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Effectiveness of Fish Ladders in the Grand River

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[1]Contribution from Michigan Project AFS-22-4.

ABSTRACT

Fish ladders were built on the Grand River to allow anadromous salmonids to migrate from Lake Michigan to the Lansing area (184 miles upstream). The first ladder was completed at Grand Rapids in 1975 and five other ladders were completed between there and Lansing in 1981. This study was started in the fall of 1982 to evaluate (1) the species composition of fish using the ladders, (2) the efficiencies of the ladders for passing fish, and (3) the fishing pressure and catch of anadromous fish.

Fish using the fish ladders were sampled initially with dip nets and trap nets, but these nets missed some species and some larger salmonids. A combination of drawdown and DC electrofishing gave better samples. Apparently, all species appeared to migrate up through the ladders without difficulty. Coho salmon (Oncorhynchus kisutch), chinook salmon (Oncorhynchus tshawytscha), suckers (Moxostoma spp. and Catostomus spp.), and steelhead (Salmo gairdneri), were the most frequent users. Fair numbers of channel catfish (Ictalurus punctatus), smallmouth bass (Micropterus dolomieui), carp (Cyprinus carpio), and walleye (Stizostedion vitreum) used the ladders also.

Visual counts were made at each fish ladder in spring and fall on a random around-the-clock basis to measure the number of salmonids moving upstream. The ladders above Grand Rapids were essentially 100% efficient in passing salmonids. Generally, the number of salmonids migrating past upstream points declined curvilinearly with distance. Many fish were removed by anglers, strayed into major tributaries, or stopped to spawn between Grand Rapids and Lyons. Spring floods appeared to aid steelhead migration but hindered fishing.

Creel census was used to measure fishing. In the fall, chinook salmon and coho salmon comprised 66.9% of the catch, on the average. Most were caught below the 6th Street Dam at Grand Rapids. Few salmon (9.5% m, less than 4,000 per year) were caught in the Lansing area. The spring salmonid catch, made up almost entirely of steelhead, occurred between Grand Rapids and Lyons.

Returns of stocked salmonids to the Grand River fishery were roughly estimated by comparing average number stocked to average number harvested. Returns were about 2.8% for coho, 3.4% for chinook, and 2.2% for steelhead.

INTRODUCTION

In 1975 the first fish ladder on the Grand River was completed at the 6th Street Dam in Grand Rapids (42 miles from Lake Michigan). This was a pool-and-weir type ladder. Subsequently, by fall of 1981, five other ladders were built upstream from Grand Rapids to allow anadromous fish to migrate from Lake Michigan to the South Lansing Dam, 184 miles upstream. They were built at Lyons Dam (a vertical-slot ladder) about 65 miles upstream from Grand Rapids, Weber Dam (a pool-and-weir ladder) about 7 miles upstream from Lyons, Portland Dam (a vertical-slot ladder) about 10 miles upstream from Weber, Grand Ledge (a vertical-slot ladder) about 35 miles upstream from Portland, and North Lansing Dam (a pool-and-weir ladder) about 24 miles upstream from Grand Ledge (Fig. 1).

A study was conducted from 1982 to 1985 to estimate the number of fish of various species that utilize the ladders during the spring and fall migration seasons, to determine the efficiencies of each ladder in allowing migration of fish, and to estimate the fishing pressure and catch of salmonids during the spring and fall seasons from Grand Rapids to Lansing.

METHODS

Random creel surveys were conducted each spring and fall from Grand Rapids to Lansing to estimate catch and fishing effort. These censuses began in the fall of 1982 and ended in the spring of 1985. The fall surveys encompassed migrations of chinook salmon, coho salmon, lake trout, brown trout, and steelhead (refer to Tables 1 and 2 for the scientific names of fishes used in this report). The spring surveys covered migrations of steelhead. The census covered approximately 142 miles of the Grand River mainstream and each of the major tributaries upstream to their first dam.

The method used to determine efficiencies of the pool-and-weir ladders for passing fish was based on visual counts of salmonids entering each ladder. Counts were made randomly on a 24-hour-per-day basis. White counting boards were installed at all count locations except Weber Dam, which had a viewing window. Counts of salmonids exiting the pool-and-weir ladders were also made, but samples of the fish exiting the vertical-slot ladders could not be obtained because of water depths. The average number of salmonids exiting per hour was estimated for each of the pool-and-weir ladders on a weekly and seasonal basis. These estimates were divided by similar seasonal estimates of salmonids entering each of the pool-and-weir ladders to generate estimates of passage efficiencies.

The efficiencies of the vertical-slot ladders had to be estimated less directly because the fish exiting these ladders could not be observed. The number of salmonids entering each of these ladders was compared to the estimated number reaching the next ladder and the estimated number harvested between the ladders. However, these efficiency estimates are not corrected

for fish dying natural deaths, straying into tributaries, or stopping to spawn between ladders. Fortunately, after the salmonids passed the Lyons Dam (approximately 65 miles above Grand Rapids) these unaccounted losses were minimal.

A sampling method had to be designed to determine the species composition of fish using the ladders. During the first fall of sampling, in 1982, a dip net that would fit inside the raceways of the fish ladders was tested. This type of net proved to be impractical and its use was discontinued early in the season. Several species of fish, including the larger salmonids, would escape the net before it could be lifted; apparently they could detect the vibration of the net lines when a lift was attempted. Next, modified trap nets attached to the upstream ends of the fish ladders were tested. These nets were used in the vertical-slot ladders for the remainder of the 1982 season. The pool-and-weir ladders were drawn down to sample species composition of fish using these ladders. The trap nets showed a negative bias towards catching larger salmonids and several other species of fish. No species composition samples were taken in spring 1983 due to a manpower shortage.

Beginning in the fall of 1983, all fish ladders were modified at the upper end to allow drawdown of water. A combination of drawdown and electrofishing with modified 220-V DC shocking gear was then used to sample fish in the ladders. This method appeared to be the most unbiased method in terms of both size of fish and species. This method of sampling was used from the fall of 1983 until the spring of 1985. Fish found in the ladders could have been migrating either upstream or downstream, but observations confirmed that all species were able to swim up through the ladders.

All estimates in this report are given with 95% confidence limits. All statistical tests were made with $\alpha = 0.05$.

RESULTS

Composition of species using fish ladders

Fall season

With an analysis of variance (Scheffé 1961), I could detect no differences in the composition of fish species using individual ladders ($F_{5,15df} = 1.01$) or types of ladders (pool-and-weir versus vertical-slot) ($F_{1,15df} = 0.91$). In 1983 and 1984 rare species were more frequently observed than in 1982 samples (Table 1). This was undoubtedly due to experimentation with sampling gear. Therefore, the percentage values given below are weighted averages of the three fall seasons combined.

The two salmon species (coho and chinook) made up 63.6% of the total fish using the ladders (Table 1). Steelhead, brown trout, and lake trout accounted for 2.7%, 0.9%, and 0.1% of the users, respectively. The next most important group of species was the catostomids,

primarily redhorses, which accounted for 10.1% of the total. Smallmouth bass, bluegill, pumpkinseed, walleye, carp, and channel catfish comprised 1 to 5% of the users. Many other species were observed in the ladders as well (Table 1).

Spring season

The species composition of the fish using the ladders in spring was sampled in 1984 and 1985 (Table 2). On the average, suckers (redhorse, 45.2% and white, 21.9%) were the most frequent users. Steelhead comprised 26.3% and all other salmonids combined comprised 0.6% of the fish in the ladders. Walleyes, bass, and other species were of minor importance.

Efficiency of fish ladders

The efficiencies of fish moving through the pool-and-weir fish ladders are given in Table 3. These efficiencies are defined as the quotient of the estimated number of salmonids exiting the top of the ladder divided by the estimated number of salmonids entering the bottom of the ladder (Freeze 1962). In all cases the estimates of efficiency overlap 100.0%. Therefore, with 95% confidence, I could not say that any of the efficiencies were less than 100.0%. The efficiency point estimates ranged from a low of 70.1% for the Weber Dam fish ladder in the fall of 1982 to a high of 99.9% for the 6th Street Dam ladder in the spring of 1984 (Table 1). There was a tendency for all efficiency point estimates to be higher in spring than in fall. I believe that the ladders were more efficient in spring than in fall because water levels were higher in spring.

Spring flows were extremely high in 1983 and 1985 compared to 1984 and that affected steelhead passage. There was a straight line relationship between water level and the percentage of steelheads exiting the Grand Rapids ladder that eventually reached the North Lansing Dam (Fig. 2). The sum of the daily mean flows of the Grand and Red Cedar rivers at Lansing (U. S. Geological Survey gauging stations) was used as an index to water level.

The spring relationship for the 3 years surveyed is:

$$\text{Fish reaching Lansing} \div \text{fish leaving Grand Rapids} = 0.7072\ (\text{flow}) - 108.43$$

This equation has an r value = 0.78 but is based on only three points.

This relationship can also be seen in Figure 3 where the estimated number of steelhead reaching various points upstream from Grand Rapids in the spring is regressed upon the number of river miles that they had traveled. Here again, the 1983 and 1985 spring seasons had high water levels and essentially all the steelhead that left Grand Rapids reached Lansing; i.e., the slope of the lines were not significantly different from zero. The 1984 spring season, with lower water levels, had a curvilinear relationship between the number of steelhead reaching

various points on the river and the number of linear miles of river traveled. This relationship is expressed by the equation:

$$\text{Steelhead reaching mile X} = 2{,}496 - 35.4(\text{mile X}) + 0.1244(\text{mile X})^2 \qquad R = 0.90$$

Where: X = number of linear river miles above the 6th Street Dam

Actually, the two spring high water seasons (1983 and 1985) may have had a curvilinear relationship also. Steelheads were observed jumping over the main structure of the 6th Street Dam during high water. Thus for these years the estimates of steelhead passed at Grand Rapids (which are based on ladder counts) are too low. This bias may have made the regressions appear more linear than curvilinear.

All of the fall migrations of salmonids had curvilinear relationships between number of salmonids reaching a point upstream from Grand Rapids and the number of linear river miles fish had to travel (Fig. 4). The three annual relationship are:

$$\text{Fall 1982: } \hat{Y} = 24{,}735 - 305.89(X) + 0.9573(X)^2 \qquad R = 0.9666$$

$$\text{Fall 1983: } \hat{Y} = 37{,}679 - 521.50(X) + 2{,}0334(X)^2 \qquad R = 0.9216$$

$$\text{Fall 1984: } \hat{Y} = 32{,}674 - 250.00(X) + 0.7683(X)^2 \qquad R = 0.8108$$

$$\text{Combined fall data: } \hat{Y} = 31{,}696 - 359.13(X) + 1.2530(X)^2 \qquad R = 0.9021$$

Where: $\hat{Y}$ = Number of salmonids reaching mile (X) above the 6th Street Dam

Angler catch and effort

I have divided the Grand River into four major sites to make fishing effort and catch comparisons. These four sites are (1) the Grand Rapids area; (2) tributaries (Rogue River, Thornapple River, Flat River, Prairie Creek, and the Maple River including Fish Creek); (3) Lyons to Grand Ledge area (Lyons Dam, Weber Dam, Portland Dam, and Grand Ledge Dam); and (4) Lansing area (North Lansing Dam, Red Cedar River, and the downstream area of South Lansing Dam).

Fall 1982

The 1982 fall season had a total fishing pressure of 180,198 hours (Table 4). The Grand Rapids area made up 54.3% of the total fishing pressure and the tributary area accounted for 33.5%. The Lyons to Grand Ledge area had 8.0% of the total fishing pressure and 4.2% occurred in the Lansing area.

An estimated 24,173 chinook salmon were harvested from the study areas (Table 4). The catch was highest in the Grand Rapids area (61.4%) and lowest (3.7%, 899±827 chinook) in the Lansing area. The total catch of coho salmon was 3,633. Nearly all (81.9%) were caught in the Grand Rapids area. The coho catch in the Lansing area was only 142±114. The

number of steelhead caught in the entire census area was 3,748. The Grand Rapids area produced 83.8% of these; the remaining 16.2% were caught in the tributaries. Lake trout catch was 3,061—all from below the 6th Street Dam in Grand Rapids.

The overall salmonid catch rate for the entire river in the fall of 1982 was 0.1921 per hour (Table 4). The Grand Rapids area had the highest catch rate of 0.2455 salmonids per hour. The Lyons to Grand Ledge area had the lowest and most variable catch rate of 0.0278 ± 0.1552.

Fall 1983

The fishing pressure for all areas during the 1983 fall survey was estimated at 160,023 angler hours (Table 4). The Grand Rapids area accounted for 53.7% of this pressure, the Lansing area had 8.1%, the tributary areas had 28.8%, and the remaining 9.4% occurred in the Lyons to Grand Ledge area.

Catches in 1983 were similar to those in 1982 except that fewer numbers of chinook salmon were caught (Table 4). The 1983 survey estimated that only 10,296 chinook salmon were caught in the entire area, with 61.47% caught in the Grand Rapids area. None were caught in the Lansing area, the tributary areas accounted for 33.3%, and the remainder were caught in the Lyons to Grand Ledge area. The total coho salmon catch was 5,772—51.9% in the Grand Rapids area and 34.8% in the Lansing area. The tributary areas and the Lyons to Grand Ledge area accounted for 9.1% and 4.2% of the coho catch, respectively. All of the lake trout (3,067) were caught below the 6th Street Dam at Grand Rapids. The Grand Rapids area accounted for 84.1% of the fall steelhead catch; the remaining steelhead were caught in the tributary areas.

The catch per hour rates for all salmonids combined, ranked from highest to lowest, were 0.1689 in the Grand Rapids area, 0.1554 in the Lansing area, 0.0938 in the tributary areas, and 0.0522 in the Lyons to Grand Ledge area (Table 4). During the fall season of 1983 the census clerks recorded the number of salmonids "foul-hooked" (snagged) by area. Few (less than 1%) salmon and trout were snagged at Grand Rapids, whereas most (91.2%) were snagged in the Lansing area. Therefore, even though the catch rates in the Grand Rapids area and the Lansing area were very similar (0.1689 compared to 0.1554) the method of fishing was quite different.

Fall 1984

The fishing pressure for the entire census area in the fall of 1984 was estimated at 199,735 angler hours (Table 4). The Grand Rapids area fishing pressure dropped to 50.0% of the total. Conversely, the Lansing area fishing pressure increased to 14.3% of the total.

Catches of chinook and coho salmon for the entire area were almost equal (20,619 and 18,592, respectively). This was a significant increase in the catch of coho compared to the two previous seasons. Again, the majority of coho and chinook salmon catch was made in the Grand Rapids area—60.6% of the chinook catch and 59.9% of the coho catch. The Lansing area accounted for 3.7% of the chinook catch and 34.1% of the total coho catch. This was by far the most successful fall fishery of the 3 years in all areas, and particularly in the Lansing area. No lake trout were harvested due to changes in fishing laws which prohibited the taking of lake trout in fall 1984. Compliance appeared to be complete.

Salmonid catch rates were more evenly distributed on the mainstream of Grand River in 1984. These rates ranged from a high of 0.2899 ± 0.0371 at Grand Rapids to a very similar value of 0.2485 ± 0.0712 salmonids per hour in the Lansing area. The Lyons to Grand Ledge area catch rate had an intermediate and highly variable value of 0.2495 ± 0.2034. The tributary area had a catch rate of 0.0968 ± 0.0419, which was very similar to the two previous fall seasons.

Spring angler catch and effort

The spring fishing pressure for all areas ranged from 41,755 angler hours in 1983 to 88,392 angler hours in 1984 (Table 5). The 1985 estimate of 49,307 hours was only slightly higher than the 1983 estimate. On the average, the Grand Rapids area had 49.3% of the total pressure, the tributaries had 38.6%, the Lansing area had 7.6%, and the Lyons to Grand Ledge area had 4.5%.

The catch of steelhead for the entire area ranged from a low of 813 in 1983 to a high of 7,973 in 1985 (Table 5). The 1984 spring season had a steelhead catch of 3,282. Virtually all were caught at the 6th Street Dam or in the tributary area. Only one steelhead was censused above the tributary area. This one was seen caught at the Lyons Dam in spring 1985. This one fish accounts for the highly variable catch estimate of 104 ± 103 rainbows for that area. For the three spring seasons the mean percentages of the total steelhead catch made in the Grand Rapids area were as follows: 1983—24.1%, 1984—66.0%, and 1985—56.1%. All other spring steelheads were caught in tributary areas.

At Grand Rapids, steelhead catch rates per angler hour estimates ranged from 0.0095 in 1983 to 0.1836 in 1985. In the tributary areas, steelhead catch rates per angler hour ranged from 0.0245 in 1984 to 0.2012 in 1985.

DISCUSSION

All six of the fish ladders were effective in passing fish and none of the ladders could be shown to be less than 100% efficient. Apparently all species of fish used the ladders, but primarily salmon in the fall and suckers and steelhead in the spring. Some salmon and steelhead moved through all of the ladders and reached the Lansing area. Lake trout and brown trout rarely passed the ladder at Grand Rapids.

The number of salmonids migrating upstream from Grand Rapids declined with distance. The relationship was usually curvilinear, but in two high-water springs it appeared to be linear—probably due to steelhead bypassing the counter in the ladder at the 6th Street Dam. Probably more steelhead migrated upstream during flood conditions, but anglers could not fish effectively then. Many of the salmonids stopped in the area between Grand Rapids and Lyons (42 to 107 miles above Lake Michigan). This area offered some spawning habitat and had many tributaries.

During both fall and spring seasons, most of the fishing pressure and catch on the Grand River occurred below the 6th Street Dam and on the large tributary rivers between Grand Rapids and the Lyons Dam. This was especially true when chinook salmon strayed into these tributaries. Steelhead plantings provided no fishery in either spring or fall further upstream than Lyons. The fishery generated at Lansing was smaller than expected, less than 4,000 salmonids per year—all in the fall. Coho provided a better Lansing fishery than chinook in two out of three fall seasons. Lake trout provided a fairly important fall fishery in Grand Rapids in years when they could be harvested legally.

Large numbers of salmonids were stocked in the Grand River above Grand Rapids to produce this fishery (Table 6). Annual plants for 1979–83 averaged over 300,000 coho, 500,000 chinook, and 300,000 steelhead. For the study section, Grand Rapids area to Lansing, annual harvest estimates in 1982–85 averaged over 9,000 coho, 18,000 chinook, and 7,000 steelhead. Thus, returns of planted fish to the river fisherman were only 2.2 to 3.4%. These estimates of return are not very precise because stocking rates (especially of steelhead) have varied from year to year. They do not include those planted fish caught in Lake Michigan, the lower end of the Grand River, or in other river systems (strays). On the other hand, some of the salmonids in the Grand River fishery could have been from natural reproduction or strays from other plants.

RECOMMENDATIONS

The creel census estimates for catch and fishing effort on the Grand River from Grand Rapids to Lansing are representative of the fishery that actually occurred during the seasons of salmonid migrations. To evaluate the success of individual plantings, and the return of these

fish to the anglers, requires that each plant be distinctively marked by fin clip or micro-tag. This is imperative for evaluating planting sites (upstream versus downstream), strains or sizes of fish (fall fingerlings versus yearlings), or the contributions from natural reproduction or straying from other rivers. To evaluate the amount of natural reproduction and straying, a study of downstream smolt migrations should be incorporated in any future studies of this type.

Better estimates of ladder efficiency could be obtained if a method could be devised to determine the number of fish gathered immediately below the dam or the fraction which actually passed through the ladder. This is of particular interest at the 6th Street Dam where there is concern that some fish may not be able to find the ladder.

Viewing windows installed in each ladder are the most reliable method of counting and identifying species. In conjunction, video tape cameras could be used to make continuous counts and reduce manpower needs (especially at odd hours). A 7-hour tape can be scanned in only 1 hour, and tapes can be easily stopped to identify individual fish. The salmonids did not move through the ladders at evenly spaced time intervals; consequently, many hours were wasted by on-site viewers. The periods when no fish are moving can be scanned rapidly on a video tape. A video camera was tested at the Weber Dam viewing window for 1 day and the results of the fish counts were very favorable.

Ideally, projects of this type should incorporate year-around census of all fishing with population estimates of native species to thoroughly evaluate the effects of allowing new fish species access to new parts of a watershed. Also, they should extend for a minimum of 5 to 7 years to eliminate some of the year-to-year variation, allow a fishery time to become established, and allow fishermen time to learn techniques. Every evaluation should have four measurement cells: a pre-treatment and a post-treatment period, and an experimental and a control area.

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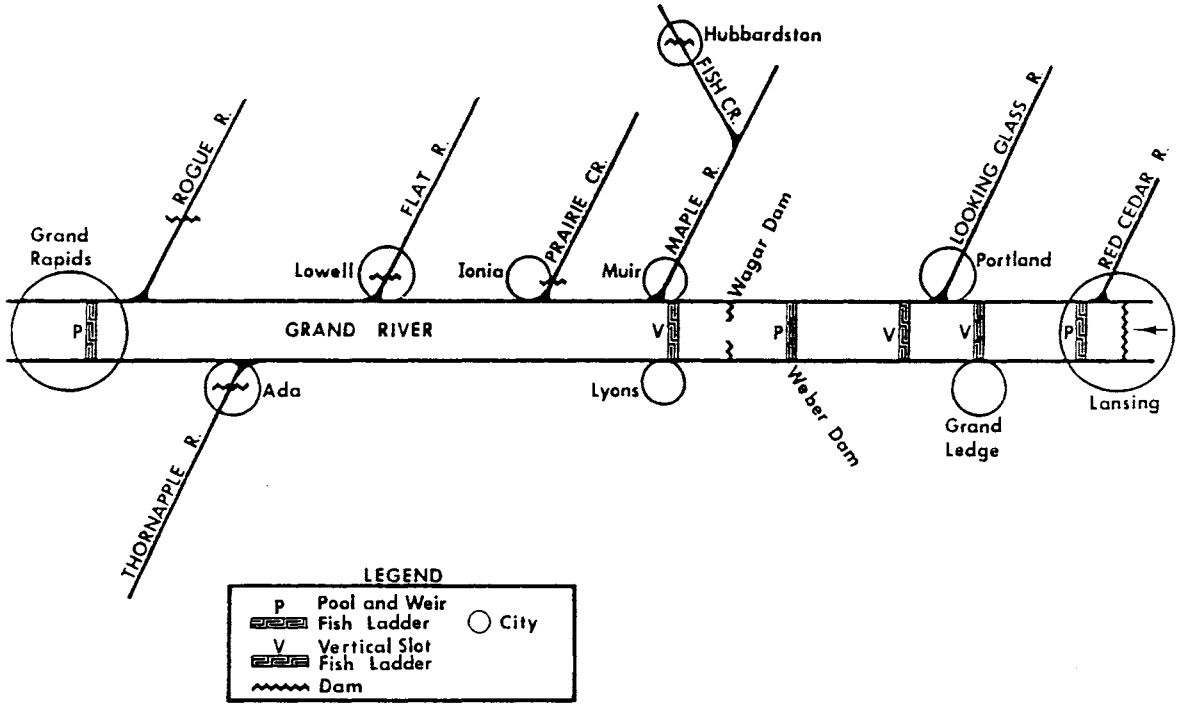

Figure 1. Schematic map of the Grand River drainage from Grand Rapids to Lansing showing location of fish ladders and dams.

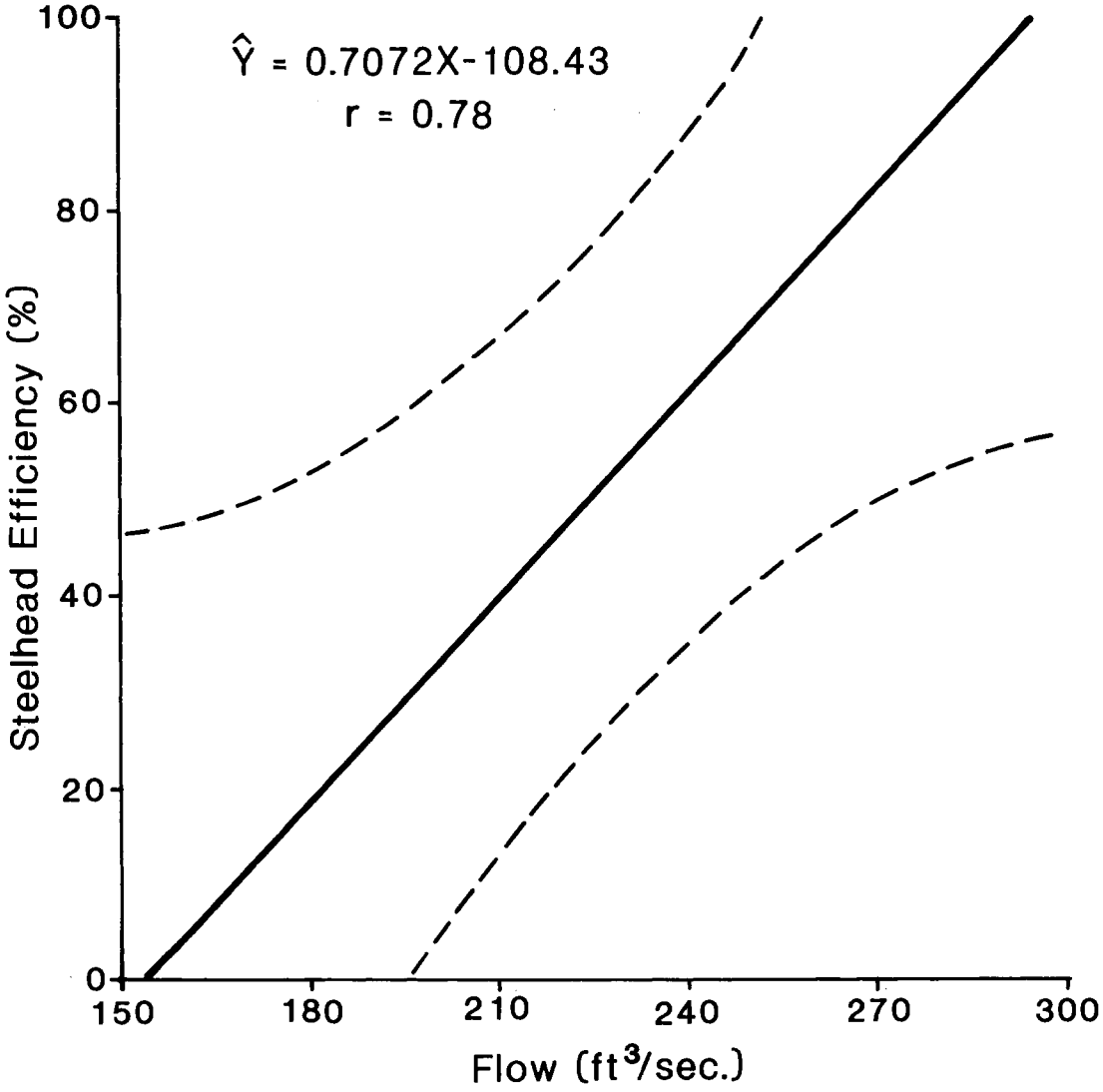

Figure 2. Regression, and 95% confidence limits (dashed lines), between the percent efficiency of steelheads reaching Lansing from Grand Rapids and the sums of the mean daily flows (March-May) of the Red Cedar plus Grand River at Lansing for the 1983–85 spring seasons.

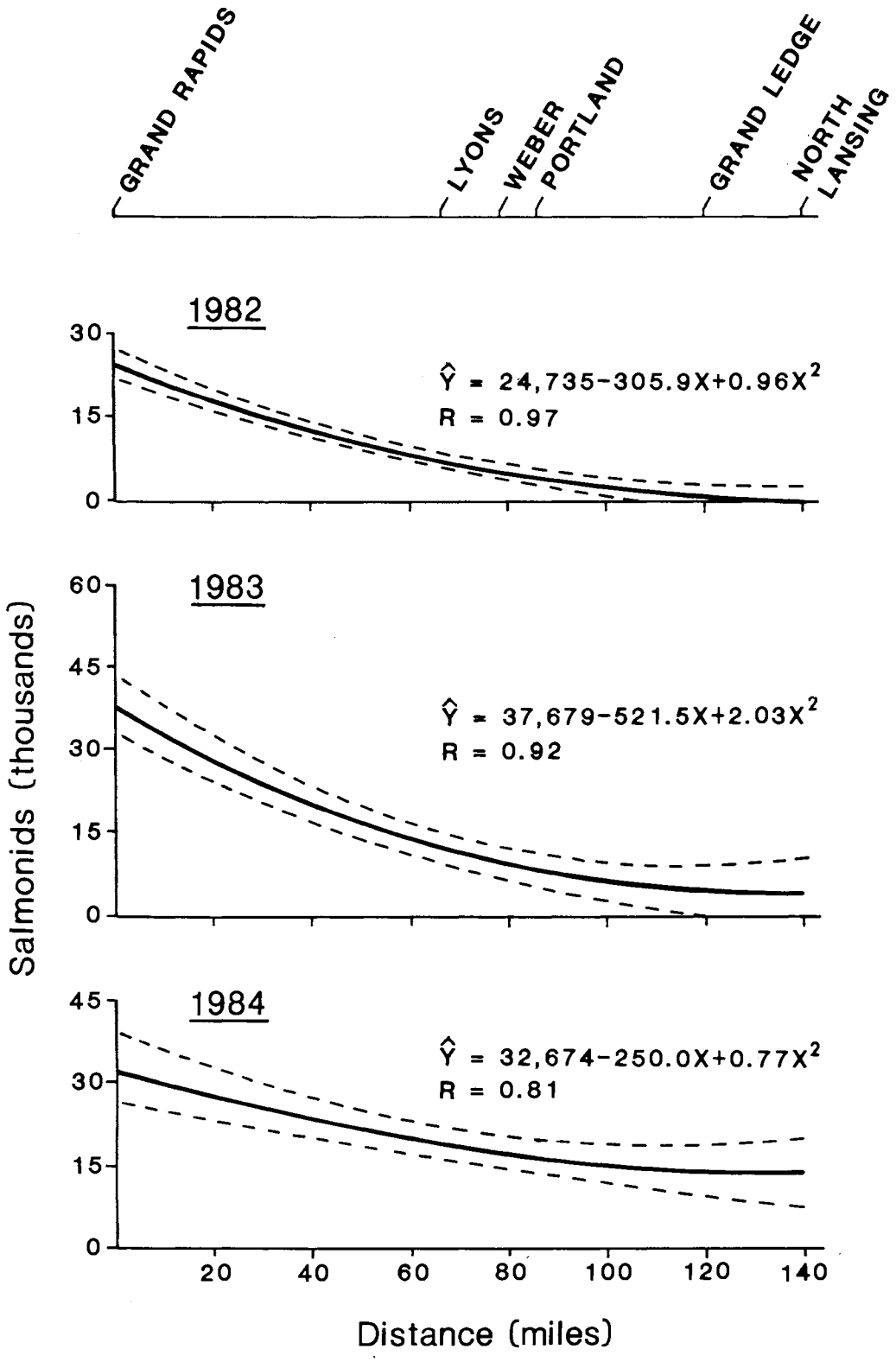

Figure 3. Regressions, and 95% confidence limits (dashed lines), between estimated number of steelheads passing various ladders on the Grand River and distance upstream from Grand Rapids for spring seasons of 1983–85.

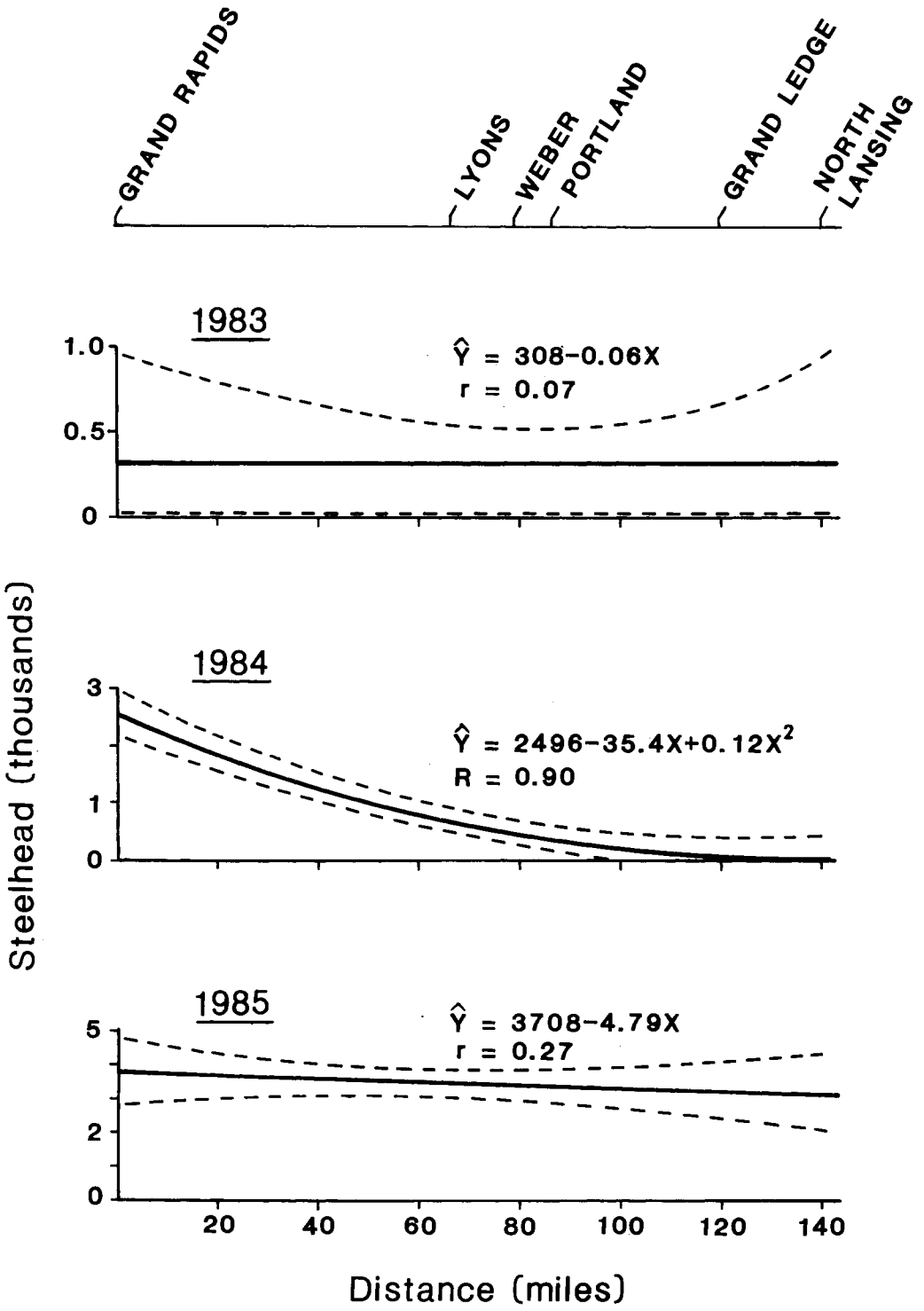

Figure 4. Regressions, and 95% confidence limits (dashed lines), between estimated number of salmonids passing various ladders on the Grand River and distance upstream from Grand Rapids for fall seasons of 1982-84.

Table 1. Average percent species composition (±95% confidence limits) of fish using the Grand River fish ladders during the fall seasons.

Species	Year			1982–84 weighted average
	1982	1983	1984	
Coho salmon (Oncorhynchus kisutch)	62.2±4.4	29.2±3.4	37.1±1.9	38.9±1.6
Chinook salmon (Oncorhynchus tshawytscha)	31.8±4.2	41.5±3.7	18.8±1.5	24.7±1.4
Steelhead (Salmo gairdneri)	1.2±1.0	3.4±1.4	2.8±0.6	2.7±0.5
Brown trout (Salmo trutta)	0.8±0.8	0±0	1.1±0.4	0.9±0.3
Lake trout (Salvelinus namaycush)	0±0	0±0	0.1±0.1	0.1±0.1
Largemouth bass (Micropterus salmoides)	0±0	0±0	0.2±0.2	0.2±0.1
Smallmouth bass (Micropterus dolomieui)	1.0±1.9	0.7±0.6	5.1±0.9	3.8±0.6
Crappie (Pomoxis spp.)	0±0	0±0	0.6±0.2	0.2±0.1
Bluegill (Lepomis macrochirus)	0.4±0.6	0±0	5.4±0.9	3.8±0.6
Sunfish (Lepomis spp.)	0±0	0±0	1.8±0.5	1.2±0.4
Rock bass (Ambloplites rupestris)	0.8±0.8	0±0	0.1±0.1	0.2±0.1
Walleye (Stizostedion vitreum)	0.2±0.4	6.0±1.8	2.4±0.6	2.8±0.5
Carp (Cyprinus carpio)	1.2±1.0	0±0	4.6±0.8	3.3±0.6
White sucker (Catostomus commersoni)	0.2±0.4	0.7±0.6	0.2±0.2	0.3±0.2
Redhorse (Moxostoma spp.)	0.2±0.4	0.7±0.6	13.7±1.4	9.7±1.0
Northern hog sucker (Hypentelium nigricans)	0±0	0±0	0.2±0.1	0.1±0.1
Channel catfish (Ictalurus punctatus)	0±0	13.2±2.6	4.3±0.8	5.4±0.7
Bullhead (Ictalurus spp.)	0±0	4.6±1.6	0±0	0.9±0.3
Shiners (Notropis spp.)	0±0	0±0	1.2±0.4	0.9±0.3
Freshwater drum (Aplodinotus grunniens)	0±0	0±0	0.3±0.2	0.2±0.2

Table 2. Average percent species composition (±95% confidence limits) of fish using the Grand River fish ladders during the spring seasons.

Species	Year		1984–85 weighted average
	1984	1985	
Chinook salmon	0.3±0.4	0±0	0.2±0.2
Steelhead	15.5±2.6	42.2±4.3	26.3±2.5
Brown trout	0.1±0.3	0.4±0.5	0.2±0.3
Lake trout	0±0	0.6±0.7	0.2±0.3
Smallmouth bass	0.1±0.3	0.8±0.8	0.4±0.3
Crappie	0±0	0.6±0.7	0.2±0.3
Sunfish	0.1±0.3	0.2±0.4	0.2±0.2
Rock bass	0.1±0.3	0.2±0.4	0.2±0.2
Walleye	0.1±0.3	2.3±1.3	1.0±0.6
Carp	0.4±0.4	6.4±2.2	2.7±0.9
Goldfish (Carassius auratus)	0.1±0.3	0±0	0.1±0.2
White sucker	23.0±3.0	20.3±3.5	21.9±2.3
Redhorse	58.7±3.6	25.4±1.9	45.2±2.8
Longnose sucker (Catostomus catostomus)	0.1±0.3	0.2±0.4	0.2±0.2
Northern hog sucker	1.2±0.8	0.2±0.4	0.8±0.5
Channel catfish	0.1±0.3	0.2±0.4	0.2±0.2
Gizzard shad (Dorosoma cepedianum)	0.1±0.3	0±0	0.1±0.2

Table 3. Average efficiencies (estimated number of salmonids exiting the latter ÷ estimated number of salmonids entering the ladder), and their 95% confidence ranges, for pool-and-weir ladders.

Season	Site			Average of the three ladders
	6th Street Dam Grand Rapids	Weber Dam	North Lansing Dam	
Fall 1982	71.4<92.4<100.0	42.1<70.1<100.0	31.7<79.3<100.0	60.9<80.6<100.0
Spring 1983	89.1<98.0<100.0	69.6<97.0<100.0	— — —[1]	83.1<97.5<100.0
Fall 1983	64.3<93.0<100.0	3.1<100.0<100.0	— — —[1]	46.0<96.5<100.0
Spring 1984	99.0<99.9<100.0	89.2<99.0<100.0	— — —[1]	94.5<99.4<100.0
Fall 1984	78.9<96.0<100.0	66.8<99.0<100.0	92.7<99.9<100.0	87.3<98.3<100.0
Spring 1985	82.1<99.0<100.0	70.8<93.4<100.0	77.0<99.5<100.0	85.3<97.3<100.0
Fall average	80.6<93.8<100.0	54.4<89.7<100.0	65.2<89.6<100.0	73.4<91.8<100.0
Spring average	84.3<99.0<100.0	84.2<96.5<100.0	77.0<99.5<100.0	91.6<98.1<100.0
Average of all seasons	89.0<96.4<100.0	73.6<93.1<100.0	75.2<92.9<100.0	85.1<94.9<100.0

[1] Unable to measure salmonids entering the lower end of the ladder accurately; therefore, efficiency estimates could not be made.

Table 4. Estimates (±95% confidence limits) of fall fishing effort and salmonid catch on the Grand River, 1982–84.

Date and site	Species					Total salmonids	Hours fished	Salmonid catch per hour
	Chinook salmon	Coho salmon	Steelhead	Lake trout	Brown trout			
Sep 8-Nov 30, 1982								
Grand Rapids	14,849 ±2,268	2,977 ±924	3,141 ±912	3,061 ±820	0 ±0	24,028 ±2,859	97,892 ±5,308	0.2455 ±0.0321
Tributaries	5,807 ±1,582	133 ±136[1]	607 ±244	0 ±0	0 ±0	6,547 ±1,606	60,343 ±6,242	0.1085 ±0.0289
Lyons to Grand Ledge	2,618 ±2,133	381 ±222	0 ±0	0 ±0	0 ±0	2,999 ±2,145	14,433 ±3,101	0.0278 ±0.1552
Lansing area	899 ±827	142 ±114	0 ±0	0 ±0	0 ±0	1,041 ±835	7,530 ±807	0.1382 ±0.1119
Total	24,173 ±3,589	3,633 ±966	3,748 ±944	3,061 ±820	0 ±0	34,615 ±4,006	180,198 ±8,798	0.1921 ±0.0241
Sep 24-Nov 15, 1983								
Grand Rapids	6,322 ±716	2,993 ±1,373	1,785 ±667	3,067 ±1,234	356 ±352	14,523 ±2,118	85,969 ±4,956	0.1689 ±0.0265
Tributaries	3,433 ±823	525 ±305	338 ±177	0 ±0	27 ±71[2]	4,323 ±898	46,068 ±2,663	0.0938 ±0.0202
Lyons to Grand Ledge	541 ±388	245 ±140	0 ±0	0 ±0	0 ±0	786 ±412	15,060 ±5,268	0.0522 ±0.0003
Lansing area	0 ±0	2,009 ±1,164	0 ±0	0 ±0	0 ±0	2,009 ±1,164	12,926 ±1,320	0.1554 ±0.0914
Total	10,296 ±2,390	5,772 ±1,831	2,123 ±690	3,067 ±1,234	383 ±359	21,641 ±2,610	160,023 ±7,820	0.1352 ±0.0176

Table 4. Continued:

Date and site	Species: Chinook salmon	Coho salmon	Steelhead	Lake trout	Brown trout	Total salmonids	Hours fished	Salmonid catch per hour
Sep 7-Nov 25, 1984								
Grand Rapids	12,490 ±2,338	11,138 ±1,997	4,115 ±1,235	0 ±0	704 ±381	28,447 ±3,335	99,842 ±6,098	0.2849 ±0.0377
Tributaries	5,413 ±2,383	307 ±322[3]	57 ±88[4]	0 ±0	0 ±0	5,777 ±2,406	59,701 ±7,120	0.0968 ±0.0419
Lyons to Grand Ledge	1,949 ±2,147[5]	808 ±792	136 ±233[6]	0 ±0	0 ±0	2,893 ±2,300	11,594 ±2,097	0.2495 ±0.2034
Lansing area	767 ±461	6,339 ±1,859	0 ±0	0 ±0	0 ±0	7,106 ±1,915	28,598 ±2,780	0.2485 ±0.0712
Total	20,619 ±4,000	18,592 ±2,841	4,308 ±1,260	0 ±0	704 ±381	44,223 ±5,086	199,735 ±10,035	0.2214 ±0.0278

[1] Actual observed catch was 5 coho salmon.

[2] Actual observed catch was 13 brown trout.

[3] Actual observed catch was 59 coho salmon.

[4] Actual observed catch was 12 steelhead trout.

[5] Actual observed catch was 81 chinook salmon.

[6] Actual observed catch was 79 steelhead trout; all below the Lyons ladder.

Table 5. Estimates (±95% confidence limits) of spring fishing effort and steelhead catch on the Grand River, 1983–85.

Date and estimates	Site				Total
	Grand Rapids	Tributaries	Lyons to Grand Ledge	Lansing area	
Mar 18-Apr 30, 1983					
Steelhead caught	196 ±139	547 ±317	0 ±0	0 ±0	813 ±346
Hours fished	20,579 ±3,125	15,566 ±1,820	1,627 ±282	3,983 ±576	41,755 ±3,673
Catch per hour	0.0095 ±0.0069	0.0351 ±0.0208	0.0000 ±0.0000	0.0000 ±0.0000	0.0195 ±0.0085
Mar 1-May 5, 1984					
Steelhead caught	2,165 ±975	959 ±1,734[1]	0 ±0	0 ±0	3,282 ±1,989
Hours fished	43,488 ±3,729	39,180 ±20,877	2,175 ±300	3,549 ±594	88,392 ±21,218
Catch per hour	0.0498 ±0.0228	0.0245 ±0.0461	0.0000 ±0.0000	0.0000 ±0.0000	0.0371 ±0.0242
Mar 18-May 5, 1985					
Steelhead caught	4,470 ±3,264	3,399 ±1,715	104 ±103	0 ±0	7,973 ±3,689
Hours fished	24,344 ±3,119	16,893 ±1,608	3,573 ±150	4,497 ±606	49,307 ±3,564
Catch per hour	0.1836 ±0.1361	0.2012 ±0.1033	0.0291 ±0.0289	0.0000 ±0.0000	0.1617 ±0.0757

[1] Actual observed catch was 33 steelhead trout.

Table 6. Annual plantings of fish in the Grand River, average annual catch (fall 1982-spring 1985), and their ratio.

Year	Species		
	Coho salmon	Chinook salmon	Steelhead and rainbow
1979	300,000	300,000	588,363
1980	399,981	600,000	490,600
1981	290,016	425,174	50,000
1982	300,044	700,052	368,348
1983	400,000	643,085	213,540
Average planting	338,008	533,757	342,170
Average (%) annual catch	9,332±1,172	18,363±1,960	7,416±1,514
Ratio (%)	2.8±0.5	3.4±1.0	2.2±1.3

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