CAL FISH + GAME 44(2) 91-124
1958

CHEMICAL CONTROL OF ROUGH FISH IN THE RUSSIAN RIVER DRAINAGE, CALIFORNIA[1]

HERBERT E. PINTLER and WILLIAM C. JOHNSON
Region 3, Inland Fisheries
California Department of Fish and Game

TABLE OF CONTENTS

[1] Submitted for publication September, 1957. A portion of this work was performed by personnel of Dingell-Johnson Project California F-4-D, "Stream and Lake Improvement", supported by Federal Aid to Fish Restoration funds.

INTRODUCTION

The chemical control of fish populations is an important form of fisheries management. Undesirable fishes have been eliminated or at least controlled, and game fish populations have been established or improved. This form of management, although commonly used in lakes and ponds, has not been used to any great extent in streams.

Preliminary fish population sampling in the Russian River drainage showed that rough fish [2] composed almost 100 percent of the population

TABLE 1

Streams in the Russian River Drainage Chemically Treated to Control Rough Fish

Stream	County	Miles treated
Main Russian River		
East Branch to Healdsburg	Sonoma-Mendocino	62
Tributaries		
Russian River, West Branch	Mendocino	18
Forsythe Creek	Mendocino	7
Mill Creek	Mendocino	1
York Creek	Mendocino	1
Russian River, East Branch	Mendocino	16
Bush Creek	Mendocino	3
Mewhinney Creek	Mendocino	2
Ackerman Creek	Mendocino	3
Sulphur Creek	Mendocino	4
Robinson Creek	Mendocino	5
McNab Creek	Mendocino	5
Feliz Creek	Mendocino	8
McDowell Creek	Mendocino	1
Pieta Creek	Mendocino	2
Coleman Creek	Mendocino	1
Cumminsky Creek	Mendocino	4
Big Sulphur Creek	Sonoma	13
Little Sulphur Creek	Sonoma	5
Maacama Creek	Sonoma	11
Briggs Creek	Sonoma	4
Little Briggs Creek	Sonoma	1
Coon Creek	Sonoma	1
Bear Creek	Sonoma	1
Ingalls Creek	Sonoma	1
Redwood Creek	Sonoma	1
Dry Creek	Sonoma	33
Gallaway Creek	Sonoma	4
Cherry Creek	Sonoma	5
Warm Springs Creek	Sonoma	6
Pena Creek	Sonoma	10
Mill Creek	Sonoma	5
Porter Creek	Sonoma	1
Mark West Creek	Sonoma	9
Windsor Creek	Sonoma	2
Laguna de Santa Rosa	Sonoma	6
Santa Rosa Creek	Sonoma	11
Green Valley Creek	Sonoma	10
East Austin Creek	Sonoma	3
Total miles treated		286

Streams are listed from north to south, with the various indentations indicating sequence of tributaries; e.g., Mill Creek is a tributary to Forsythe Creek, which in turn is a tributary to Russian River, West Branch.

[2] For the purposes of this report, the collective term "rough fish" includes all undesirable fishes the presence of which may be detrimental to steelhead and other game fishes.

in certain tributary stream sections. It was believed that if control of these rough fish would reduce predation and competition for food and space, an increase in game fish production and harvest would result.

Preliminary chemical control of rough fish in the Russian River drainage began in 1952 on several tributary test streams and continued in 1953. As more extensive sampling of the drainage was undertaken, it became evident that control should include the large numbers of adult rough fish in the main river. It is through this area that yearling steelhead rainbow trout *(Salmo g. gairdnerii)* pass on their migration to the sea. The project was therefore extended through 1954 to include nearly half the entire river drainage, or about 286 stream miles (Table 1).

The project was directed toward control, rather than eradication, since various sources for future infestation by rough fish would still exist. Primary consideration was given to the tributary streams which serve as nursery grounds for juvenile steelhead.

The evaluation of the project began with immediate follow-up checks of the fishes killed, and will continue for several more years.

DESCRIPTION OF THE RUSSIAN RIVER DRAINAGE

The Russian River originates in the higher portions of the Coast Range in Mendocino County and flows southward through Sonoma County, where it turns rather abruptly west and flows into the Pacific Ocean at Jenner, about 57 miles north of San Francisco (Figure 1). The river system has a total of some 576 miles of stream, of which the main river makes up 108 miles. It drains an area of about 1,485 square miles.

Since 1908, water has been diverted through a tunnel from Van Arsdale Reservoir (Cape Horn Dam) on the Eel River, Mendocino County, to the East Branch of the Russian River to generate power in the Potter Valley plant of the Pacific Gas and Electric Company.

The Russian River system flows through a narrow, limited valley, the central part of which broadens out enough to permit considerable agriculture near Cloverdale, Geyserville, and Healdsburg. The surrounding hills, which are part of the Coast Range, rise to slightly more than 4,200 feet in elevation.

Climatic extremes range from short, rainy winters to long, hot, dry summers, seldom relieved by rain except in the headwater areas. Nearly 80 percent of the annual rainfall occurs between November and March. As a result of this climatic pattern, the Russian River and its tributaries are subject to great fluctuations in volume of flow. Records at Guerneville have ranged from less than 70 cubic feet per second (c.f.s.) to 89,000 c.f.s. The lower sections of many tributaries become intermittent during the summer months.

Chemical analysis of the river water reveals no apparent problem. The dissolved oxygen content is satisfactory for anadromous fishes except in a few extremely limited areas in the main river above the mouth of the East Branch in the summer, where the entire flow of the river is derived from ground waters a short distance upstream. Summer water temperatures reach 80 degrees F. in the lowermost part of the river.

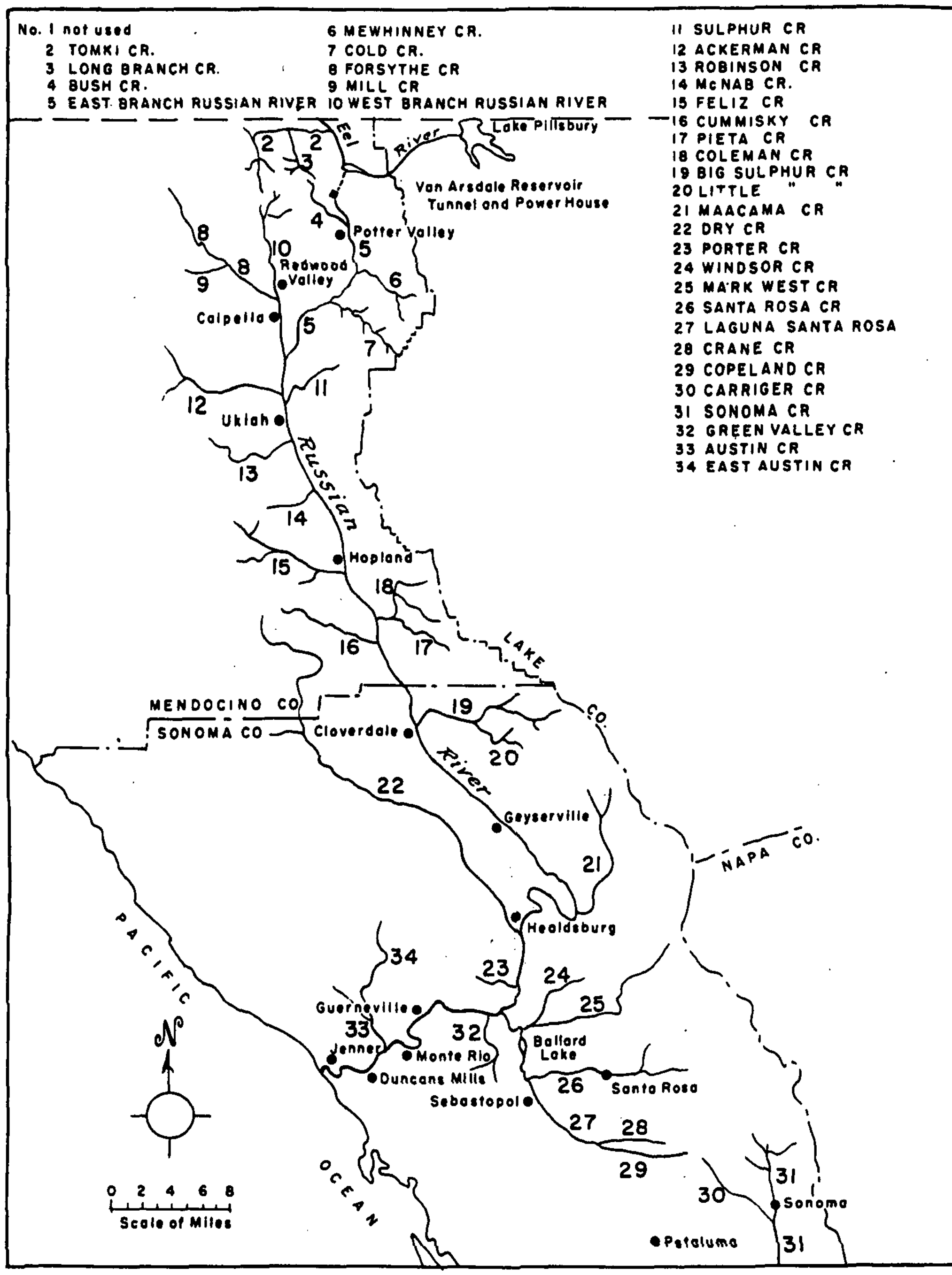


FIGURE 1. The Russian River drainage, California.

THE FISHES AND THE FISHERY OF THE RUSSIAN RIVER

At least 32 species of fishes are known from the freshwater portion of the Russian River (Table 2). Of this number, 21 are native and 11 are introduced forms [3].

The principal fishery of the Russian River in the winter is for steelhead trout and is of considerable magnitude. Unpublished records of the Department of Fish and Game have shown a projected high of 81,000

[3] Marine forms which only occasionally enter the river are not included in the list.

angler days of use for the peak month of December, 1953, with a projected catch per unit of effort figure of 0.32 steelhead per angler day. The recreational value of the fishery is quite important. Silver salmon

TABLE 2

Fishes of the Russian River

Common name	Scientific name
Family Petromyzontidae. Lampreys.	
1. Pacific lamprey	*Entosphenus tridentatus*
2. Brook lamprey	*Lampetra planeri*
Family Acipenseridae. Sturgeons.	
3. White sturgeon*	*Acipenser transmontanus*
4. Green sturgeon*	*Acipenser medirostris*
Family Clupeidae. Herrings.	
5. American shad†	*Alosa sapidissima*
Family Salmonidae. Salmon and trout.	
6. Pink salmon*	*Oncorhynchus gorbuscha*
7. Silver salmon	*Oncorhynchus kisutch*
8. King salmon	*Oncorhynchus tshawytscha*
9. Brown trout†	*Salmo trutta*
10. Rainbow-steelhead trout	*Salmo gairdnerii*
Family Catostomidae. Suckers.	
11. Western sucker‡	*Catostomus occidentalis*
Family Cyprinidae. Minnows.	
12. Carp†	*Cyprinus carpio*
13. Greaser blackfish	*Orthodon microlepidotus*
14. Hardhead	*Mylopharodon conocephalus*
15. Hitch	*Lavinia exilicauda*
16. Sacramento squawfish	*Ptychocheilus grandis*
17. Splittail	*Pogonichthys macrolepidotus*
18. Venus roach	*Hesperoleucus venustus*
Family Ictaluridae. Catfishes.	
19. White catfish†	*Ictalurus catus*
Family Poeciliidae. Top-minnows.	
20. Mosquitofish†	*Gambusia affinis*
Family Serranidae. Sea basses.	
21. Striped bass†	*Roccus saxatilis*
Family Centrarchidae. Sunfishes.	
22. Smallmouth bass†	*Micropterus dolomieu*
23. Largemouth bass†	*Micropterus salmoides*
24. Green sunfish†	*Lepomis cyanellus*
25. Bluegill†	*Lepomis macrochirus*
26. Sacramento perch	*Archoplites interruptus*
27. Black crappie†	*Pomoxis nigromaculatus*
Family Embiotocidae. Viviparous perches.	
28. Tule perch	*Hysterocarpus traskii*
Family Cottidae. Sculpins.	
29. Riffle sculpin	*Cottus gulosus*
30. Prickly sculpin	*Cottus asper*
31. Aleutian sculpin	*Cottus aleuticus*
Family Gasterosteidae. Sticklebacks.	
32. Three-spined stickleback	*Gasterosteus aculeatus*

*Forms not observed during the project but known to exist in the system.
†Introduced forms not native to California.
‡Some of the suckers killed may possibly have been the Humboldt sucker, *Catostomus humboldtianus*, although no attempt was made to distinguish between the two species in the field.

contribute a brief but often excellent secondary winter fishery in the lower portion of the river. King salmon are rarely taken.

The summer fishery of the Russian River consists almost wholly of yearling steelhead caught in the tributaries during the trout season, especially around the opening and closing of the season. Smallmouth bass, American shad, striped bass, white catfish, green sunfish, black crappie, and bluegill all provide a portion of the summer fishing. During the trout season, various rough fish, particularly Sacramento squawfish, are also caught.

The present stocking of fish in the Russian River drainage consists of juvenile steelhead derived from salvage operations in the same watershed. In some dry years as many as 350,000 rescued fish are planted.

THE CONTROL PROJECT

Methods

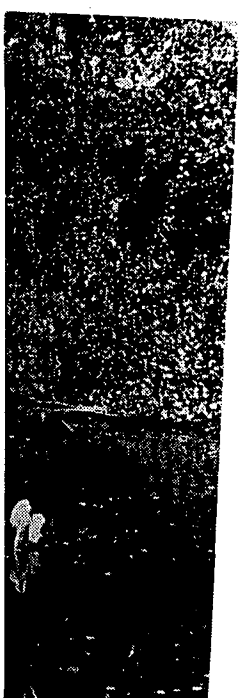
Dry cubé powder, containing between 2 and 5 percent rotenone, was applied by several different methods, depending upon the volume of water encountered and the degree of access to the stream channel. The simplest method was to put a measured amount of the powder into the stream a short distance above a falls or riffle. The churning action of the falls and the turbulence for some distance below mixed the powder with the water. Another method was to put from 1 to 10 pounds of the powder in a wet burlap sack and to "dunk" this in the stream at intervals while on foot or in a boat (Figure 2). This method was slow, laborious, and resulted in uneven application, although requiring a minimum of equipment.

FIGURE 2. Applying cubé powder by boat in lower Mark West Creek.

inter fishery in the
taken.
ts almost wholly of
g the trout season,
season. Smallmouth
reen sunfish, black
ıe summer fishing.
ularly Sacramento

drainage consists
tions in the same
) rescued fish are

ent rotenone, was
on the volume of
eam channel. The
e powder into the
urning action of
nixed the powder
to 10 pounds of
in the stream at
method was slow,
ugh requiring a



Creek.

FIGURE 3. The "Cubé Emulsifier" in action. A 50-pound sack of cubé powder has just been dumped into the tank and the outboard motor is running.

Two quite successful ways of applying the chemical utilized a premixed solution of cubé powder and water. One was by means of a four-gallon capacity back pump. Equipped with a spray nozzle, the pumps were used where vehicles could not go. The operators applied a continuous spray of the mixture to the water. Two men were required for this method, one carrying a pack loaded with cubé powder in order to refill the pump. The other quite successful means of applying the chemical was through the use of the "Cubé Emulsifier" (Figures 3 and 4). This apparatus was designed by the junior author. The Cubé Emulsifier consisted of a tank carried on a jeep pickup truck, an air-cooled outboard motor which mixed the powder with water, and motor-driven pumps used to fill the tank and to spray the mixture into the stream.

The determination of how much rotenone to use for the project posed an extremely difficult problem. Extreme variations in flow and temperature existed in each of the tributaries, as well as in various stretches of the main river. In the main river, toward the end of the project a heavy rainstorm increased the flow to more than 600 c.f.s. This required considerably heavier doses of cubé powder and reduced the cumulative effect of the powder coming downstream from previous applications. Further complications existed because some of the cubé powder had apparently lost some of its strength. Although chemical assays were made of this material, the results were not uniform and the minimum known rotenone content was 2 percent.

Difficult access to certain areas of the drainage was another reason why the amount of rotenone required could not be predetermined accurately. Once the treatment was started on a stream, it had to continue without lengthy lapses if the rough fish were to be prevented from entering treated areas. This required the introduction of varying amounts of the chemical, depending upon the distance between access points. Methods of testing the rotenone content of the treated water were relatively ineffectual because of continuous variations in the thoroughness of the mixing by the current. Figures 5 and 6 show examples of the extremes in channel conditions encountered during chemical treatment.

It was concluded that rotenone would have to be used in quantities many times the estimated amount necessary to kill fish life. Careful and immediate checks of the treated areas were made more or less continuously. Where there was any doubt, the rate of application was increased and the area retreated. Deep pools were usually additionally treated with cubé powder "mud balls" to get the chemical down to the bottom.

For spraying, one pound of cubé powder was mixed with four gallons of water in a back pump. This four-gallon mixture was applied, in tributaries, to about a 100-yard section of the stream where the flows were from four to five c.f.s., to give a minimum concentration of slightly more than 9.2 parts per million (p.p.m.) of 5 percent cubé powder.[4]

On the tributaries the back pump operator made certain that he managed to spray the entire surface of the water. The cumulative

[4] Although 0.5 p.p.m. of 5 percent cubé powder are considered lethal for most fishes, carp have been known to withstand up to 50 p.p.m.

ical utilized a
by means of a
ray nozzle, the
erators applied
were required
ibé powder in
ns of applying
fier" (Figures
hor. The Cubé
truck, an air-
er, and motor-
xture into the

project posed
low and tem-
rious stretches
the project a
This required
ne cumulative
applications.
powder had
assays were
the minimum

other reason
redetermined
, it had to
be prevented
of varying
tween access
eated water
ions in the
and 6 show
ered during

quantities
fe. Careful
ore or less
ication was
dditionally
al down to

with four
as applied,
where the
tration of
cent cubé

n that he
umulative

most fishes,

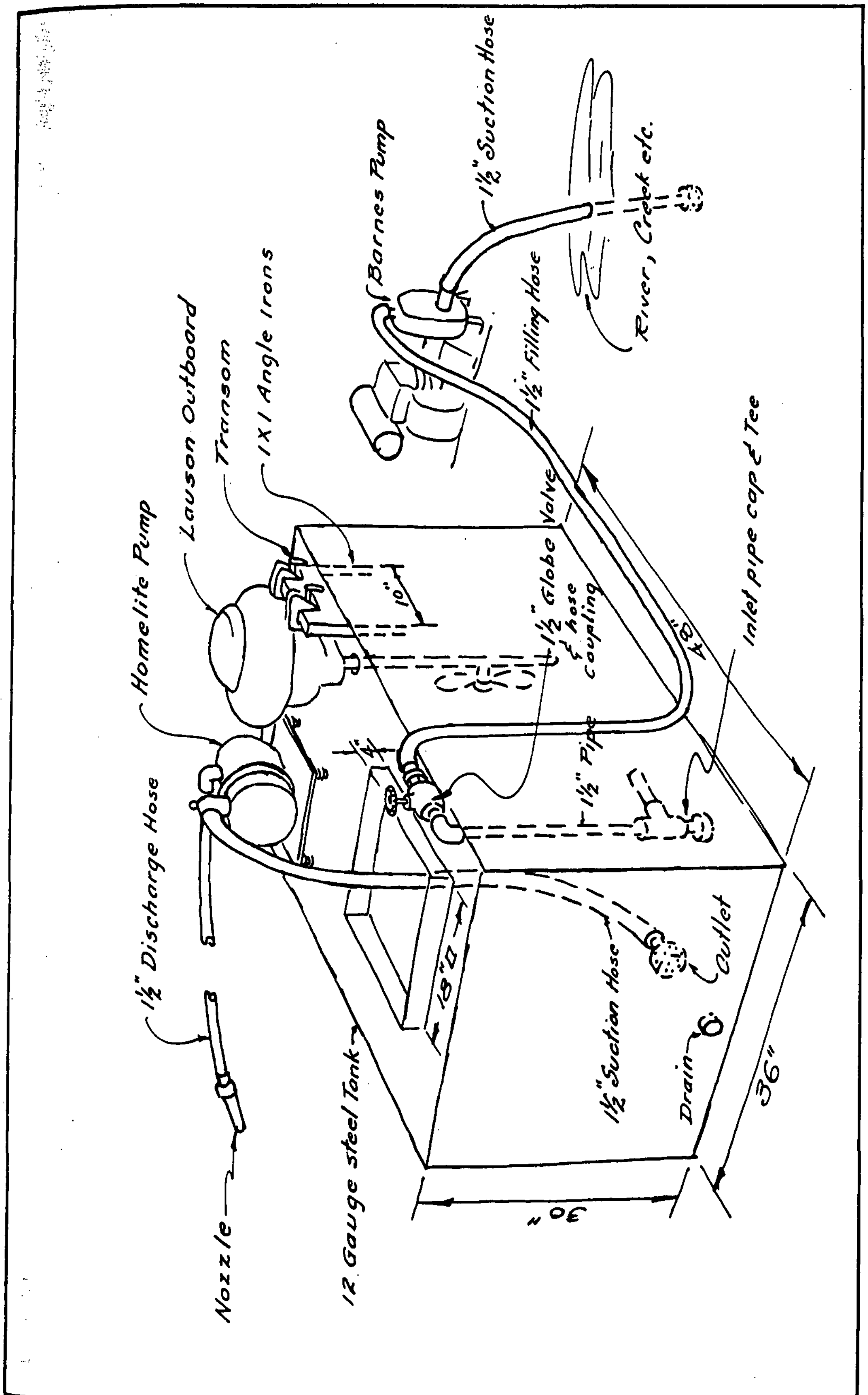


FIGURE 4. Diagram of the "Cubé Emulsifier", an apparatus for mixing and applying cubé powder.

FIGURE 5. The upper portion of Ackerman Creek, showing one type of channel encountered in the chemical treatment project.

effects of the mixture appeared to make up for any localized sublethal concentrations.

At one point in the treatment program fluoresceine ("Sea Dye") was mixed with the cubé powder mixture in a ratio of one-quarter of a

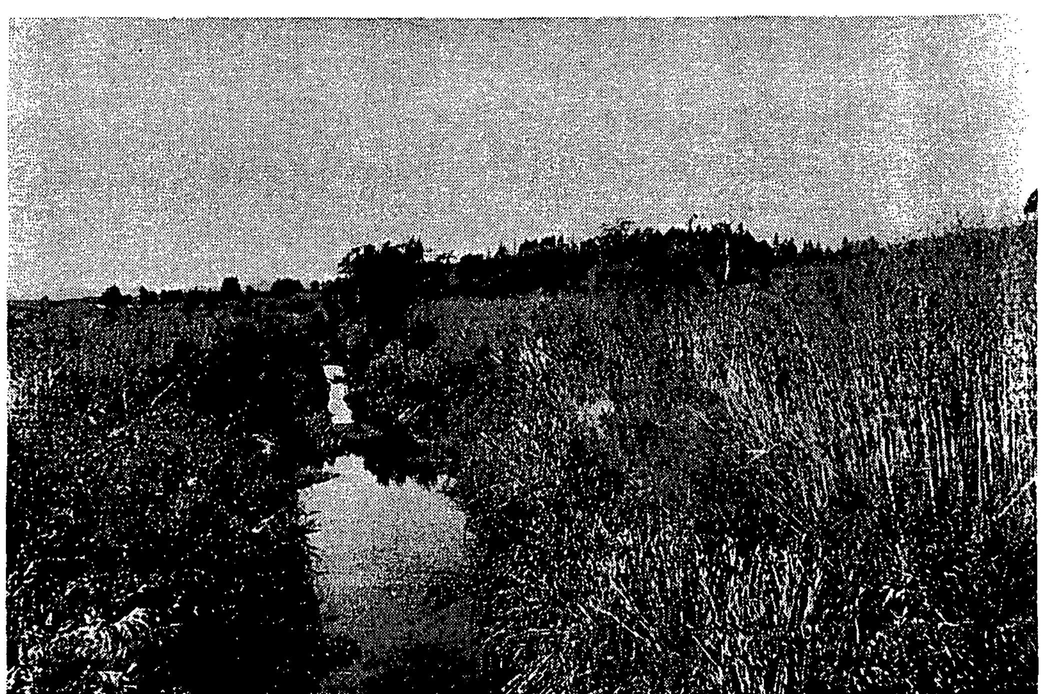
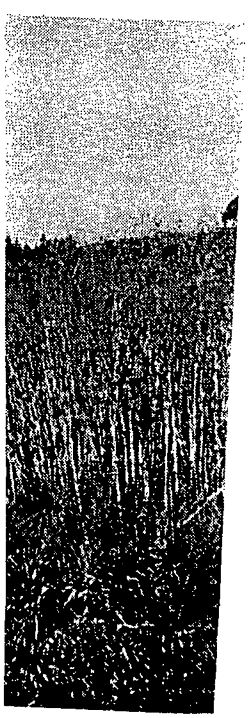


FIGURE 6. This ditch-like, nearly stagnant section of Santa Rosa Creek contained many carp.

type of channel

ocalized sublethal

"Sea Dye") was
one-quarter of a



itained many carp.

pound of dye to 250 gallons of the mixture in an attempt to follow the progress of the cubé powder downstream. Results were disappointing, for in flows over 10 c.f.s. the dye soon became diluted and disappeared. It was noted, incidentally, that the effects of the rotenone consistently showed up ahead of the dye. A heavier concentration of the dye might have given better results.

In order to speed up the operation in the main river and its principal tributary, the East Branch, arrangements were made with the Pacific Gas and Electric Company to shut down its Potter Valley diversion from the Eel River. The decreased flow concentrated the fish life and reduced the amount of cubé powder needed. A similar though smaller shutdown was made by the Santa Rosa Sewage Treatment Plant, in order to facilitate operations on Mark West Creek and lower Santa Rosa Creek.

Data accumulated by pretreatment sampling of the tributaries were used to determine not only which streams should be treated but also at what point on the stream treatment should begin. Streams containing Sacramento squawfish were treated upstream to a point where that species was no longer found. The maximum upper limit for any stream was chosen as that point where young steelhead or trout outnumbered the rough fish approximately 100 to 1. The downstream limits were usually automatically fixed by the point where the stream went underground or dried up. On the main river the downstream limit was set at the summer recreation dam at Healdsburg. This point was chosen because it was believed that the dam was a partial barrier to rough fish moving upstream during the summer period of low flow. Not enough was known of the fish population in the main river below this point to risk a possible kill of game fish.

ROUGH FISH CONTROL ON THE TRIBUTARIES

Pilot Experiments, 1952-53

Three streams were used for initial experiments in the chemical control of rough fish in the Russian River drainage. These were Big Sulphur Creek (1952), Dry Creek (1952 and 1953), and Maacama Creek (1953).

Big Sulphur Creek

Big Sulphur Creek, Sonoma County (Figure 7), was chosen for the initial sampling for several reasons. Local interest in rough fish control was high. A natural falls near its mouth acted as a rough fish barrier. The stream was safe for experimenting, since its mouth was dry in the summer and there was no danger of the chemical reaching the main river. Access was excellent throughout most of its length. Pretreatment sampling showed that rough fish were abundant, although the stream had a past history as a steelhead nursery.

The treatment began on October 9, 1952, when the mouth of the creek was still dry, using burlap sacks containing cubé powder. It began about one mile below The Geysers resort and continued downstream 13 miles to where the stream dried up. Little Sulphur Creek, the major tributary, was treated beginning October 11, 1952, starting at a point about three-quarters of a mile upstream from the mouth

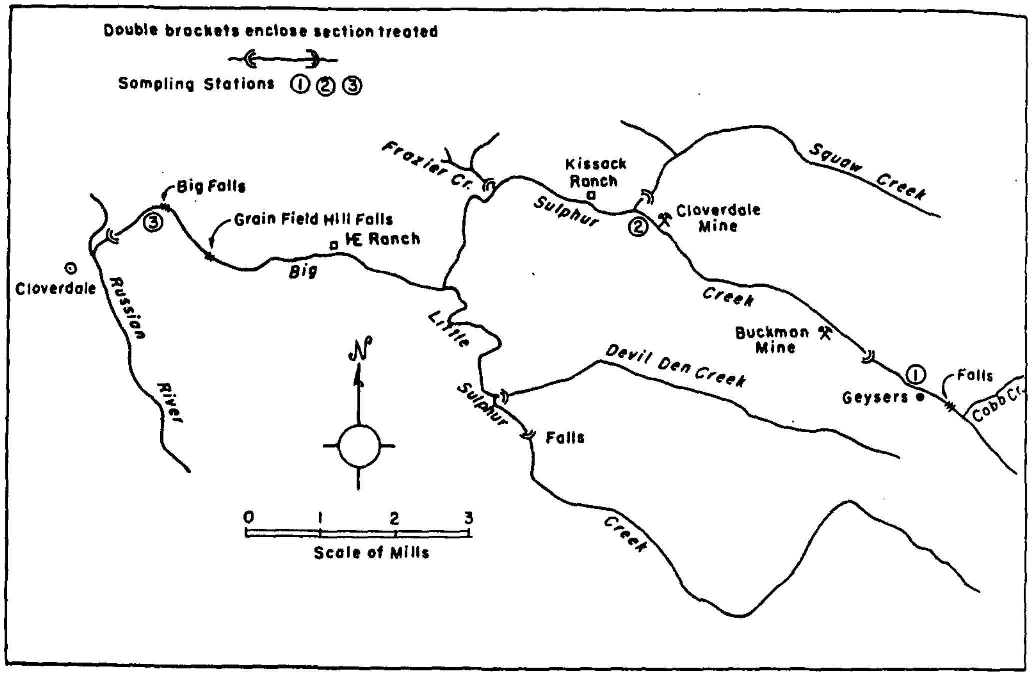


FIGURE 7. Map of Big Sulphur Creek drainage, showing sections chemically treated to control rough fish, and sampling stations.

of Devil Den Creek and continuing five miles to the junction with Big Sulphur Creek.

Dry Creek

Partial chemical treatment of Dry Creek, Sonoma County (Figure 8), was conducted between November 2 and 16, 1952. Treatment began a short distance above the mouth of Cherry Creek and continued eight miles downstream to a point where the creek went underground. Application was by burlap sack and back pump. Subsequent examination showed that the partial treatment was not successful, however, and a complete treatment was recommended for 1953.

There were two additional reasons why Dry Creek was chosen for chemical treatment again in 1953. First, it was important to treat a stream which contained no barriers to rough fish, in order to learn the rate of rough fish re-entry. Second, it was necessary to try out rough fish control on a large scale in order to perfect techniques which could be applied to the entire Russian River drainage.

Following the preliminary sampling, Dry Creek and its major tributaries, Gallaway, Cherry, Warm Springs, Pena, and Mill creeks, were chemically treated with about 950 pounds of cubé powder from about one-half mile below Yorkville to a point where the creek dried up. This took place between October 5 and 11, 1953, and included over 63 miles of stream. The project was accomplished by five two-man crews, plus two helpers and five service vehicles. A total of 84 man days was required, although not all of this was spent in actual application of the chemical. A visual and spot-rotenoning recheck of the area eight days later revealed a nearly complete kill, with the exception of a minor pool containing a few dozen sticklebacks, which were destroyed.

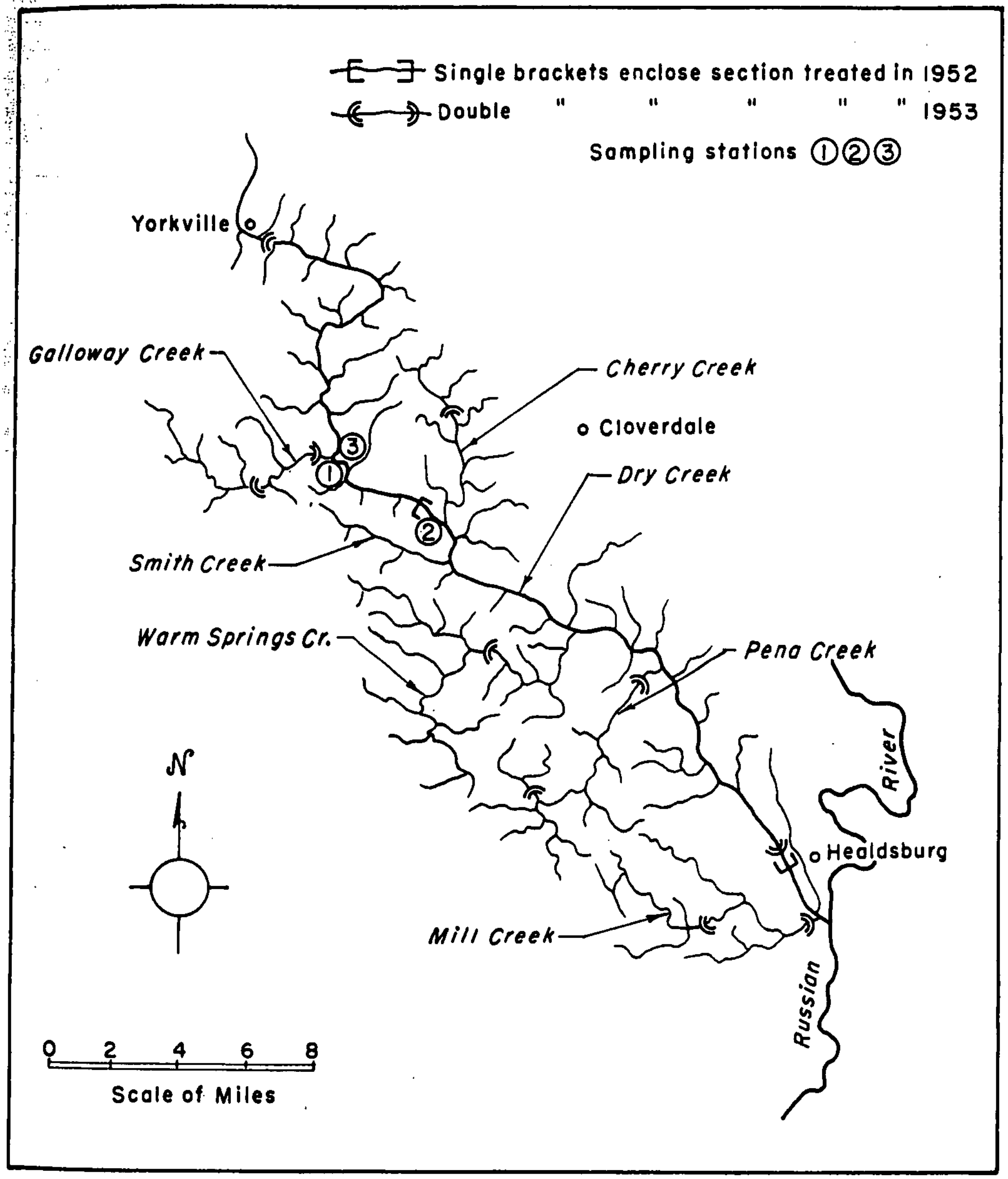


FIGURE 8. Map of Dry Creek drainage, showing sections chemically treated to control rough fish. Sampling stations are numbered.

The Dry Creek treatment showed the value of back pumps in applying the cubé powder (Figure 9) and the efficiency resulting from the use of two- and four-man back pump crews, each assigned to a two- to five-mile stretch of the creek and operating on their own. This released supervisors for coordination and liason activities, and rechecks of treated areas.

Maacama Creek

Immediately following the Dry Creek treatment of 1953, rough fish control work began on Maacama Creek (Figure 10). This creek was chosen as an experimental stream in order to gain supplemental data. It was possible on this stream to check the effect of erecting a temporary flashboard dam about two and one-half miles above the mouth

FIGURE 9. On this section of Dry Creek the use of two 2-man crews greatly increased efficiency and speed. Note dead fish in the foreground. *Photograph by E. L. Daggett.*

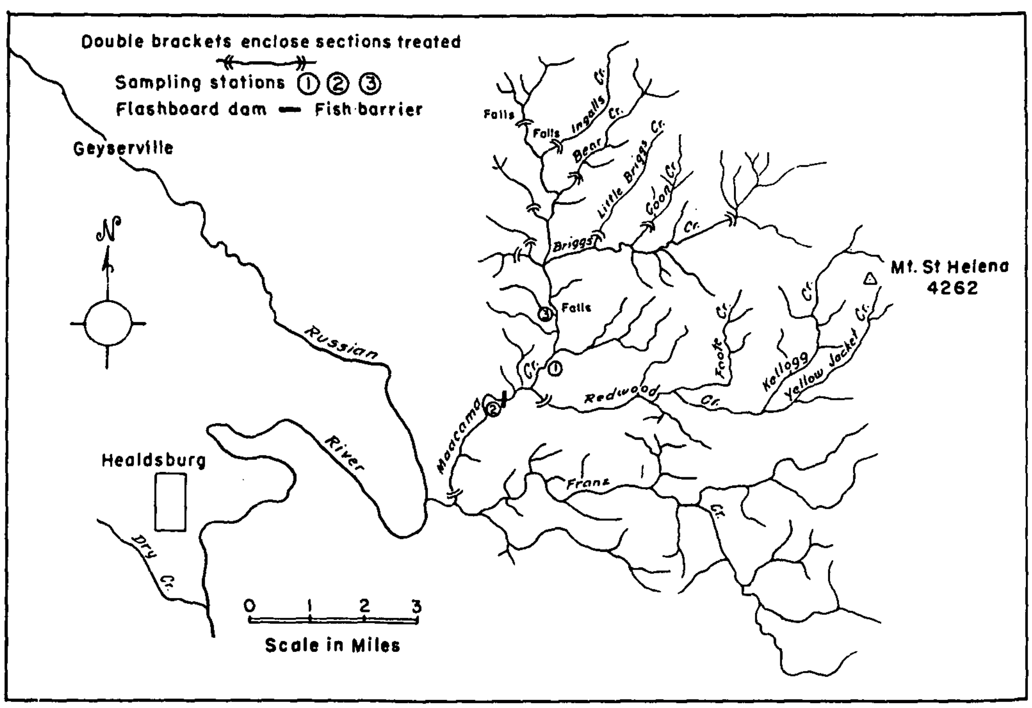
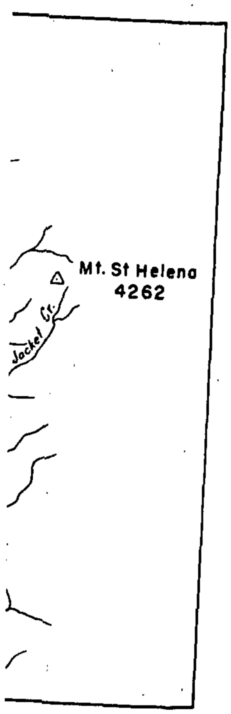


FIGURE 10. Maacama Creek drainage, showing sections chemically treated to control rough fish. Sampling stations are numbered.

ly increased efficiency
L. Daggett.



to control rough

after the winter runoff. It was thought that the majority of the rough fish migrated upstream later in the season and could be prevented from re-entering the stream.

Slightly more than 20 miles of Maacama Creek and its tributaries were chemically treated with about 350 pounds of cubé powder during the period from October 13 to 15, 1953. Short sections of the headwater areas were omitted, since rough fish were not observed there in any numbers, while members of the rainbow-steelhead trout complex were abundant. The operation was accomplished by four two-man crews, plus two helpers and four vehicles. A total of 23.5 man days was required, of which 7 man days were spent on preliminary and post surveys and retreatment.

The powder was applied as a mixture with back pumps at a rate of 17.5 pounds per mile.

The flashboard dam was installed late in April, 1954, and again in May, 1955. It apparently was quite successful in blocking re-entry of rough fish, although the chemical treatment of the main river in November, 1954, removed a potential source of rough fish which might have moved upstream before the barrier was installed.

Control on the Remaining Tributaries, 1954

In 1954 the program was further extended as a result of favorable results from the experimental treatment of the three pilot streams and consisted of chemical treatment of all the remaining tributaries where rough fish occurred in abundance. The East Branch of the Russian River was omitted and considered with the main river for later treatment.

No attempt was made to retreat the three experimental tributaries in 1954, despite their being a possible source of rough fish, because it was desirable to avoid interfering with continued post-treatment sampling. The remainder of the treated tributaries are listed in Table 8.

Information gathered during the preliminary field surveys was used to make out a schedule of chemical treatment which would leave sufficient time for treatment in the main river. This part of the program consumed nearly all of the time between August 31, when treatment was begun on Ackerman Creek, Mendocino County, and October 22, when the tributary treatment was terminated with the completion of the lower portion of Windsor Creek, Sonoma County. Twenty tributaries in Mendocino and Sonoma counties, totaling 107 miles in length, were chemically treated. Using a crew of six men, about 300 man days were required. One boat and four service vehicles were used in distributing approximately two tons of cubé powder. It was during this phase of the work that the Cubé Emulsifier was designed, built and first used.

Variations in flow, terrain, and stream channel types were wide. In general, the streams north of Healdsburg had greater flows, steeper gradients, and cleaner channels, although tending to go underground near their mouths. Excellent shade existed in most cases, with little of the characteristic brushy, bankside ''jungles'' found below Healdsburg. The water was quite clear and flowed through rocky gorges and over boulder-covered bottoms. Although rough terrain required walking out the streams with back pumps, treatment was rapid and the clarity of the water permitted more accurate rechecks for species composition and completeness of kill. Higher flows also carried the cubé powder in lethal concentrations much farther downstream.

Below Healdsburg many of the streams were slow-flowing delta or flood plain types. Frequently the banks were of mud and the water was nearly or completely stagnant. Heavy underbrush grew all the way to the water line, although shade trees were lacking. The water was deep and wide in these sections. Application of the cubé powder by crews walking the banks with back pumps was slow, both because of obstacles and because the pumps were emptied frequently. The Cubé Emulsifier, mounted on the jeep, proved the only feasible means of treatment.

Immediate rechecks of the treated areas on the tributary streams were made during the progress of the treatment to verify preliminary observations of the abundance of rough fish and to make certain the kill was complete.

ROUGH FISH CONTROL ON THE MAIN RIVER

Chemical Treatment

The treatment of the main Russian River and the East Branch of the Russian River followed closely upon treatment of the tributaries. It was completed between November 6 and November 10, 1954, and terminated at the Healdsburg Recreation Dam, covering a distance of about 78 miles. The work was accomplished by a crew of nine men and seven vehicles over a five-day period. A total of 43 man days was required, although not all of this was spent in actual application of the chemical. The average rate of application of the cubé powder was 54.1 pounds per mile.

A nonstop schedule was prepared, in order to maintain a continuous lethal block of the chemical despite dilution. The operation was facilitated by arrangements with the Pacific Gas and Electric Company to shut down their Eel River diversion to 10 c.f.s., in order to reduce the amount of chemical needed and to speed up the operation. The date of the treatment was largely determined by the time when this shutdown could most economically be effected by the company. It was also believed desirable to complete the treatment prior to the onset of the winter rains, which might stimulate the spawning migration of silver salmon and steelhead, as well as carry the accumulated rotenone in in lethal quantities downstream. This was ony partially successful, since rain during the latter part of the treatment raised flows to over 600 c.f.s. and some silver salmon were killed at the mouth of the river.

The first introduction of the chemical was made November 6, 1954, in the tailrace of the Pacific Gas and Electric Company's power plant in Potter Valley. The Cubé Emulsifier, mounted on a jeep, was used to mix the cubé powder, and the mixture was sprayed into the water through a fire hose.

Besides the use of the Cubé Emulsifier, other methods of introducing the chemical, as dictated by expediency and conditions, were used, such as mixing the dry powder with water in a pit dug in the beach beside the river, or by slowly dumping sacks of the dry powder in a riffle or above a falls.

The movement of the chemical in the river was checked by observing the effect upon fish life downstream. Distances traveled by the chemical varied with flows, the amount of chemical introduced, and characteristics of the stream channel. In the upper sections of the East Branch, the low flow of 10 c.f.s. and numerous check dams prevented the chemical from being carried effectively for more than about one mile before additional chemical was needed. The maximum distance and speed traveled by the chemical was recorded during treatment in the Hopland area. In this instance, with the flow about 90 c.f.s., a total of 1,000 gallons of the mix containing 225 pounds of powder was introduced by the Cubé Emulsifier. On the following day the effects of this dose were traced, by means of dead fish in and along the river, for 16 miles. This distance was covered in almost exactly 16 hours. It is possible that the effects might have extended still farther if there had not been additional dilution from Pieta Creek at the lower end, and if a light rain had not begun about the time of the introduction.

Attempts were made to meet changing conditions by increasing or decreasing the amounts of chemical added to the river at various stations. Changes in stream channel characteristics were easily handled, but abrupt changes in weather and flows were more difficult. Intermittent rain fell throughout the latter half of the treatment. In addition, water released by the power company on November 9, 1954, increased the flow in the East Branch from 10 to 100 c.f.s. in a single 24-hour period. The fluctuations in flow shown in Table 3 indicate the effects of both the rain and the later release from the diversion.

Results

Rechecks of the treated areas to determine the completeness of the kill were made almost continuously during the five-day period, including a reconnaissance by boat of a 10-mile section. In no place were live fish discovered. The spreading of the high concentration of the chemical by moving water made adequate coverage much more certain than is the case in lakes and ponds. Dispersal of the chemical appeared excellent, for effects showed up in back eddies and even in connected side pools throughout the treated area. Although most invertebrates were not seriously affected by the rotenone, it was noted that at the point of initial introduction of the chemical a few crayfish started to crawl out of the water.

Effects of the chemical did not automatically stop in the vicinity of the Healdsburg Recreation Dam, where treatment ended. It was expected that the effects would travel up to 10 or 15 miles farther downstream with constantly diminishing strength. The flushing action of the early rain, however, greatly increased the downstream movement of the chemical. In addition, the cumulative buildup of the chemical apparently counteracted the increased dilution caused by the rain. The result was that fish were affected all the way to the mouth of the river at Jenner, a distance of more than 22 miles from the last point at which the chemical was introduced. Carp were observed in distress, but only a small number of them were eliminated, judging by the scarcity of carcasses along the banks later. Other fish were also affected and about 150 silver salmon were killed in the area below Monte Rio.

TABLE 3

United States Gaging Station Records for Various Locations and Dates, East Branch of Russian River and Russian River

		Flows in cubic feet per second				
		East Branch of Russian River near Calpella	East Branch of Russian River near Ukiah	Russian River near Hopland	Russian River near Cloverdale	Russian River near Healdsburg
October, 1954, means		308	303	301	304	311
November, 1954, means		270	259	302	408	770
5-year means for November, 1946-1950		239	----	324	----	659
November	1	313	306	304	318	332
	2	288	288	304	318	335
	3	162	153	230	275	335
	4	158	151	183	203	285
	5	94	88	146	175	240
East Branch and main Russian River treatment period	6	22	30	104	131	232
	7	18	13	75	105	180
	8	24	24	75	131	200
	9	26	25	70	131	640
	10	112	105	72	98	430
	11	317	311	172	187	299
	12	327	315	315	366	605
	13	320	294	296	330	517
	14	362	343	334	837	618
	15	552	511	887	1,960	5,580
	16	412	390	722	1,070	2,600
	17	342	324	452	664	1,410
	18	332	315	382	500	1,020
	19	330	312	354	436	914
	20	330	318	342	414	765
	21	327	315	338	390	695
	22	327	315	330	381	645
	23	327	315	330	372	610
	24	327	312	327	363	580
	25	327	315	327	357	559
	26	327	315	323	351	535
	27	327	315	323	348	517
	28	327	315	319	345	499
	29	327	315	319	345	490
	30	327	312	319	342	478

The above figures, with the exception of the five-year means, were obtained from unpublished records (subject to revision) of the Water Resources Division, U. S. Geological Survey.

The five-year means were computed from the reports on Surface Wat r Supply of Pacific Slope Basins in California for the years 1946 through 1950, inclusive, published by the U. S. Geological Survey.

Immediate checks of the lower river showed that this was not a complete kill of the spawning run.

A list of the species observed, giving approximate distribution, locations of greatest abundance and, wherever possible, size ranges, is shown in Table 4.

Estimates based upon direct observations yielded a weight of from one to one and one-half tons of dead fish per mile for the section of the river above Healdsburg and one-half ton of dead fish per mile in the section below. Observations in the latter section were extremely difficult because of high and turbid water, and for that reason represent a con-

TABLE 4

Sizes and Distribution of Fishes Observed During Treatment of the East Branch and Main Russian River—1954

Species	Where found	Area of greatest abundance	Size range (inches)	Remarks
Pacific lamprey	Throughout treated area	Ukiah	----	Lamprey ammocoetes greatly outnumbered other species.
Brook lamprey	Only near Ukiah	Not abundant anywhere	6	A few also found in lower Mark West Creek.
Silver salmon	Jenner to Monte Rio	Mouth of river (Jenner)	----	50% adults, 50% grilse.
King salmon	Mouth of river (Jenner)	Not abundant anywhere	----	Only 2 adults observed.
Rainbow-steelhead trout	Throughout entire river	Not abundant anywhere	5-25	
Western sucker	Throughout entire river	Throughout entire river	1½-24	Absent only in extreme upper part of East Branch Russian River.
Carp	River below point 4 miles above Cloverdale	Mouth of Mark West Creek and Duncans Mills	7-35	Majority were adults 14 inches or more in length.
Greaser blackfish	Geyserville to Healdsburg	Not abundant anywhere	5-16	Most were found in Healdsburg gravel pits in river bed.
Hardhead	Potter Valley to Healdsburg	Mouth of East Branch Russian River	4-22	
Hitch	Hopland to mouth of Mark West Creek	Not abundant anywhere	6-10	
Sacramento squawfish	Throughout entire river	Healdsburg and above	3-34	
Venus roach	Throughout entire river	Scarce—mainly at mouths of tributaries	¾- 5	
White catfish	Healdsburg and vicinity	Scarce everywhere	6-10	
Striped bass	Guerneville bridge	Not abundant anywhere	----	Only 2 adults observed; 20 lbs. and 35 lbs.
Smallmouth bass	Mouth of Cold Creek downstream	Monte Rio to mouth	4-14	Only 20 were above 9 inches long.
Largemouth bass	Geyserville side channels	Very scarce everywhere	18	
Green sunfish	Throughout entire river	Geyserville-Healdsburg sloughs	¾- 6	Present only in limited numbers.
Bluegill	Geyserville side channels	Very scarce everywhere	4	
Sacramento perch	Geyserville side channels	Very scarce everywhere	3½-4½	
Tule perch	Below lower end of Potter Valley	Fairly abundant everywhere	2- 6	
Sculpins	Potter Valley area	Very scarce everywhere	7	Only one specimen observed.
Three-spined stickleback	Geyserville and vicinity	Not abundant anywhere	1- 3	

servative estimate. The estimated total amount of fish killed was 95 tons.

COST OF THE PROJECT

The costs of the operating phases of the project totaled about $6,000. This is computed on the basis of $2,100 for salaries, $1,400 for operating expenses, and $2,500 for materials. The costs of preliminary and follow-up survey are not included in these figures. The cost of treatment per mile of stream averaged about $20.

EVALUATION

Pretreatment sampling of the fish population, both to determine whether or not a particular stream warranted treatment and to be able to evaluate the results of the treatment by a comparison of the fish populations before and after treatment, was carried out.

Methods

Visual checks were used on most of the shallow tributaries to determine the upstream limits of both Sacramento squawfish and other rough fish. They were also used in a limited way in rechecking some of the tributaries several weeks or months after treatment. Observations on numbers and kinds of fishes killed were also made on foot and by boat, both at 100-foot sections and sometimes continuously, immediately following the treatment. While this method gave a limited qualitative check on live fish, its best use was in a recheck following the kill.

Seines and sampling gill nets were used in deep portions of the main river. This, too, was entirely qualitative. In inaccessible stretches of water, or during periods when the electric shocker was not available, sampling was performed by means of spot rotenoning and a subsequent

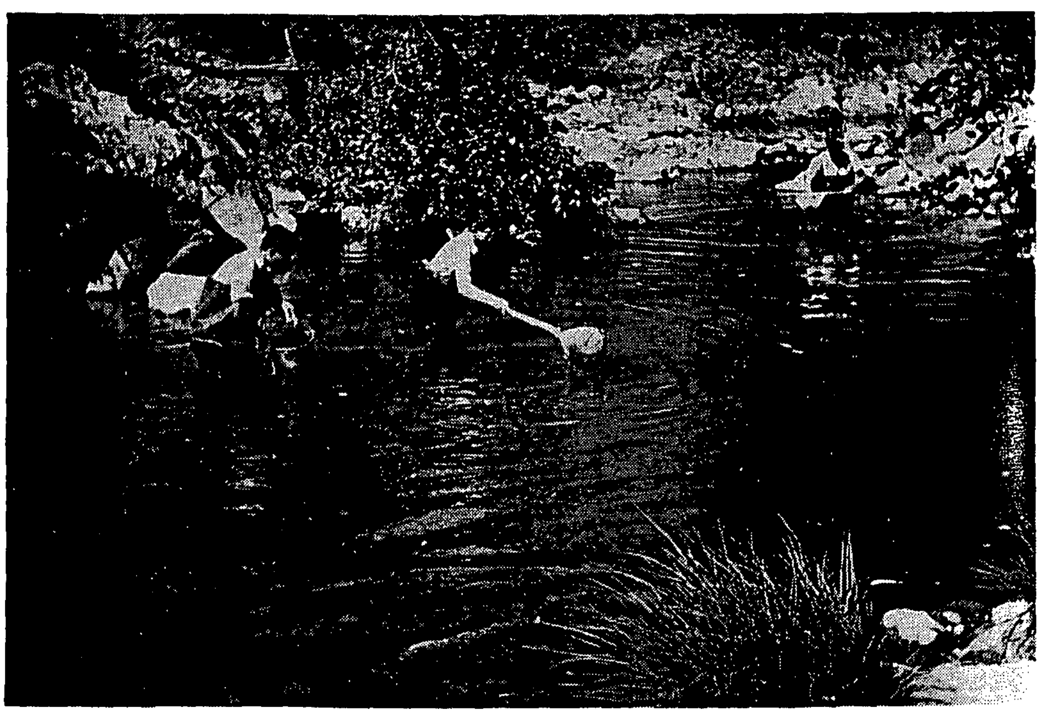


FIGURE 11. Part of the crew collecting fish killed by spot rotenone sampling in Forsythe Creek.

count of the dead fish along a given stretch of stream which had been blocked by seines (Figure 11).

Two types of electric shockers were used for sampling. One was a 110-volt A.C. shocker and the other was a 230-volt D.C. shocker. The latter was especially helpful, since fish were attracted to the positive electrode. A 100-foot section was blocked with seines and the area shocked until no more fish appeared. This method frequently revealed a much larger and more varied population of fishes than was observed by a visual check.

Tributary Stream Fish Population Sampling

Big Sulphur Creek

Preliminary sampling on this creek showed that rough fish in the form of suckers, squawfish, and roach composed 95 percent of the fish population. The remaining 5 percent were juvenile steelhead.

Post-treatment sampling in 1953, although limited, indicated that young steelhead made up almost 100 percent of the fish population. Suckers made up the remainder and squawfish and roach were absent. Table 5 compares pretreatment and post-treatment sampling at various stations.

The information on population change indicated by sampling was supplemented by creel checks made during the first few weeks of the trout season in 1953, 1954, and 1955. Prior to 1953, according to wardens' reports, the fishery was poor and sporadic. Only the expert angler was able to make a good catch, usually either just after the opening or just before the closing of the season. On the first two days of the season in 1953, wardens reported that only two of 47 anglers failed to have their limits of 15 juvenile steelhead.

A brief survey of this same stream on May 1, 1954, while not reflecting the same degree of success, did reveal a catch of 252 juvenile steelhead by 30 anglers for a catch per angler day of 8.4 fish. Whether or not the increase in numbers of steelhead was the direct result of the treatment is still questionable. The source of these fish is also unknown, since they were in their second year in the stream and could have come either from the tidewater area near the mouth of the river or from the untreated headwater areas. The latter source is the most likely, but too little is known of fish movement within the drainage system to be certain.

During the winter of 1953-54, further movement of the slide in the area of the falls barrier resulted in a complete block to upstream movement of steelhead, so that some of the value of rough fish control was not fully realized upstream. A separate project has since altered the falls, so that it again acts only as a rough fish barrier.

In 1955 further post-treatment electrosampling was performed on Big Sulphur Creek, as part of the long-term evaluation of the chemical treatment project. The three stations sampled produced 822 juvenile steelhead, 128 suckers, and 170 roach. At one of the stations (Station No. 2) it was found that the suckers were back to about the pretreatment level of abundance, but the steelhead continued to predominate by about 3 to 1. Creel censuses also showed excellent fishing again, as was observed in 1953 and 1954. The over-all picture was quite favorable three years after treatment.

TABLE 5

A Comparison of Fish Population Sampling in Big Sulphur Creek Be:ore and After Chemical Treatment

Species	Station No. 1				Station No. 2				Station No. 3
	Pretreatment 1952	Post-treatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1952	Post-treatment 1953	Post-treatment 1954	Post-treatment 1955	Post-treatment 1955
Rainbow-steelhead trout	35	31	13	38	0	3,393	--	363	421
Western sucker	9	4	12	5	134	23	--	121	2
Sacramento squawfish	0	0	0	0	97	0	--	0	0
Venus roach	351	544	751	148	0	0	--	0	22

Station No. 1 was located at The Geysers about three-quarters of a mile above start of treatment. An electric shocker was used in sampling. Practically the entire fish population was removed and counted.

Station No. 2 was obliterated by road building in 1954. About 30 rainbow-steelhead trout and a few suckers were observed in the area that year.

Dry Creek

Visual observations of Dry Creek in 1952 had shown that many rough fish were present, but no quantitative sampling was done. A check of the fishes killed in the treatment showed that roach and suckers predominated, with squawfish a close third. Trout, although abundant in a few areas, were generally scarce. Tule perch were well distributed in small numbers, but no smallmouth bass were found. The figures on the kill represent estimates made during brief observations. The 1953 electrosampling indicated that there was some reduction of rough fish in the treated area and an accompanying increase in the numbers of young steelhead. Table 6 shows, under the column "Station No. 2", the relatively large number of steelhead found in a 100-foot section. This is larger than the total number of steelhead estimated killed in the entire eight-mile treated area in 1952.

Population sampling was carried on in 1953 and a survey was conducted on the tributary streams to determine the upstream limits of squawfish and roach. In referring to Table 6 again, it may be seen that six species of rough fish made up the bulk of the pretreatment fish population at each of the two sampling stations checked by electric shocker in 1953. The average percentage of rough fish in the population was 84.

Post-treatment sampling in the Dry Creek drainage in 1954 revealed that hardheads, cottids, and sticklebacks virtually had been eliminated. Suckers, squawfish, and roach were still found in greatly reduced numbers. It is possible that they migrated into Dry Creek from the Russian River during the winter or that some of them were overlooked in determining the starting point of treatment in the tributary headwaters. It is encouraging to observe that in the first year following treatment the rough fish did not make a complete comeback, even though no barrier existed. No tule perch showed up in the 1953-54 pretreatment and post-treatment sampling.

Further sampling in Dry Creek in 1955 showed that this stream was returning rapidly to the pretreatment condition. Roach, suckers, and squawfish increased beyond the 1954 figures, while the juvenile steelhead population appeared to decline. The most obvious source of the rough fish was the main river. No barrier existed for the eight months when the creek was "live" to its mouth. Dry Creek was treated again in the summer of 1955, when spot rotenoning was undertaken to kill concentrations of squawfish.

Maacama Creek

Preliminary population sampling and a check on upstream limits of rough fish were made prior to treatment in 1953. Table 7 shows the sampling results. Seven rough fish and two pan fish species were originally present. Roach made up about 50 percent and squawfish about 16 percent of the rough fish. Juvenile steelhead made up 15 percent of the population.

The results of the Maacama Creek chemical treatment may be divided into two parts. At Station No. 2, in the area below the flashboard dam installed April 14, 1954, electrosampling showed a large increase in roach. Green sunfish and tule perch were also found in larger numbers than before treatment, and bluegills appeared where none had been

TABLE 6

A Comparison of Fish Population Electrosampling in Dry Creek Before and After Chemical Treatment

Species	Station No. 1			Station No. 2			Station No. 3		
	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955
Rainbow-steelhead trout	0	22	51	387	56	37	Not Sampled in 1953	402	10
Western sucker	44	17	19	260	120	151		68	9
Hardhead	2	0	0	15	0	0		0	0
Sacramento squawfish	36	0	8	119	6	65		15	2
Venus roach	7	5	126	985	18	19		27	0
Sculpin	0	0	0	3	1	0		0	7
Three-spined stickleback	0	0	0	123	10	0		0	3

Station No. 2 is located in a section of the stream included in the 1952 partial treatment. Lampreys are not included, although they appear to have been reduced in numbers.

partial treatment. Lampreys are not included, although they appear to have been reduced in numbers.

TABLE 7

A Comparison of Fish Population Electrosampling in Maacama Creek Before and After Chemical Treatment

Species	Station No. 1			Station No. 2			Station No. 3		
	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955	Pretreatment 1953	Post-treatment 1954	Post-treatment 1955
Rainbow-steelhead trout	21	81	445	12	9	192	Not	127	356
Western sucker	8	0	1	18	4	9		2	1
Hardhead	0	0	0	13	0	0	Sampled	0	0
Sacramento squawfish	6	0	0	38	7	27		0	0
Venus roach	147	38	130	0	102	202		21	67
Bluegill	0	0	0	0	4	0	in	1	0
Green sunfish	0	0	1	3	20	2		0	0
Tule perch	0	0	0	1	10	2		0	0
Sculpin	0	0	3	1	1	0	1953	3	2
Three-spined stickleback	0	2	1	0	0	0		1	2

Stations Nos. 1 and 3 are located above a flashboard dam which was operated in the spring prior to the 1954 sampling. Station No. 2 is located below the flashboard dam.

observed earlier. Suckers, hardheads, and squawfish showed an appreciable reduction, but the steelhead population remained at its former low level. In the areas above the flashboard dam the steelhead population increased at least fourfold, while all rough fish showed a marked reduction in the population, with hardhead, squawfish, green sunfish, and tule perch absent. These findings, while less striking than in Big Sulphur and Dry creeks, show the same trend. It is evident that the installation of the flashboard dam was of value in preventing the reentry of rough fish.

In 1955 additional sampling showed that the ratio between young steelhead and rough fish had improved still more in favor of the former. Steelhead had increased to as much as 20 times the abundance found in 1954, while the population of roach, the only rough fish showing a significant increase, about tripled.

Other Tributaries

Extensive preliminary field surveys were conducted in 1954.

Electrosampling on Mark West Creek and spot rotenoning on East Austin Creek showed that these streams were infested with rough fish far exceeding the young steelhead in numbers. Results were similar to those which were found on the experimental streams. Visual checks on the other tributaries showed the same condition.

Population checks during treatment were made on nine of the tributaries by selecting random 100-foot stretches and counting all the dead fish seen. The percentage composition of the species was computed from these checks (Table 8). Two streams were too turbid to afford rechecks of much accuracy, but because of the amount of cubé powder used, there was little doubt that a high percentage of kill had occurred. Samples of the kill taken on the tributary streams indicated that the fish population was composed of an average of 14 percent game fish, including smallmouth bass and green sunfish, and 86 percent rough fish.

Evaluation by electrosampling the fish population was carried out in 1955 at selected stations on five of the tributaries for which pretreatment data were available. Table 9 shows the differences between pretreatment and post-treatment for these streams. The number of yearling and fingerling steelhead increased from 157 in 1954 to 1,673 in 1955. The change in abundance of rough fish for the same period was from 895 in 1954 to 130 in 1955, or to one-seventh of their former abundance. Exceptional trout fishing on some of the tributaries during the opening of the 1955 season was also observed.

Some of the five streams exhibited individual trends in population shift considerably at variance with the over-all picture. For example, on Forsythe Creek and the West Branch of the Russian River, Sacramento squawfish appeared at sampling stations where none were found before treatment. In the case of the latter stream, there was an almost equal increase in abundance of both juvenile steelhead and squawfish. Mark West Creek showed a 66 percent decrease in the numbers of juvenile steelhead in 1955. At the same time, however, there was a 92 percent decrease in rough fish.

Four other treated tributaries for which no comparable pretreatment figures were available were sampled with an electric shocker in

TABLE 8

Percentage Composition of the Fish Populations at Various Stations on Selected Tributary Streams of the Russian River Chemically Treated From August Through October, 1954

Stream	Game and pan fish				Rough fish					
	Brown trout	Rainbow-steelhead trout	Small-mouth bass	Green sunfish	Western sucker	Hardhead	Sacra-mento squawfish	Venus roach	Tule perch	Sculpin
Ackerman Creek		4.83			23.39		12.91	58.87		
Robinson Creek		7.31			45.41		0.85	46.09		0.34
Feliz Creek		22.73			17.17		8.43	51.67		
Forsythe Creek	0.33	21.64	3.35	1.17	15.77		2.88	54.86		
Mill Creek		21.23		3.91	15.08			58.10		1.68
Sulphur Creek (Mendocino County)					8.68		23.29	68.03		
Russian River, West Branch		0.49	9.32		29.45	3.66	15.47	38.77	2.84	
McNab Creek		8.95			18.69		7.53	64.83		
Porter Creek		18.05			22.55		9.03	45.11		5.26
Percentage by species, all streams combined	0.37	11.50	1.16	0.56	21.86	0.41	8.98	54.04	0.31	0.81
Percentage by type	13.59				86.41					

TABLE 9

Comparison of Electrosampling Results Before (1954) and After (1955) Chemical Treatment of Selected Tributaries of the Russian River

Name of stream	Species																				Types					
	*Trout		Western sucker		Sacramento squaw fish		Venus roach		Mosquito fish		Small-mouth bass		Green sunfish		Tule perch		Sculpin		Stickle-back		*Trout		Other		Totals	
	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955	1954	1955
Feliz Creek	6	986	29	0	31	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	686	986	113	0	119	986
Forsythe Creek	35	325	22	0	3	16	85	0	0	0	12	0	2	0	0	0	0	0	0	1	35	325	124	17	159	342
Mark West Creek	71	24	4	0	1	0	324	0	0	18	0	0	0	14	1	0	27	0	106	7	71	24	463	39	534	63
Robinson Creek	43	269	17	0	2	0	21	0	0	0	0	0	0	0	0	0	21	0	0	1	43	269	61	1	104	270
Russian River, West Branch	2	69	59	2	37	68	0	0	0	0	38	0	0	2	0	0	0	0	0	1	2	69	134	73	136	142
Totals	157	1,673	131	2	74	84	483	0	0	18	50	0	2	16	1	0	48	0	106	10	157	1,673	895	130	1,052	1,803

* Includes resident rainbow trout and juvenile steelhead trout.

1955. The results are shown in Table 10. The favorable trend in species composition was evident here, as in other treated streams. Rough fish made up only about 10 percent of the total number of fish one year after treatment. The majority of the remainder were juvenile steelhead and a few juvenile silver salmon.

TABLE 10

Electrosampling Results for 1955 on Four Russian River Tributary Streams for Which No Pretreatment Data Are Available

Streams	Species							Total rough fish	Grand totals
	Trout*	Silver salmon	Western sucker	Sacramento squawfish	Venus roach	Sculpin	Stickleback		
Cumminsky Creek	83	0	1	0	13	0	0	14	97
East Austin Creek									
Station No. 1	139	0	0	2	54	1	0	57	196
Station No. 2	278	33	0	0	14	8	0	22	333
Mewhinney Creek	14	0	0	4	0	0	0	4	18
Pieta Creek	319	0	0	0	0	0	0	0	319
Totals	833	33	1	6	81	9	0	97	963

* Includes resident rainbow trout and steelhead trout.

From the first year's follow-up electrosampling on a number of the treated tributaries of the Russian River, it was concluded that in general the chemical treatment was at least temporarily successful. It resulted in a reduction in the numbers of rough fish, with a simultaneous increase in juvenile steelhead, in nearly all of the tributaries. Sampling showed that juvenile steelhead, together with other game fish, made up less than 1 percent of the fish population before treatment. In 1955, about 67 percent of the population was in this category, increasing about 13 times. Of the remaining 33 percent, 17 percent were roach and 6 percent squawfish. No smallmouth bass were observed, but suckers, sculpins, sticklebacks, and tule perch were found in small numbers.

Sampling the Main River

Preliminary work on the Russian River rough fish control project, especially on the three experimental streams, raised a pertinent question concerning the fish population in the main river. If juvenile steelhead were scarce in the tributaries, was it because they had sought refuge in the larger water? However, poor angler success for trout in the main river suggested a very low population there. Fishing for other game species was also poor. It was suspected, therefore, that the main river also had a large rough fish population. In 1953, advantage was taken of the emergency shutoff of the Pacific Gas and Electric Company power plant diversion in Potter Valley to sample fish populations between October 24 and October 27, 1953. During this period a survey of the fish population was made at selected stations between Potter Valley on the East Branch and Hacienda on the main Russian River. Although the flow was cut almost to zero at the powerhouse, the effect on the river below was to reduce its flow to 50 c.f.s. The fish population was sampled by beach seines, gill nets, and spot rotenoning. The results showed a population of 90 percent rough fish, 8 percent warmwater game fish, and 2 percent resident trout and juvenile steelhead.

An additional survey, using beach seines, was made in July of 1954 in a 20-mile section between Mirabel Park and Jenner. This section has a low gradient and, with the exception of the brackish estuary, appears to offer an ideal habitat for warmwater fishes. The results revealed a population dominated by rough fish. Carp were most prominent by weight and by numbers, with suckers second in abundance, among the rough fish. Warmwater game fish were scarce, with smallmouth bass being the only species taken in significant numbers. In the lowermost stretch of the river, shad fingerlings were the most abundant of any species encountered.

Rechecks of the fish population following treatment of the main river revealed 22 species of true fishes and 2 species of lampreys. Of the dead fish observed in the treated area, suckers were estimated to represent approximately 90 percent of the total population. Sacramento squawfish were second in abundance, comprising about 5 percent. Tule perch accounted for about 2 percent and smallmouth bass less than 0.5 percent. The remaining 14 species were scarce and together comprised only 2.5 percent of the population. The rough fish, therefore, represented at least 97 percent of the fish population.

The only evaluation of the results of the control program on the main river has been in the form of observations of summer fishing. Prior to treatment fishing in this part of the river was primarily for warmwater fishes. The spring and summer of 1955 saw a large, successful summer fishery for trout (juvenile steelhead) where none had existed for years. Whether or not this fishery is only a temporary condition will be revealed by further evaluation work.

The Follow-up Program

The follow-up program consists of a five- to eight-year study of changes in the fish population in the Russian River and its tributaries. Through population sampling, an attempt will be made to discover the recovery rate of the rough fish, the amount of increase in the juvenile steelhead population, and the length of time that the beneficial results of the treatment will last. Winter creel censuses on the main river should reflect the effect of the treatment project upon the runs of adult steelhead, while censuses during the trout season should give an idea of the role of juvenile steelhead in the summer fishery.

DISCUSSION

Sources of Reinfestation

Final examination of the treated areas revealed no living fish, but it is scarcely conceivable that every pool supporting rough fish was discovered and treated. Furthermore, it is known that numerous sources for reinfestation of rough fish exist. As mentioned earlier, preliminary sampling of the upstream limits of rough fish in the tributary streams revealed high concentrations of salmonids in many instances. Where the latter were in a ratio of more than 100 to 1 over the rough fish, it was not believed justifiable to treat. In other cases, again because of the preponderance of salmonids, the upstream limits were fixed by the extent of the distribution of Sacramento squawfish. Therefore, the headwaters still contained some rough fish after the treatment was concluded.

Three streams, Big Sulphur, Dry, and Maacama creeks, were treated the previous two seasons but not in 1954. It was learned through subsequent electrosampling that large rough fish had managed to enter Dry Creek during the winter of 1953-54. Some rough fish may also have entered the two other streams.

It has already been mentioned that, although the lowermost application of rotenone was made at Healdsburg, the effects were felt all the way to the mouth of the Russian River. The resulting kill was not universal and many undesirable fish in that area were still free to travel upstream. The Healdsburg Recreation Dam acts only as a partial fish barrier. Literally thousands of carp were made sick by the exposure to cubé powder below Healdsburg. Judging from the few dead carp found, however, most of them probably recovered.

Another source of rough fish is by way of the Pacific Gas and Electric Company diversion from Van Arsdale Dam on the Eel River to the headwaters of the East Branch of the Russian River in Potter Valley. Although carp, Sacramento squawfish, and the majority of other warmwater fishes are absent from the Eel River, Humboldt suckers, green sunfish, and sculpins are present in the river above Van Arsdale Dam.

Many farm ponds are scattered throughout the Russian River drainage. A large share of these have been stocked with fish by the California Department of Fish and Game as part of its farm fish pond program, but others have been subject to indiscriminate and unauthorized planting with a variety of fishes by the owners. The farm ponds are located on the tributaries and, in general, are inaccessible to rough fish from the river. Rough fish existed in these tributaries prior to construction of the ponds, however, and the ponds may thus present another source of infestation.

A final source is the accidental or deliberate spread of rough fish by anglers and other persons. Some individuals attempt independently to help fish conservation by planting fish, while anglers frequently use bait minnows obtained from different drainages.

The Role of Public Relations

Public relations was found to play a major role in the rough fish control project. Although attention was given to this aspect of the work through newspapers, radio, and word of mouth, it was evident from complaints that still more effort could have been expended. It is obvious that public support is valuable in such a drastic management procedure as chemical control of rough fish in an entire drainage system.

Thorough advertisement and a program of public education regarding the purpose of the project and the manner of accomplishment are needed. If this is done, it should, in a large measure, offset adverse criticism.

Observed Effects of Rotenone

The effects of rotenone should be considered in three categories. First is its general killing effect as it varied under different flow conditions. One thing of interest is the apparent flushing action of the rapidly increasing flows caused by rain. During the tributary treatment this phenomenon was first noticed and it served to explain in part why the main river treatment carried so far. Near the end of the treatment program in East Austin Creek a steady two-day rain occurred. Until that time, the distance the chemical traveled downstream was limited to not more than a mile. It is thought that a low flow and dilution were responsible for the limited effect. Following the rain, however, fish in untreated Austin Creek, of which East Austin is a tributary, began dying and the effects were noted as far downstream as the Russian River. It is believed that much of the cubé powder in the initial application, in spite of its suspension in highly divided form in the water, had settled and otherwise become static on the sides and bottom of the streams. The flushing of the channel by rain, which at least doubled the flow, seems to have churned up the chemical and pushed it farther downstream, counteracting the dilution to some extent.

Similar changes occurred in the Russian River. Treatment began in Potter Valley on November 6. Intermittent rain fell throughout the latter half of the treatment, which ended on November 10. Rain on the previous day, coupled with the release of 100 c.f.s. of water from the powerhouse diversion, caused the river to rise several feet, with effects resembling those on East Austin and Austin creeks. In other tributary streams, where the flow remained stable, no such action was observed.

There were noticeable differences in the effects of the rotenone upon the various species of fishes in the drainage. It took from as little as 10 minutes to as much as two hours for the chemical to kill fish. The speed with which the chemical killed depended upon species, temperature, and the character of the stream bottom. Despite the low flow and the shallow areas in the headwaters of the tributaries, the low temperatures required a longer exposure of the fish before they died. In lower stretches, where temperatures were higher, killing was much quicker. Deep pools also caused the rotenone to take longer to become effective, mainly because of difficulty in spreading the mixture throughout the lower levels of the pool and because of underflow.

In general, fish of any given species succumbed to the rotenone in direct relation to their size, the smaller ones dying first. This was not entirely due to the behavior of the large fish, which generally fled to the bottom, for small fish died even when seeking refuge in deeper water.

There was also a marked species difference in susceptibility. Of the fishes observed dying from chemical treatment, susceptibility to the rotenone is rated as follows, with the most susceptible species first:

1. Rainbow-steelhead trout;
2. Tule perch;
3. Hardhead;
4. Sacramento squawfish;
5. Smallmouth bass;
6. Roach;
7. Western sucker;
8. Three-spined stickleback;
9. Hitch;
10. White catfish;
11. Carp.

Recovery was noted only among the carp.

Literature regarding the effects of rotenone upon man has, in the past, dealt only with lake treatment, where exposure to the chemical, although severe, has been limited to only one or two days. In this project, personnel were exposed more or less continuously for periods up to three weeks. Symptoms of rotenone poisoning similar to allergic reactions were observed. Headache, sore throats, and other cold symptoms were the primary complaint. In addition, sores developed on mucous membrane areas. The skin wherever moist from perspiration, broke out in an eczema-like rash. This was most prominent in areas such as under the arms and where the clothing was tight, as at the neck and wrists. This was followed by a sloughing of the skin and resulting tenderness. Eyes were also severely irritated and inflammation lasted for a week or more. Loss of appetite and inability to taste accompanied the other symptoms. It is possible that protective devices might be found which would prevent some of the symptoms. In the future, preference could be given to newer forms of the chemical as, for example, wettable rotenone powder or paste, or emulsifiable rotenone in liquid form. Emulsifiable rotenone has the additional advantage of better dispersal. The increased safety and health of the personnel should warrant the higher cost of these newer products.

ACKNOWLEDGMENTS

Acknowledgments are due the many California Department of Fish and Game employees who assisted with the chemical application and electrosampling at various periods throughout the project. Special thanks should go to the host of sportsmen and ranchers who contributed their labor, interest, and cooperation. We are indebted to the City of Santa Rosa and to the Pacific Gas and Electric Company for their cooperation in controlling water releases for us.

SUMMARY

Nearly half the Russian River drainage system in Mendocino and Sonoma counties, California, was treated chemically to control rough fish and improve the steelhead fishery. This form of management was chosen because it was believed that rough fish were affecting the fishery adversely. There was little precedence for chemical control of rough fish in streams on this scale, so the project was largely experimental in nature.

The operational phases of the project took place over a three-year period from 1952 to 1954, inclusive, and included pretreatment population sampling and rechecking immediately following treatment. A total of 286 miles of stream, covering the tributaries and most of the main

river, was chemically treated at an estimated cost of approximately $6,000, or $20 per mile. Slightly more than 9,720 pounds of cubé powder were applied.

Twenty-nine species of fishes, including two lampreys, were observed following the treatment. From counts of dead fish it was estimated that the population in the drainage during the summer consisted of less than 1 percent game fish. The dominant rough fish was the Western sucker, representing 90 percent of the total. Roach, carp, and squawfish ranked second, third, and fourth in the population check. Salmonids, most of which were juvenile steelhead, were scarce except in the headwater areas of the tributary streams. Other game fish, of which the smallmouth bass was the most prominent, were so scarce that they could hardly provide a fishery. Observations following chemical treatment indicated an almost complete kill in the treated areas.

Electrosampling in 1955, the first year after treatment, indicated that at least temporary benefits were derived from the project. The sampling, which was largely restricted to the tributary streams, showed that the juvenile steelhead population increased about 13 times, while at the same time the rough fish population was drastically reduced.

Future work will consist of an extensive sampling program and creel checks to evaluate the work in terms of benfits to the steelhead fishery. The economic feasibility of the project should be revealed by the permanency of the increase of game fish and the rate of recovery of the rough fish population. This part of the project may require as much as eight years.