Survival of Rainbow Trout Stocked in a Lake Superior Tributary 1971-1973

Wilbert C. Wagner
and
Thomas M. Stauffer

Fisheries Research Report No. 1859

September 29, 1978

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Research Report No. 1859

September 29, 1978

SURVIVAL OF RAINBOW TROUT STOCKED IN A LAKE SUPERIOR TRIBUTARY, 1971-1973 [1]

By Wilbert C. Wagner and Thomas M. Stauffer

Abstract

Experimental plantings of marked domestic rainbow trout (30,000) and steelhead (30,000) were made in the Huron River near its mouth in May and June 1971-1973. Domestic trout were 19-month-old progeny of fall-spawning broodstock held in a hatchery and steelhead were 13-month-old progeny of spring-spawning wild trout from Lake Michigan. The purposes of the plants were to compare returns of adult domestic and steelhead to the angler, assess results of "imprinting" and determine the effect of differences in water hardness between the hatchery and receiving water on early survival of planted trout. Return to the angler was assessed by examination of a portion (about 20%) of the anglers' catch in the Huron River at the times that trout in the plants were expected to mature and return to the Huron River. Trout were imprinted by holding them in cages in the river for about a week before release. Early survival was assessed by counts of dead trout on arrival at the river and by observation of mortality in samples of the plants that were retained in cages in the river.

Known results of adult trout to anglers were virtually nil (0.005%) as were estimated returns (0.06%). Other plantings of rainbow trout in Lake Superior tributaries have produced equally dismal results. The causes of the low return in our study were not identified, but stresses due to time in transit and transfer from hard (130-172 ppm, total hardness) to soft water (40 ppm) seemed to be contributing factors. For trout in transit for 9 to 13.5 hours from the Platte River (160 ppm) and Oden (172 ppm)

---

[1] Contribution from Dingell-Johnson Projects F-31-R and F-35-R, Michigan.

hatcheries, mortality for about 1 week after planting was 9-32%. in contrast, trout in transit for 5 hours from Thompson Hatchery (130 ppm) had no mortality for a comparable length of time. However, stress of transportation and water hardness change does not seem to be the entire answer because survival to adulthood for Thompson trout was also nil. We recommend that stocking of rainbow trout in Lake Superior tributaries be terminated until the causes of the low return are determined and corrected.

Introduction

Michigan is involved in a large program of stocking yearling hatchery-reared rainbow trout (Salmo gairdneri) of two strains in Great Lakes tributaries to produce more lake-run trout for anglers. The "domestic" strain of trout are 19-month-old progeny (178-216 mm, average total length) of fall-spawning hatchery broodstock and the steelhead strain are 13-month-old progeny (141-174 mm, average total length) of spring-spawning wild trout from Lake Michigan. Many of these fish are planted in the spring in or near mouths of Great Lakes tributaries. They migrate offshore, where they remain 1-3 years before they return to the planted tributary as adult fish weighing 1-5 kg. The present study was designed to provide fisheries managers with information on numbers surviving to the creel and on stocking methods to enhance survival. The potential to improve rainbow fishing is great because if stocked in a way to insure good initial survival, they can be expected to take advantage of the good growth potential in the Great Lakes.

There are several prior studies on rate of return from plants of rainbow trout. In 1955-1959, Hansen and Stauffer (1971) evaluated returns of 2- and 3-year-old rainbow trout planted in the Great Lakes. King and Swanson (1973) reported on returns of planted yearling rainbow trout in Wisconsin waters of Lake Superior. Evaluation of rainbow trout stocking in Pacific Ocean tributaries included research by Larson and Ward (1954), Hallock et al. (1961), Wagner and Wallace (1963), and Wagner (1968, 1969).

These studies provided much information on rate of return in relation to time and location of stocking for yearling West Coast trout. Although considerable work has been done on assessment of returns from planting, none is strictly applicable to the trout now being stocked in Lake Superior and other Great Lakes. Trout now stocked in Michigan, although of the same genetic strains tested by Hansen and Stauffer (1971), are 1 year younger and smaller when stocked so their survival and behavior cannot be predicted. While returns of 1-year-old fish have been evaluated in western states and in Wisconsin, the genetic background of 1-year-old Michigan fish is no doubt different as is the environment into which they are introduced, suggesting that their survival and returns cannot be predicted from western results.

In the present study, plantings of trout were made to compare returns to the angler from the two strains and also to assess the effect of "imprinting" and of differences in water hardness between the hatchery and receiving water on initial survival. Observations by hatchery workers, our preliminary observations and the literature (Craigie 1963; Schofield 1965; Poloiak and Williams 1971) suggest that an appreciable initial mortality is, on occasion, associated with a transfer of trout from hard to soft water. Since Michigan rainbow trout hatcheries have a total hardness in the range of 130 to 172 ppm and Lake Superior tributaries, as exemplified by the Huron River (40 ppm), are very soft, the great difference in water hardness may be of prime importance in limiting return to the angler.

The Huron River, tributary to central Lake Superior, was chosen for the study. Here, we expected to get maximum survival because the river was suitable for rainbow trout as evidenced by the large natural population (Miller 1974). Also, since the river was rather heavily fished, we expected enough returns to permit statistical analysis and comparison of the returns from various groups. The Huron River and its tributaries have a total length of 148 km and a drainage area of 207 km^2 (Brown 1944). The volume of flow varies greatly. Stream flow during July to October in 1958-1974 ranged from 0.3 to 2.3 m^3/sec; the average was 1.3 m^3. [2]

[2] Personal communication. Jerome Zimmerman, chemist, USFWS, Marquette, Michigan.

Methods

Stocking, early survival, and migration

Each year during May-June in 1971-1973, about 10,000 fin-clipped domestic and 10,000 fin-clipped steelhead trout were planted near the mouth of the Huron River (Table 1). The only access by hatchery truck to the river in the vicinity of the mouth is located 60 m from the mainstream on a bayou that connects with the river 300 m from Lake Superior. The two strains of trout were mixed when loaded in the hatchery trucks to eliminate effects caused by differences in transportation. All plants were made in the evening to minimize gull predation. Hatchery of origin, dates of stocking and stocking methods varied from year to year. Procedures are described below for each year.

In 1971, the plants were made to compare returns of domestic and steelhead trout. Steelhead were reared at Wolf Lake Hatchery and transferred to Thompson Hatchery on 17 May. Domestic trout were reared at Thompson. Both strains were fin clipped during 25-27 May. On 14 June, the fish were loaded on hatchery trucks at a rate of 173 kg/m^3. Water temperature in the tank was 11 C. Upon arrival at the river, the tank water was tempered and the fish were netted into stock tanks (water temperature 20 C) aboard a boat and transported about 275 m downstream where they were netted from the tanks into the stream (water temperature 18 C). Visual observations were made the following 2 days to determine if mortality occurred and the extent of migration into Lake Superior and upstream from the planting site.

In 1972, the plants were made to evaluate the effect of imprinting. Steelhead were reared at Platte River Hatchery and domestic trout were reared at Oden Hatchery. These fish were fin clipped at least 1 week before planting. On 7 June, 5,025 steelhead and 5,000 domestics were transported to the Huron River at a loading rate of 192 kg/m^3. Tank water temperature on arrival was 16 C and the river was 20 C. The fish were transferred by stock tanks to five live cages of 13-mm square wire mesh

Table 1.--Domestic and steelhead trout stocked in the Huron River, 1971-1973.

Date and strain	Hatchery of origin	Number planted	Loading rate (kg/m^3)	Mean total length (mm) and S.D.	Mark [a]
14 June 1971					
Domestic	Thompson	10,107	173	181 ± 17	LV
Steelhead	Thompson	8,935	173	165 ± 30	RV
7 June 1972					
Domestic (imprint)	Oden	5,000	192	197 ± 21	RM
Steelhead (imprint)	Platte	5,025	192	141 ± 16	RP
14 June 1972					
Domestic	Oden	5,000	219	206 ± 18	LM
Steelhead	Platte	5,250	219	141 ± 17	LP
22-23 May 1973					
Domestic	Oden	5,179	200	178 ± 28	LP-A
Steelhead	Platte	5,187	200	174 ± 17	RP-A
Domestic	Thompson	5,089	146, 194 [b]	216 ± 19	LV-A
Steelhead	Thompson	5,273	146, 194 [b]	171 ± 20	RV-A

[a] L = left, R = right, V = ventral, P = pectoral, M = maxillary, A = adipose.

[b] Fish were equally divided between two trucks with different capacities.

that were anchored in a gently flowing portion of the river. Loading rates in the 1- × 1- × 3-m cages were 48 kg/m^3. The fish were held in the cages for 7 days to imprint them. Each morning dead fish were removed and measured. Before the remaining live fish were released, a sample was measured and examined for fin clip quality which was rated as: good (regeneration not likely), fair (possible regeneration), or poor (complete regeneration expected).

A second load of 5,250 steelhead and 5,000 domestics was transported to the Huron River on 14 June. The loading rate for this trip was 219 kg/m^3. Water temperature in the truck was 18 C and the river was 19 C. The fish were netted into live cages in the bayou and then were towed to the mainstream of the river where the fish were released. At the same time, the fish held in cages for imprinting were also released. A sample of 120 domestics and 251 steelhead from the nonimprinted plant was placed in a cage for observation of delayed mortality. The loading rate in the cage was 8 kg/m^3. Each morning dead fish were removed and measured. Prior to release all remaining fish were measured and condition of fin clips examined.

Gill nets were set in Lake Superior during 15-23 June at various locations as far as 1.2 km from the mouth and in the Huron River during 19 June-7 July as far as 1.2 km upstream to determine the direction of migration of planted fish. The nets were 1.5 m deep and consisted of 7.6-m long panels of 19-, 22-, 25-, 32-, 38-, and 44-mm mesh (stretch measure).

In 1973, to test the effect of transferring rainbow trout from hard hatchery water to the soft water of the Huron River, half of each strain was reared at Platte River and Oden (total hardness, 160 and 172 ppm) and half at Thompson (total hardness, 130 ppm). All fish were fin clipped at least a month before planting so stress of clipping would have no effect on the fish when they were planted. The fish from Platte River and Oden were transported to the river on 22 May at a loading rate of 200 kg/m^3. On arrival, tank water temperature was 13 C and river temperature was 10 C. The fish were moved from the truck to the river through a 15-cm irrigation pipe. A sample of the fish was placed in each of three live cages which

were floating in the river near the discharge end of the pipe. Fish in one cage were measured and released the following day. Fish in the other two cages were held for 9 days so delayed mortality could be recorded. On 23 May, domestic and steelhead trout at Thompson were equally divided between two trucks at loading rates of 146 and 194 kg/m^3 (the trucks had different capacities). Temperature of both the transport water and the river was 10 C. Unloading and sampling procedures were the same as for Platte River and Oden fish. On arrival at the Huron River, samples of the transport water were obtained for analysis from the Oden and Platte River truck and from the two Thompson trucks. Each morning the dead fish in the live cages were removed and measured. Those surviving at the end of 9 days were measured and released. Condition of the fin clip was recorded as in 1972.

Gill nets were fished in Lake Superior during 23-27 May and 12-14 June to monitor the outward migration of the stocked fish. The nets were the same as used in 1972. Nets were located 0.2 and 1.0 km east of the mouth of the river and 0.4 and 1.2 km west of the mouth. All nets were set perpendicular to shore, with the inshore end in 1.0 to 1.2 m of water. They were usually set in the afternoon or evening and lifted in the morning. Boom shocker collections of 20- to 30-minute duration were made during 27 May-13 June at three stations located 0.4, 0.8, and 1.2 km upstream from the stocking site to determine if stocked fish were migrating upstream. Two collections were made at each of the lower two stations and one collection was made at the upper station.

Survival to the creel

Various sampling methods were used to determine rate of return of adult trout. From 23 September to 5 November 1972, a stratified, random creel census was conducted near the mouth of the Huron River and near Big Erics Bridge. These were the only important fishing areas in the fall. During 1-27 April 1973, another stratified, random creel census was conducted near Big Erics Bridge, where nearly all fishing was done. Each spring in 1974, 1975, and 1976, adult rainbow trout caught by anglers were

examined for fin clips to determine the proportion of stocked fish in the catch. All fin-clipped fish that were seen during the creel census and examinations were measured (total length), weighed, and scale sampled. In 1975, seven anglers who usually fished the Huron River were asked to report their total fall catch, the number of fin-clipped fish, and to measure and scale sample fin-clipped fish. Scale samples were taken because age determination was necessary to distinguish trout in our study from trout with the same marks planted in other years.

Results

Early mortality and migration

In 1971, 72 domestic and 228 steelhead trout were dead on arrival at the Huron River after a 5-hour trip from Thompson. The following morning 11 domestics and 45 steelhead were found dead in the vicinity of the planting site. This represents an initial mortality of 0.8% for domestics and 3.1% for steelhead. A few sea gulls were present but were not feeding on the planted fish. Two days after planting, stocked fish were observed in Lake Superior 0.2 km offshore and some had moved 0.8 km upstream.

In 1972, transport mortality from the 7 June transfer was estimated at 250 fish and from the 14 June transfer it was about 150 fish; nearly all were domestics. Some of the steelhead had been on the truck for 13.5 hours and domestics a minimum of 9 hours. Mortality of the 7 June plant in the live cages was severe (Table 2). The total mortality at the end of 7 days was the same for both groups (26.8 and 26.3%) but the pattern of mortality was greatly different. Nearly all mortality among domestics occurred during the first 2 days. Steelhead did not have the high initial mortality, but died at a relatively constant rate while confined. Since the rate was still quite high at release, we assume that steelhead continued to die at an abnormally high rate. The average length of steelhead that died was 135 ± 2 mm (95% confidence limits) and the length of those that survived was 141 ± 3 mm. The average length of domestics that died (191 ± 2 mm)

Table 2.--Percentage mortality of domestic and steelhead trout for 7-9 days after stocking,[a] Huron River, 1972-1973.

Days after stocking	Date of installation in cages, fish group[b] and origin[c]							
	1972				1973			
	7 June		14 June		22 May		23 May	
	D-O	S-P	D-O	S-P	D-O	S-P	D-T	S-T
1	21.0	5.6	14.2	0.8	15.3	12.6	0.0	0.0
2	3.8	3.0	6.7	0.0	5.0	4.4	0.0	0.0
3	0.1	2.0	1.7	0.0	0.8	1.0	0.0	0.0
4	0.4	4.9	4.2	0.8	0.0	0.0	0.0	0.0
5	0.6	4.3	1.7	2.4	0.4	1.0	0.0	0.0
6	0.5	3.3	2.5	1.6	1.1	0.5	0.0	0.0
7	0.4	3.2	0.8	2.4	0.4	1.5	0.0	0.0
8			0.0	1.2	0.0	0.0	0.0	0.0
9					0.0	0.0	0.0	0.0
Total	26.8	26.3	31.8	9.2	23.0	21.0	0.0	0.0

[a] Mortality after stocking for the 7 June plant was based on the entire plant, and for the other plants was based on a sample size of 120 to 286 trout.

[b] D = domestic, S = steelhead.

[c] O = Oden, P = Platte River, T = Thompson Hatchery.

also was less than of those that survived (197 ± 4 mm) but the difference was not significant.

For the trout transferred on 14 June, domestics again showed the same pattern of severe mortality (31.8%), most died during the first 2 days (Table 2). Steelhead had very little mortality during the first 4 days, then mortality began to increase. Again the length of steelhead that died was less than those that survived (124 ± 6 and 141 ± 2 mm). The length of domestics that died was not significantly less than those that survived (200 ± 6 and 206 ± 3 mm).

Seven gill net sets in Lake Superior during 15-23 June caught 37 stocked fish (Table 3). Nonimprinted fish (domestics and steelhead combined) migrated into the lake sooner than imprinted fish ($\chi^2 = 7.6$, $P < 0.01$) but there was no difference between strains. The five gill net sets in the river during 19 June-7 July caught 39 stocked fish. Significantly more domestics migrated upstream than did steelhead ($\chi^2 = 9.2$, $P < 0.01$).

In 1973, steelhead from Platte River were on the truck from 11.5 to 13.5 hours and domestics from Oden were on the truck a minimum of 9 hours. When the fish were planted they were in poor condition. The following morning many fish were observed swimming near the surface in a disoriented manner. Sea gull predation on these fish was extreme throughout the day. The fish from Thompson were on the truck for 5 hours and appeared to be in excellent condition when they were planted. The following morning few fish were seen and predation by sea gulls was very light.

There was no mortality among the 248 domestic and 184 steelhead trout from Thompson that were held in live cages for 9 days (Table 2). However, there was considerable mortality among the 286 domestics from Oden (23.0%) and 206 steelhead from Platte River (21.0%). Most mortality occurred during the first 2 days, thereafter losses were normal. The average length of domestics from Oden that died (156 ± 8 mm) was significantly less than the average length of those that survived (182 ± 3 mm). But the length of steelhead from Platte River that died (176 ± 5 mm) was not different from the length of those that survived (174 ± 3 mm).

Table 3.--Number of planted domestic and steelhead trout caught with gill nets and a boom shocker in Lake Superior and in the Huron River, May-June 1972-1973.

Location and gear	Year, fish group[a] and origin[b]							
	1972				1973			
	D-I-O	S-I-P	D-O	S-P	D-O	S-P	D-T	S-T
Lake Superior								
Gill net	7	4	11	15	2	9	15	9
Shocker					1	0	1	1
Huron River								
Gill net	20	4	9	6				
Shocker					38	41	39	22

[a] D = domestic, I = imprinted, S = steelhead.

[b] O = Oden, P = Platte River, T = Thompson Hatchery.

All parameters of the water samples taken from the transport units upon arrival at the Huron River were "normal" except ammonia nitrogen which was abnormally high (Table 4). Only the un-ionized ammonia (NH_3) portion of ammonia nitrogen is toxic to fish and the proportion of un-ionized ammonia is affected by pH and temperature (Trussell 1972) which varied among loads. The amounts of un-ionized ammonia in the samples were 0.07, 0.07, and 0.06 ppm. Thus, there was little difference in the amounts of un-ionized ammonia, but fish from Platte River and Oden were exposed to it for a longer time than were Thompson fish.

Within 2 days after planting, fish from all four groups were collected in Lake Superior as far as 0.4 km from the river mouth. The 20 gill net sets and 2 shocker runs caught 38 planted fish (Table 3). More domestics from Oden but fewer domestics from Thompson migrated into the lake than did steelhead ($X^2 = 8.8$, $P < 0.05$). Six boom shocker runs in the river took 140 stocked fish. Fewer steelhead from Thompson migrated upstream than any of the other groups, but the difference was not significant ($X^2 = 6.58$, $0.05 < P < 0.10$).

Survival to the creel

A total of 466 adult rainbow trout from the Huron River were examined; 4 in September-October 1972, 160 in April 1973, 100 in April 1974, 103 in April 1975, 30 in September-November 1975, and 69 in April 1976. These were the years in which the majority of the surviving planted fish should have matured and returned to the Huron River to spawn. Only three marked fish were found that were from our experimental plants. They were a steelhead and an imprinted domestic planted in 1972 and a domestic from Thompson Hatchery planted in 1973. Three more were found in the Dead River, some 65 km east of the Huron River. These were a domestic planted in 1971, an imprinted steelhead planted in 1972, and a steelhead from Platte River Hatchery planted in 1973. An additional 17 trout had marks that were the same as used in the Huron River plants. Scale examination, however, indicated that they were not fish of the experimental plant.

Table 4.--Chemical characteristics of the water in which rainbow trout were transported to the Huron River, May 1973.

Characteristics [a]	Transport unit		
	Oden and Platte R.	Thompson	Thompson
pH	7.05	7.20	7.30
Conductivity	426	354	270
Alkalinity	202	168	160
Calcium hardness	126	118	96
Total hardness	163	149	151
Chloride	59	21	20
Phosphate	9	4	2
Nitrite nitrogen	0.01	0.08	0.02
Nitrate nitrogen	10	8	8
Ammonia nitrogen	28	22	14

[a] Conductivity measured in micromhos, other characteristics measured in ppm.

Discussion

Returns to the angler of adult trout from the plants were virtually nil. The known catch of three marked fish in the Huron River during the times that fish were examined represented a return of 0.005%. The actual return was several times greater, though still very low, because only a portion of the catch was examined, some fish regenerated their fins, and others strayed. Based on our 1972 and 1973 creel census and the number of fish reported by Miller (1974), the yearly catch at the Huron River was in the neighborhood of 500 adult rainbow trout. Thus, roughly 20% of the angler catch was examined annually. When the condition of the fin clips was examined in 1972 and 1973, we concluded that about 20% of the fish would regenerate their fins and would not be recognized as marked fish. Straying was assumed to be similar (about 50%) to that reported by Hansen and Stauffer (1971). When these factors are considered, about 0.06% of the planted fish were caught by anglers.

The low rate of return that we observed is common for rainbow trout planted in Lake Superior. Two strains of imprinted yearling rainbow trout were planted in or near the mouth of the Brule River, Wisconsin (King and Swanson 1973). Returns to the Brule River of the marked trout were evaluated by creel checks and from an electrical sea lamprey weir. The returns from the two strains were 0.05 and 0.003%. Jaw-tagged rainbow trout planted at several locations in Wisconsin had a return of 1.8% as shown by voluntary angler reports (King and Swanson 1973). Jaw-tagged rainbow trout stocked in or near the mouths of 13 Michigan tributaries of Lake Superior as 2- and 3-year-old fish gave a return (from voluntary angler reports) to the angler of 1.0% (Hansen and Stauffer 1971).

The causes of the low rate of return in our study were not identified, but almost certainly stresses due to transportation and transfer from hard to soft water were contributing factors. Fish raised at Oden and Platte River were in transit for 9 to 13.5 hours, while fish raised at Thompson were on the hatchery trucks for only 5 hours. Observations on

mortality of trout confined in live cages at the planting site for at least a week showed that delayed mortality was light for fish from Thompson but was severe for fish from Oden and Platte River. For nearly all groups of Oden and Platte River fish, highest mortality was during transit and during the first 12 hours after stocking. The literature suggests that mortality may have been caused by build-up of ammonia nitrogen which is one of the principal products of excretion; the toxicity of ammonia solution is determined by the un-ionized ammonia present (Burrows 1964). McKee and Wolf (1963) reported that concentrations of 0.6 ppm of un-ionized ammonia for 100 to 200 minutes were lethal to rainbow trout. Analysis of the transport water in 1973 showed that un-ionized ammonia ranged from 0.06 to 0.07 ppm, which was about 10 times less than the reported lethal concentration. However, Oden and Platte hatchery trout were exposed to un-ionized ammonia for 9-13.5 hours and the longer exposure time at a lower concentration may have caused the mortality. Nearly 40% of the total mortality of fish held in live cages for 7 to 9 days in 1972 and 1973 occurred after the first 12 hours. We suspect that this mortality was due to the change in water hardness from hatchery to stream, plus the stresses during the long period of transit. Change in water hardness does not necessarily cause mortality per se. Rainbow trout were transferred from water containing 77 ppm to water containing 2 ppm calcium and held for 2 weeks with very low losses.[3] While fish are in transit, however, they are under stress, and while under stress they excrete calcium at an increased rate (Wedemeyer et al. 1976). If the body calcium reserves go below a certain level they cannot recover (Hilden 1967). The fish from Thompson did not have as great a change in water hardness and were under stress a shorter time, which no doubt accounts for their having no mortality during the 9 days they were held in cages at the Huron River.

Stream temperature or the change in temperature from truck to stream were not, by themselves, the cause of mortality. In 1971 and 1972, stream temperatures were 18 to 20 C, which is below the upper limit

[3] Personal communication. J. E. Camper, Hatchery Biologist, USFWS, Heber Springs, Arkansas.

for stocking rainbow trout (Borgeson 1977). The greatest temperature change from transport unit to stream was from 11 to 18 C in 1971 when mortality was light. Horak (1967) tested the stamina of hatchery-reared rainbow trout and found they had their greatest stamina between 21 and 24 C, and Threinen (1958) showed that rainbow trout could survive a temperature change from 10 to 19 C when planted in Wisconsin water.

Migration of the planted fish into Lake Superior and upstream showed some significant differences but they were not consistent. For instance, in 1972, significantly more domestics migrated upstream than did steelhead, but in 1973, there was no difference between the two strains. There were no differences in migration between strains into Lake Superior in either 1972 or 1973. In fact, the total number of fish caught during both years were 37 domestics and 38 steelhead. Thus, the only meaningful findings from the migration studies were to prove that soon after planting some fish of each strain moved into Lake Superior and some moved upstream.

Recommendations

The return of planted fish to the angler in our study was virtually nil and other plants of rainbow trout in Lake Superior tributaries have been relatively unsuccessful. Therefore, we recommend that stocking of rainbow trout into Lake Superior tributaries be terminated until the causes of the low return are determined and corrected.

Acknowledgments

Albert Vincent, Paul R. Hannuksela, and James W. Peck assisted with the collection of early survival and migration data and examination of angler-caught fish. James R. Ryckman offered statistical advice. The assistance of Dr. Thomas D. Wright, Michigan Technological University, in the analysis of the water samples and the interpretation of his findings, is appreciated. The manuscript was reviewed by James W. Peck and Warren G. Yoder.

Literature cited

Borgeson, David P. 1977. Fish stocking guidelines, 1977 revision. Mich. Dep. Nat. Resour., 31 pp.

Brown, C. J. D. 1944. Michigan streams--their lengths, distribution and drainage areas. Mich. Dep. Conserv., Inst. Fish. Res. Misc. Publ. 1, 21 pp.

Burrows, Roger E. 1964. Effects of accumulated excretory products on hatchery-reared salmonids. U.S. Fish Wildl. Serv. Res. Rep. 66, 12 pp.

Craigie, David E. 1963. An effect of water hardness in the thermal resistance of the rainbow trout, Salmo gairdnerii, Richardson. Can. J. Zool. 41: 825-830.

Hallock, Richard J., William F. Von Woert, and Leo Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (Salmo gairdnerii gairdnerii) in the Sacramento River system. Calif. Dep. Fish Game, Fish. Bull. 114, 74 pp.

Hansen, Martin J., and Thomas M. Stauffer. 1971. Comparative recovery to the creel, movement and growth of rainbow trout stocked in the Great Lakes. Trans. Am. Fish. Soc. 100(2): 336-349.

Hilden, Donald A. 1967. Halide and hardness effects on rainbow trout survival. PhD thesis, Utah State Univ., Logan, 120 pp.

Horak, Donald L. 1967. Evaluation of hatchery-reared rainbow trout. Colo. Div. Game Fish Parks, Fed. Aid Job Completion Rep. Proj. F-28-R-3, 26 pp.

King, George R., and Bruce L. Swanson. 1973. Progress report of fish management on Lake Superior. Wis. Dep. Nat. Resour., Div. For. Wildl. Recreation, 39 pp.

Larson, Ralph W., and John M. Ward. 1954. Management of steelhead trout in the State of Washington. Trans. Am. Fish. Soc. 84: 261-274.

McKee, Jack Edward, and Harold W. Wolf. 1963. Water quality criteria. 2nd ed. State Water Quality Control Board, Sacramento, Calif. Publ. 3-A, 550 pp.

Miller, Barry. 1974. The spawning migration and age and growth studies of steelhead in the Huron River, Baraga County, Michigan, 1966-1970. Mich. Dep. Nat. Resour., Fish. Div. Tech. Rep. 74-10, 19 pp.

Poloiak, H. A., and R. C. Williams. 1971. Effects of heavy metal ions on the absorption of dissolved calcium by brown trout. Fish. Res. Bull. 34. The nutrition of trout. Cortland Hatchery Rep. 39 for the year 1970, pp. 53-65.

Schofield, Carl L. 1965. Water quality in relation to survival of brook trout, Salvelinus fontinalis (Mitchill). Trans. Am. Fish. Soc. 94(3): 227-235.

Threinen, C. W. 1958. Cause of mortality of a midsummer plant of rainbow trout in a southern Wisconsin lake, with notes on acclimation and lethal temperatures. Prog. Fish-Cult. 20(1): 27-32.

Trussell, R. P. 1972. The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. J. Fish. Res. Board Can. 29: 1505-1507.

Wagner, Harry H. 1968. Effect of stocking time on survival of steelhead trout, Salmo gairdnerii, in Oregon. Trans. Am. Fish. Soc. 97(4): 374-379.

Wagner, Harry H. 1969. Effect of stocking location of juvenile steelhead trout, Salmo gairdnerii, on adult catch. Trans. Am. Fish. Soc. 98(1): 27-34.

Wagner, Harry H., and Richard L. Wallace. 1963. The seaward migration and return of hatchery-reared steelhead trout, Salmo gairdnerii Richardson, in the Alsea River, Oregon. Trans. Am. Fish. Soc. 92(3): 202-210.

Wedemeyer, Gary A., Fred P. Meyer, and Lynwood Smith. 1976. Environmental stress and fish diseases. T.F.H. Publications Inc., Neptune, New Jersey, 192 pp.

Report approved by W. C. Latta

Typed by M. S. McClure