Participants suggested in discussions between the U.S. Forest Service and the Department that the present fisheries management, principally aerial planting of fingerling trout, would reduce the quality of a "natural experience" for the wilderness visitor. Implicit in this feeling is that any foreign organism introduced into waters of Desolation Wilderness would not be "natural" and thus, the true essence of a wilderness would be lost. Items in Table 2 reflect these feelings. The information obtained from this survey, however, clearly demonstrates that for most visitors to Desolation Wilderness the present fisheries management does not reduce the quality of a "natural experience". Only 17% of the respondents held negative attitudes toward this concept (Figure 2); 2% were highly negative. In addition, scores on the wilderness evaluation dimensions were not related to scores on the "attitude toward fisheries management" dimension, indicating that the present fisheries management does not detract from their enjoyment of the Area. We conclude, therefore, that for most the present fisheries management practices do not violate the true essence of a wilderness area.

Aerial planting of fingerling trout is a fisheries management practice that is becoming a keen issue between the agencies involved in the management of wilderness and national park areas because of the sight and noise intrusion by the aircraft. Some have argued that this intrusion is enough to ruin someone's trip. Others have stated that the aircraft spends so little time in the Area that few would have a chance to experience the intrusion. Although not researched specifically in this study, the item in Table 2 regarding aerial planting would indicate that for most this experience would not be aversive. Whether people can actually relate to this experience is difficult to determine because the aircraft spends, at most, 1½ hours per year over the Area. Most people who indicated they would be disturbed by this experience probably objected on philosophical grounds rather than an actual aversive experience.

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SOME EFFECTS OF CHANNELIZATION ON THE FISHES AND INVERTEBRATES OF RUSH CREEK, MODOC COUNTY, CALIFORNIA [1]

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Channelized and unchannelized sections of the lower 7 km (4.3 miles) of Rush Creek, Modoc County, California were compared to determine the impact of channelization on fish populations, especially those of trout (*Salmo gairdneri* and *S. trutta*) and the rare endemic Modoc sucker (*Catostomus microps*), and invertebrate populations. Fish were captured with a backpack electrofisher, which provided a representative sample by numbers of the species present, although large fish were more vulnerable to capture than small fish. Channelized sections contained fewer and smaller trout, as well as a lower biomass, than the unchannelized sections. Modoc sucker numbers and biomass were also lower in the channelized sections. Only Pit sculpin (*Cottus pitensis*) were consistently more numerous in the channelized sections. Overall, total fish biomass in the channelized sections was less than one-third of that in the unchannelized sections. The biomass of invertebrates in the channelized sections was found to be less than one-third of that in the unchannelized sections. The invertebrate species composition of the two areas was also different.

INTRODUCTION

The channelization of streams for flood control is a common procedure in California as well as elsewhere in North America. Channelization converts a meandering stream with alternating pools and runs into a straight ditch with continuous runs and high banks (Funk and Ruhr 1971). The negative effects of channelization on most fish and invertebrate populations are widely recognized, but poorly documented (Schneberger and Funk 1971; Barton, et al, 1972; Wilkenson 1973). In particular, there is a lack of documentation of the effects of small-scale channelization on the biota of California streams, especially small coldwater streams. This paper reports the effects of channelization on the fish and invertebrates of Rush Creek, Modoc County. Rush Creek in most respects is typical of the small trout streams of the Pit River system of northeastern California, but it is also uniquely important as the principal home of the rare Modoc sucker, *Catostomus microps* (Moyle and Marciochi. 1975). The differences in fish species and numbers between the channelized and unchannelized sections of stream were first noticed in 1973 while I was collecting information on the Modoc sucker. I returned to the study area in 1974 to obtain fish and invertebrate biomass estimates and to validate the electrofishing procedure.

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STUDY AREA

Rush Creek, Modoc County (T 39N, R 9E), is a tributary of Ash Creek which in turn drains through extensive marshlands into the Pit River. It is a small (summer flows, 200 to 250 l/sec; 7–9 cfs), moderately warm (summer temperatures, 20 to 24C; 68 to 75F), permanent stream. The study area consisted of the lower 7 km (4.3 miles) of the creek, from its junction with Johnson Creek, its only large tributary, to its mouth at Ash Creek. Most of the creek in the study area is bordered by open or lightly wooded pastureland, although about 1.2 km (.75 mile) is heavily wooded. Both banks of the creek are privately owned and used as pasture for sheep and cattle. Fishing pressure is light because the landowners usually deny anglers access to their land. In the summer, much of the flow in the lower reaches of the study area is diverted for pasture irrigation. In the winter, the flows are occasionally high enough to threaten highway bridges and flood the bordering pastureland. Portions of the stream in the study area were channelized in an effort to control high winter flows. Landowners constructed most of the channelized sections with the technical assistance of the Soil Conservation Service (D. W. Patterson, Soil Conservation Service, pers. commun.).

The longest channelized section extends from the mouth of Johnson Creek downstream 1.6 km (.98 mile). This portion of the stream was straightened in 1969 and the soil deposited on both banks forming spoil-bank levees 2 to 4 m high (6 to 10 ft). The bottom now consists primarily of gravel and cobbles, although bedrock has been exposed in many places. During the summer, the water forms a continuous riffle 25 to 30 cm deep (10 to 12 inches). In the unchannelized, heavily wooded section immediately below this section, the creek consists of pools up to 1.2 m deep (4 ft) alternating with gravel-bottomed riffles between undercut banks. In this area, the water is heavily shaded most of the day and many bushes and logs extend into the water.

Below the wooded section, the stream is again channelized for about 250 m (820 ft) downstream from a highway bridge. It then meanders unchannelized through overgrazed pastureland for about 1 km (.62 mile). Although shade is lacking, there are large, deep pools and undercut banks. Another 500 m (1650 ft), channelized in 1968, follows. Below this, the stream again assumes its pool and riffle character for another kilometer and is bordered by numerous trees and bushes.

For the final 2 km (1.2 miles), the creek flows through open, often boggy, pastureland. Although a few large pools still exist, much of this stretch has been channelized. The most recent dredging activity was completed in June 1973, immediately prior to the study. Stream flows were generally low in most of this section due to an irrigation diversion at its beginning.

METHODS

Fish were collected from the study area on July 13–15, 1973, and on June 9–10, 1974, with a Smith-Root Type V backpack electrofisher. One worker operated the unit, while two others caught the fish with dip nets. In 1973, fish were taken from 22 unblocked subsections of stream, each 33 m (100 ft) long, from all parts of the study area. Each subsection was electrofished once and the time the unit was in operation recorded. Eleven subsections (363 m; 1100 ft) of channelized stream were electrofished for a total of 2143 seconds, while 11 unchannelized subsections (363 m; 1100 ft) were electrofished for a total of 2466 seconds. The standard length of all fish captured was measured to the nearest millimeter.

In 1974, all sampling for both fish and invertebrates was in the uppermost channelized section and the heavily wooded, unchannelized section immediately below it. These sections were chosen because the unchannelized section was the least disturbed by livestock activity of all such sections in the study area. Two subsections, each 61 m (200 ft) long, were sampled in the channelized area and two subsections, one 61 m (200 ft) long and the other 43 m (142 ft) long, were sampled in the unchannelized area. The 43 m subsection was made necessary by stream contours which dictated where block seines could be placed to effectively prevent the escape of fishes from the sample area. The upper and lower ends of each section were blocked with the seines. Each section was then electrofished three times in succession and the fish removed during each effort. Time spent electrofishing was not recorded due to a malfunction of the timer on the unit. All fish were weighed to the nearest gram with Pesola pencil scales and measured to the nearest millimeter (standard length) as they were in 1973.

Also in 1974, 20 samples of invertebrates were taken from both the channelized and unchannelized sections, from areas not electrofished, with a .093 m^2 (1 ft^2) Surber sampler. All samples were preserved in a 4% formaldehyde solution. The samples were sorted and the invertebrates identified, where possible, to genus with the keys in Usinger (1956). All invertebrates belonging to the same taxon in each of two series of collections were blotted dry and then weighed to the nearest .01 g on an analytical balance within 3 weeks of the collection date.

RESULTS

Six species of fish and one lamprey were collected in the study area: rainbow trout, brown trout, speckled dace (*Rhinichthys osculus*), Pit sculpin, Modoc sucker, Sacramento sucker (*Catostomus occidentalis*), and Pit-Klamath brook lamprey (*Lampetra lethophaga*). Sacramento suckers were found only as young-of-the-year in the lowest section. Pit-Klamath brook lampreys were common as ammocoetes but only adult or transforming individuals were included in the data analysis because the ammocoetes usually escaped through the meshes of the dip nets.

The 1973 fish samples showed that average size and numbers of rainbow trout, average size of brown trout, and numbers of Modoc suckers were less in the channelized sections than they were in the unchannelized sections, while the percentages of Pit sculpins were greater (Table 1). The catch per second data show that only brown trout and Pit sculpin were actually more abundant in the channelized sections and that fish were much more abundant overall in the unchannelized sections. A similar pattern appears in the catch (number) data from the 1974 samples, with the exception that speckled dace were more numerous in the channelized sections (Table 2). Since many of the speckled dace captured possessed breeding tubercles, it is likely that they had moved up into the channelized sections to spawn. Although more adult lampreys were collected in the unchannelized subsections in 1974, in both 1973 and 1974 ammocoetes seemed most abundant in silty areas along the edges of the channelized subsections and in the silt filled pools that were usually present at the end of the channelized sections. Chi square tests showed the differences in percent species composition between the channelized and unchannelized subsections were significant at the .05 level (1973 χ^2 = 60.42, 5 d.f.; 1974 χ^2 = 425.60, 5 d.f.). The 1974 biomass data also reflect the differences in species composition between the subsections. Eighty percent of the fish biomass in the unchannelized subsections was rainbow and brown trout, compared to 33% in the channelized subsections. Even Pit sculpins, which were more abundant in the channelized sections, tended to be larger in the unchannelized sections. The total biomass of fish in the unchannelized subsections is nearly 3.4 times that in the unchannelized subsections.

TABLE 1. Numbers, Percent of Numbers, Average Standard Lengths, and Catch per Second for Fishes Taken by Electrofishing From Channelized and Unchannelized Sections of Rush Creek, Modoc County, July 13–15, 1973. The channelized sections were electrofished a total of 2143 seconds, the unchannelized sections, 2466 seconds.

	Number	Percent	Average standard length (mm)	Catch per second
Brown Trout				
Channelized	24	9	23	.011
Unchannelized	17	4	70	.007
Rainbow Trout				
Channelized	29	11	46	.014
Unchannelized	127	30	60	.051
Pit Sculpin				
Channelized	65	25	31	.030
Unchannelized	52	12	29	.021
Speckled Dace				
Channelized	142	54	24	.065
Unchannelized	192	45	18	.078
Modoc Sucker				
Channelized	1	<1	61	<.001
Unchannelized	20	5	67	.002
Sacramento Sucker				
Channelized	4	2	10	.002
Unchannelized	16	4	13	.006
Total				
Channelized	265	100	--	.125
Unchannelized	424	100	--	.174

Repeated sampling of the four subsections in 1974 indicated that single electrofishing samples provided a fairly reliable indication of the composition of the fish community (Table 3). A Spearman rank correlation test (Steel and Torrie 1960), showed that there was no significant difference at the .05 level between the percent composition by numbers of the catch taken on the first electrofishing attempts and the percent composition of the total catch (r = .36, 4 d.f.). However, since only 44% of the fish by number but 60% of the fish by weight were taken in the first attempt, it appears that the initial sample is somewhat biased towards larger fish, especially trout. Observations of the netters on the number of fish they saw but did not capture indicated that nearly all of the fish in the subsection were taken in the three attempts.

TABLE 2. Comparisons of Numbers Taken, Percentage of Total Catch, Numbers Taken Per Meter of Stream, Average Standard Length, Grams, Percent Grams, and Grams Per Meter of Stream of Fishes Taken From Channelized and Unchannelized Subsections of Rush Creek, Modoc County, June 9–10, 1974. The channelized subsections sampled were 120 m long total and the unchannelized subsections *103 m long total.*

	Number	Percent number	Number per meter	Average standard length (mm)	Grams	Percent total grams	Grams per meter
Brown trout							
Channelized	8	4	0.07	135	296	21	3.22
Unchannelized	7	6	0.07	156	760	16	7.38
Rainbow trout							
Channelized	6	3	0.05	123	176	12	1.58
Unchannelized	33	26	0.32	159	2991	64	29.04
Pit sculpin							
Channelized	49	25	0.44	57	261	18	2.35
Unchannelized	41	32	0.40	74	430	9	4.17
Speckled dace							
Channelized	131	66	1.18	58	515	36	4.64
Unchannelized	29	23	0.28	43	53	1	0.51
Modoc sucker							
Channelized	3	2	0.02	150	188	13	1.69
Unchannelized	13	10	0.13	99	430	9	4.17
Brook lamprey							
Channelized	1	<1	0.01	149	6	<1	0.05
Unchannelized	4	3	0.04	143	30	1	0.29
Total							
Channelized	198	100	1.77	--	1442	100	13.53
Unchannelized	127	100	1.24	--	4694	100	45.56

Despite the problems of obtaining a representative sample of benthic invertebrates using a Surber sampler (discussed in Hynes 1970), the differences observed between the channelized and unchannelized sections probably reflect real differences because of the smallness of the stream, the number of the samples, and the size of the differences observed (Table 4). Spearman rank correlation tests showed significant differences, at the .05 level, (r = .64, 18 d.f.) between channelized and unchannelized sections in numbers per square meter, grams per square meter, and percent composition by grams. The samples from riffles in the unchannelized section had over three times the biomass of invertebrates of the samples from the channelized section. The invertebrates with the greatest biomass in the unchannelized section were stonefly nymphs (Plecoptera), followed by caseless caddisfly larvae (Trichoptera: *Hydropsyche, Rhacophila*). The invertebrates with the greatest biomass in the channelized sections were caddisfly larvae, both case building and caseless, followed by mayfly nymphs (Ephermeroptera), and stonefly nymphs.

DISCUSSION

The results of this study confirm more extensive, but similar studies in Montana (Whitney and Bailey 1959; Elser 1968), which showed that channelization greatly reduces the average size and number of trout per surface area of stream. It can be concluded, therefore, that the results observed are due to channelization. In Rush Creek, trout biomass was over seven times greater in unchannelized sections than it was in channelized sections. There was also a significant reduction in Modoc sucker and Pit sculpin biomass in the channelized sections, although the biomass of speckled dace increased. However, the effects of channelization reported here can only be considered as minimal for the following reasons: (1) the channelized sections studied were 4 or 5 years old, so their fish and invertebrate fauna had had ample time to partially recover; (2) the study did not take into account the reduction of stream length caused by the straightening of the stream meanders; (3) a high proportion of the unchannelized sections of lower Rush Creek had been severely disturbed by the heavy grazing of livestock on the surrounding lands, with the concomitant removal of streambank vegetation and trampling of the streambanks themselves; and (4) channelization tends to alter the geomorphology of the unchannelized sections of stream below the channelized sections through accelerated erosion and siltation (Curry 1972).

TABLE 3. **Numbers and Grams of Fishes Taken and Removed in Three Successive Electrofishing Runs in Four Blocked Sections of Rush Creek, Modoc County, June 9–10, 1974.**

	Sample Run							
	1		2		3		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Brown trout								
Number	10	7	4	4	1	1	15	5
Grams	917	25	165	10	35	4	1117	18
Mean wt. (g)	92	--	41	--	35	--	74	--
Rainbow trout								
Numbers	22	15	14	12	3	4	39	12
Grams	1855	50	972	57	340	43	3167	51
Mean wt. (g)	84	--	69	--	113	--	81	--
Pit sculpin								
Numbers	42	29	30	26	18	26	90	28
Grams	298	8	266	16	125	16	689	11
Mean wt. (g)	7	--	9	--	7	--	8	--
Speckled dace								
Numbers	56	39	64	56	40	59	160	49
Grams	228	6	217	13	123	16	568	9
Mean wt. (g)	4	--	3	--	3	--	4	--
Modoc sucker								
Numbers	12	8	1	1	3	4	16	5
Grams	410	11	60	4	148	19	618	10
Mean wt. (g)	34	--	60	--	49	--	39	--
Brook lamprey								
Numbers	1	1	1	1	3	4	5	2
Grams	3	<1	14	<1	19	2	36	1
Mean wt. (g)	3	--	14	--	6	--	7	--
Total								
Numbers	143	100	114	100	68	100	325	100
Grams	3711	100	1694	100	790	100	6195	100
Mean wt. (g)	26	--	15	--	12	--	19	--

Presumably most of the loss of fish carrying capacity observed from the channelized sections of Rush Creek was caused by the loss of pools, overhanging bushes, large boulders, and other cover. Only small riffle-dwelling fish (speckled dace, Pit sculpin) that were able to use the scant cover provided by small rocks and turbulent water maintained large populations in the channelized sections. The over three-fold reduction in the biomass of invertebrates per square meter of riffle undoubtedly also contributed to the low fish populations in the channelized sections since most of the invertebrates are used by the fishes for food. This reduction in invertebrate biomass is reflected in the over three-fold reduction in fish biomass per meter in the channelized sections (Table 2). The apparent difference in the composition of the invertebrate fauna may also have been a contributing factor to the lower fish biomass. For example, the limnephilid caddisfly larvae that were the most abundant invertebrates in the channelized sections are, because of their large size and heavy cases, largely unavailable as food to the small fishes that dominated the sections.

TABLE 4. **Numbers and Grams of Invertebrates Per Square Meter From Channelized and Unchannelized Sections of Rush Creek, Modoc County, June 9–10, 1974.**

	Sections					
	Unchannelized			Channelized		
	Numbers per square meter	Grams per square meter	Percent total grams	Numbers per square meter	Grams per square meter	Percent total grams
Plecoptera						
Acroneuria	15.07	2.42	47	2.69	0.29	17
Isoperla	4.31	0.05	1	0.54	0.01	1
Ephemeroptera						
Heptagenia	16.68	0.18	3	5.92	0.08	5
Iron	2.69	0.05	1	1.08	0.01	1
Ephemerella	4.31	0.11	2	1.08	0.03	2
Ameletus	15.07	0.07	1	17.22	0.08	5
Tricorythodes	3.22	0.01	<1	3.77	0.02	1
Unidentified	0.00	0.00	0	1.61	0.05	3
Trichoptera						
Limnephilidae						
species A	0.54	0.17	3	2.15	0.36	21
species B	3.22	0.06	1	15.07	0.12	7
Brachycentrus	3.22	0.01	<1	1.08	0.01	1
Hydropsyche	54.36	1.23	24	16.68	0.46	27
Rhyacophila	2.15	0.05	1	2.69	0.02	1
Unidentified	0.00	0.00	0	3.23	0.02	1
Diptera						
Limnophilus	5.92	0.35	7	4.31	0.02	1
Chironomidae	2.15	0.01	<1	4.31	0.02	1
Simuliidae	6.44	0.02	<1	0.00	0.00	0
Coleoptera						
Eubrianax	2.69	0.02	<1	0.00	0.00	0
Elmidae	1.61	0.02	<1	1.08	0.01	1
Noteridae	1.08	0.01	<1	0.00	0.00	0
Odonata						
Zygoptera	0.54	0.01	<1	0.00	0.00	0
Oligochaeta	3.22	0.19	4	0.00	0.00	0
Gordiida	0.54	0.12	2	0.00	0.00	0
Total	149.03	5.15	100	84.51	1.61	100

It is obvious that the severe reduction in fish populations, especially those of game fishes and rare native fishes, should be taken into account before a stream is channelized. The impact of any channelization project should be considered not only in light of its immediate effects on the stream section being channelized but also in light of its effects when combined with other changes (especially other channelization projects) of the entire stream system. Over half of the lower 7 km (4.3 miles) of Rush Creek has been channelized, not as one coordinated project but as a series of small changes over a number of years. Although the effect of each individual project has been minor relative to the stream as whole, the impact of all the projects combined on the fish populations has been drastic. The Pit River system contains many similar small streams, some of which have also been partially channelized. Future channelization projects, major and minor, should thus take into account the long term degradation of the trout fishery likely to ensue over the entire system, as well as the deleterious effects on the system's endemic nongame fish fauna, particularly the Modoc sucker.

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CONTRIBUTION OF PHYTOPLANKTON, PERIPHYTON, AND MACROPHYTES TO PRIMARY PRODUCTION IN EAGLE LAKE, CALIFORNIA [1]

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The importance of phytoplankton, periphyton, and macrophytes to primary production in each of the three basins of Eagle Lake, California was considered. Phytoplankton and periphyton production were measured using the oxygen light and dark bottle method. Production by macrophytes was determined by harvesting at maximum biomass.

Although phytoplankton accounts for 89% of the annual carbon fixed in the south basin of Eagle Lake, periphyton and macrophytes contribute as much as one third of the primary production in the shallower north and central basins.

INTRODUCTION

There are numerous investigations of phytoplankton production in lakes, but other primary producers have generally been ignored. Two reasons are involved. First, limnetic phytoplankton has been assumed to be the most important group since the littoral zone occupies a small portion of the surface area of most lakes. A few estimates of littoral primary production (Straskraba 1963, Pieczyńska and Szczepańska 1966, Westlake 1966) have shown the importance of macrophytes and periphyton in ponds and lakes with an extensive littoral zone. Secondly, measurement of periphyton and macrophyte production is often indirect, involving changes in biomass over a period of time (Wetzel *et al.* 1972), and lacks the accuracy of the well established phytoplankton methodology. Recently oxygen and ^{14}C techniques have been developed to measure littoral production (Wetzel 1964*a*, Westlake 1966, Allen 1971). Although these direct measurements are more meaningful, problems of interpretation, intercalibration of methods, and adaptation of techniques to various habitats still prevent their wide usage (Wetzel 1964*b*).

The objective of this study was to determine the relative importance of each component of primary production in Eagle Lake, a very large but relatively shallow lake.

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