects of stocking hatchery trout on wild trout populations. Pages 83–87 *in* W. King, editor. Proceedings of the wild trout management symposium, Trout Unlimited, Washington, D.C.

Butler, R. L., and D. P. Borgeson. 1965. California "catchable" trout fisheries. California Department of Fish and Game, Fish Bulletin 127.

Davis, D. E. 1949. The role of intraspecific competition in game management. Proceedings of the North American Wildlife Conference 14:225–231.

Jenkins, T. M. 1969. Social structure, position choice and microdistribution of two trout species (*Salmo trutta* and *Salmo gairdneri*) resident in mountain streams. Animal Behavior Monographs 2:57–123.

Kruger, C. C., and B. W. Menzel. 1978. Genetic impacts of stocking upon wild brook trout populations in Wisconsin. Pages 169–179 *in* J. R. Moring, editor. Proceedings of the wild trout–catchable trout symposium. Oregon Department of Fish and Game, Corvallis.

Mason, J. W., D. M. Brynildson, and P. E. Degurse. 1967. Comparative survival of wild and domestic strains of brook trout in streams. Transactions of the American Fisheries Society 96:313–319.

McLaren, J. B. 1979. Comparative behavior of hatchery-reared and wild brown trout and its relation to intergroup competition in a stream. Doctoral dissertation. Pennsylvania State University, University Park.

McMullian, S. L. 1982. Inventory and survey of the waters of the Big Hole and Beaverhead drainage. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-30, Job Ib, Helena.

Miller, R. B. 1958. The role of competitors on the mortality of hatchery trout. Journal of the Fisheries Research Board of Canada 15:27–45.

Nelson, R. A., and E. R. Vincent. 1978. Inventory and survey of the project area. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-26, Job Ia, Helena.

Newman, M. A. 1956. Social behavior and interspecific competition in two trout species. Physiological Zoology 29:64–81.

Petrosky, C. E. 1984. Competitive efforts from stocked catchable-size rainbow trout on the wild trout population dynamics. Doctoral dissertation. University of Idaho, Moscow.

Ricker, W. R. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 119.

Seber, G. A. F. 1973. Estimation of animal abundance and related parameters. Griffin, London.

Selye, H. 1973. The evolution of the stress concept. American Scientist 61:692–699.

Shetter, D. S. 1947. Further results from spring and fall plantings of legal-sized, hatchery-reared trout in streams and lakes of Michigan. Transactions of the American Fisheries Society 74:35–58.

Snedecor, G. W. 1956. Statistical methods applied to experiments in agriculture and biology. Iowa State College Press, Ames.

Snow, H. E. 1974. Effects of stocking northern pike in Murphy's Flowage. Wisconsin Department of Natural Resources Technical Bulletin 79.

Thuember, T. 1975. Fish and the blue ribbon streams. Wisconsin Conservation Bulletin 40:16–17.

U.S. Geological Survey. 1966–1976. Water survey data for Montana. Helena, Montana.

Vincent, E. R. 1969a. Evaluation of river fish populations. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-17, Job 7, Helena.

Vincent, E. R. 1969b. Madison River creel census. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-15, Job Ia, Helena.

Vincent, E. R. 1970. Evaluation of river fish populations. Montana Department of Fish, Wildlife and Parks, Federal Aid in Fish Restoration, Project Report F-9-R-18, Job 7, Helena.

Vincent, E. R. 1971. River electrofishing and fish population estimates. Progressive Fish-Culturist 33: 163–169.

Vincent, E. R. 1982. Fish population estimate techniques in Montana. Proceedings of the Annual Conference Western Association of Fish and Wildlife Agencies 62:109–115.