CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 43 JANUARY, 1957 NUMBER 1

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Published Quarterly by the

CALIFORNIA DEPARTMENT OF FISH AND GAME

SACRAMENTO

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A SIX-YEAR STUDY OF THE SURVIVAL AND VITALITY OF HATCHERY-REARED RAINBOW TROUT OF CATCHABLE SIZE IN CONVICT CREEK, CALIFORNIA[1]

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INTRODUCTION

The survival and physical vitality of hatchery-reared trout in streams are matters of serious concern to fish culturists, fishery managers, and a constantly increasing multitude of fishermen. Fish culturists and fishery managers have the responsibility of maintaining or improving trout fisheries, and in order to do so they must rely on hatchery-reared trout to supplement natural production in many lakes and streams. During the last decade, emphasis on stocking has shifted from trout of fry and fingerling size to those of legal or catchable size, causing fish-cultural activity to mushroom to meet an ever increasing demand. Concomitant with this change there have been numerous investigations designed to evaluate the success of stocking trout of catchable size, and interpretation of results ranges from extreme pessimism to guarded optimism. Literature on the subject has been reviewed by Schuck (1948), Smith (1948), Miller (1949), Wood (1953), and by the Wisconsin Department of Conservation (1953), and need not be repeated here. However, it is pertinent to list certain general conclusions that have been drawn from the investigations concerned with the survival of legal or catchable-size, hatchery-reared trout in streams.

1. Greatest returns to the creel may be expected from plantings made immediately prior to and during the open season in areas of heavy angling pressure.
2. If the trout so stocked are not caught within 2 to 4 weeks after release, most of them are no longer available to the angler and are presumed to have died.
3. Mortality in trout streams is high and affects wild as well as hatchery fish, but is significantly higher among the hatchery trout. Overwinter survival of hatchery trout is particularly low, often nil.
4. Failure of hatchery trout to survive is attributed to inability to compete with wild trout; to absence of natural selection during early life stages in the hatchery; to abnormal physical condition due to fish-cultural techniques; and, to stocking practices and methods.

Most of the investigations are based on the return of marked hatchery trout to the angler's creel and on population estimates made at

[1] Submitted for publication August, 1956.

various times through the year, usually by means of one of several electro-shocking techniques. Shortcomings are evident in some of the conclusions drawn from these procedures: (1) failure of anglers to catch the trout is interpreted to mean that the planted fish died and hence were not available; (2) population estimates made in or near the sites of liberation do not necessarily take into account the mobility of trout; and, (3) the adequacy of certain population sampling procedures, especially in larger streams, is doubtful.

Schuck (1948) and Adelman and Bingham (1955), cognizant of these and other deficiencies relative to the appraisal of survival and physical vitality of hatchery-reared trout in natural streams, stressed the importance of controlled survival experiments. Emphasis was placed on confining the test fish in limited areas where escapement could be prevented by means of screens and where the numbers of test fish could be accurately known. The importance of comparing wild and hatchery-reared trout of the same size, in the same stream, and over the same span of time was also emphasized.

The above qualifications for experimental procedure were fulfilled at Convict Creek Station. This report presents the results of six years of controlled, yearlong survival experiments using catchable-size,[2] hatchery-reared rainbow trout and resident brown trout of comparable size.

The program was conducted in cooperation with the Inland Fisheries Branch of the California Department of Fish and Game.

THE EXPERIMENTAL STREAM

To test the ability of hatchery-reared trout to survive in streams under controlled natural conditions, Convict Creek Experimental Stream was established in 1936 by the United States Bureau of Fisheries (predecessor agency of the Fish and Wildlife Service) in cooperation with the California Division of Fish and Game (now the California Department of Fish and Game) and the United States Forest Service.

The facilities of the experimental stream and the objectives of the program were described by Needham and Rayner (1939). It should be noted that these experiments were the first of their kind in the country. Effort was concentrated on the study of survival of stream-stocked, hatchery-reared fry and fingerling trout. The program was designed to test the stocking tables developed by Embody (1927) and Davis (1938), and to devise stocking policies based on the results of the new experiments. The experimental stream facilities consisted of five small side channels that were supplied with water by diversion from the main stream. These channels had a total length of 4,200 feet and each was divided into 100- to 400-foot sections by means of concrete flumes keyed for screens and flashboards. Work was limited to 3 to 5 months during the summer season and was terminated in 1943 because of World War II. Results of five years' work, from 1938 to 1942 inclusive (Needham and Slater, 1944), indicated clearly that it is uneconomical to stock small trout in natural streams, especially in those streams that contain existing populations of trout.

At the conclusion of the war, emphasis on stocking had shifted from trout of fry and fingerling size to those of legal or catchable size. Continuation of survival studies at Convict Creek necessitated the redesign

[2] 5.0 to 8.0 inches, total length.

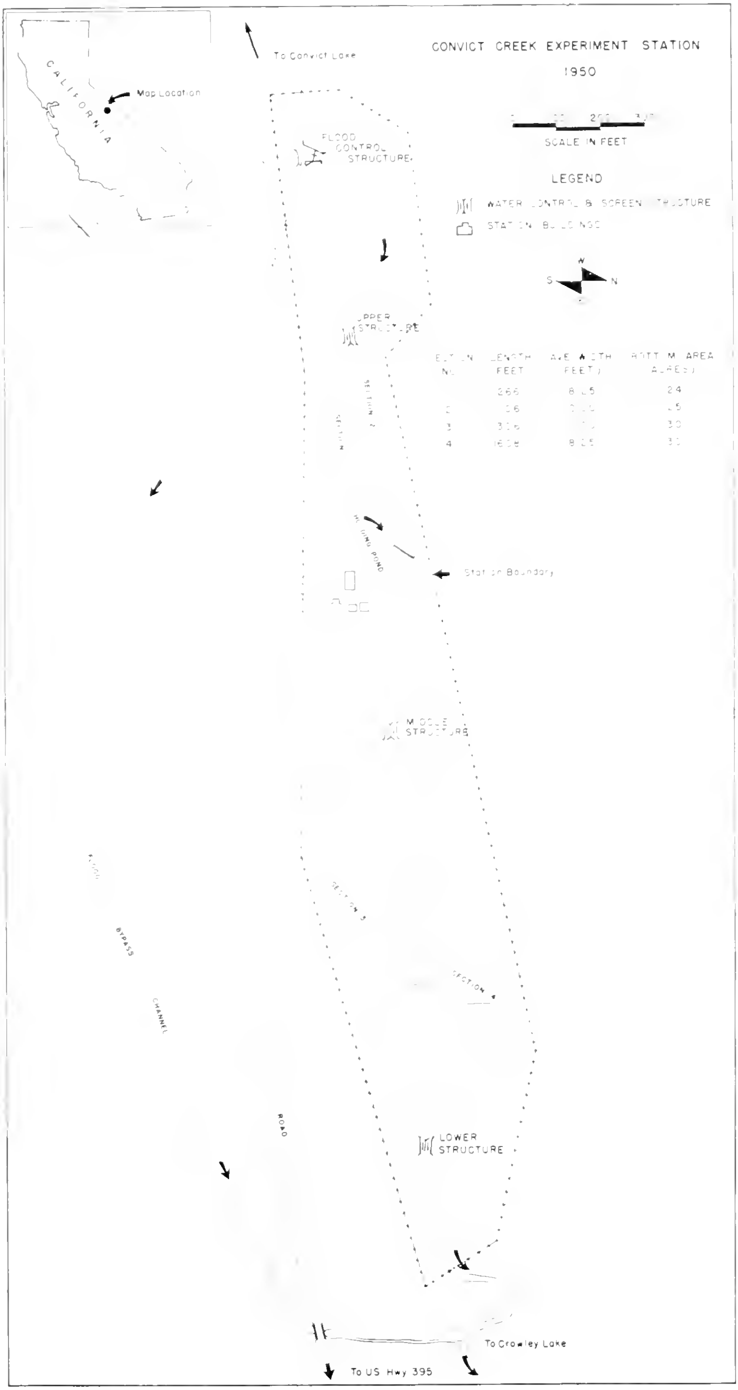

FIGURE 1. Map of statian area and experimental stream facilities.

of stream facilities to accommodate the larger fish on a yearlong basis. In 1948, all of the earlier experimental stream facilities were abandoned and the main stem of Convict Creek was placed under control (Figure 1). Three large, reinforced concrete water control and screen structures (designated upper, middle, and lower and illustrated in Figures 2, 3, and 4) were constructed to make maximum utilization of the stream within the experimental area. The upper structure receives the total flow of Convict Creek and discharges it into two lateral channels, each approximately one-quarter mile long. The middle structure

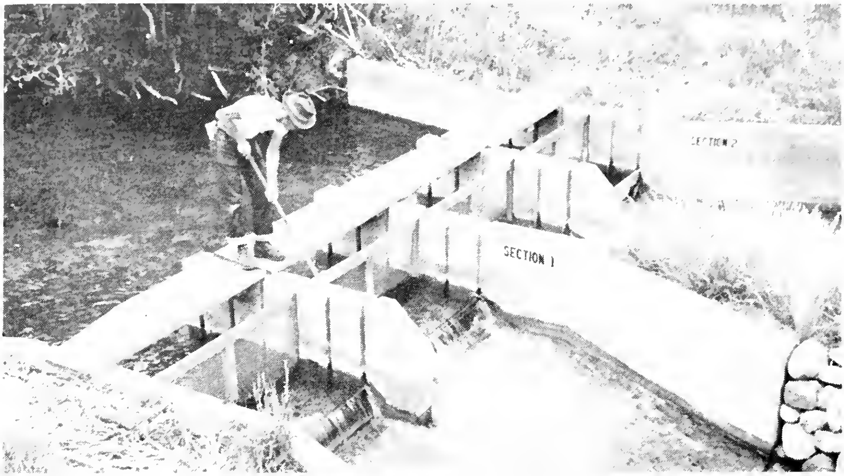

FIGURE 2. Upper water control and screen structure, showing division of main stream into experimental stream Sections 1 and 2. Multiple keyways in walls and piers provide for the use of screens in making temporary fish-holding pens of various sizes. *Photograph by E. Philip Pister, September, 1950.*

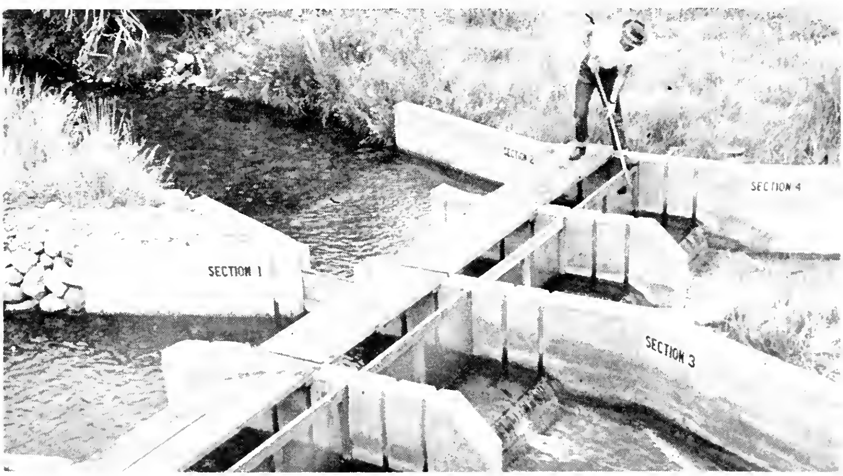

FIGURE 3. Middle water control and screen structure. The sluiceway in the upstream part of the center pier makes it possible, with the use of dam boards and the control of flow at the upper structure, to maintain flow in any three sections while a fourth section is being dewatered. *Photograph by E. Philip Pister, September, 1950.*

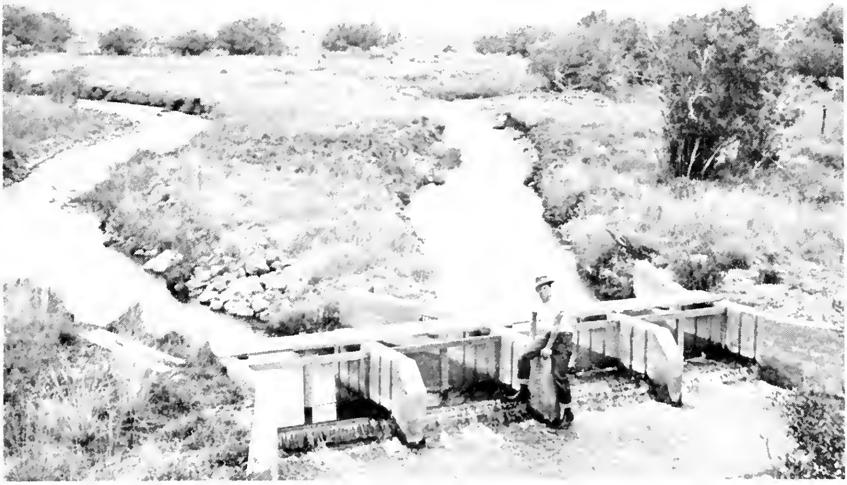

FIGURE 4. Lower water control and screen structure, showing terminal portions of Sections 3 and 4 and discharge of flow into the main stream. *Photograph by E. Philip Pister, September, 1950.*

receives these lateral channels and discharges two other laterals that continue about one-quarter mile to the lower structure, where they are received and discharged into the main stem of Convict Creek. The four experimental stream sections comprise an aggregate length of one mile and a bottom area of approximately 1.1 acres at average summer flow conditions. Total flow through the area is divided equally between the paired stream sections (numbered 1 and 3, and 2 and 4). All of the structures are keyed for flashboards and for the use of vertical, stationary screens covered with 2 by 2, 16-gauge galvanized hardware cloth. The design of the middle structure makes it possible to maintain flow in any three sections while a fourth section is dewatered.

The structures were designed to accommodate flows up to 100 cubic feet per second (c.f.s.) and flows in excess of this amount can be diverted around the experimental area by means of a bypass. Twenty-year runoff records indicate a mean daily flow of 27.7 c.f.s. Extreme flows that occurred during this period were a minimum of 1.3 c.f.s. on January 10, 1951, and a maximum of 227.5 c.f.s. on June 28, 1938. Flow records for the period of the current investigations are summarized in Table 1.

The experimental stream area lies at an elevation of 7,200 feet and is located in Mono County, California, about 35 miles north of the town of Bishop. The controlled stream is typical of many high altitude trout streams not only in the Sierra Nevada but also in other mountain ranges of the West. Conditions throughout the area are natural except for the water control and screen structures that separate the experimental stream sections. Fishing is prohibited.

The climate of the general area is characterized by moderate, dry summers and by moderate to severe winters with heavy snowfall, frequent and prolonged periods of subfreezing temperatures, and almost constant winds, which sometimes attain velocities in excess of 80 miles

TABLE 1

Mean Monthly, Seasonal, and Annual Flows in Cubic Feet Per Second in Convict Creek, May, 1950, to June, 1956

Month/year	May	June	July	Aug.	Sept.	Oct.	Summer mean	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Winter mean	Annual mean
5/50-4/51	33.3	61.8	42.6	15.7	12.2	7.1	28.8	18.9	23.0	10.6	10.1	8.3	11.2	13.7	21.3
5/51-4/52	30.9	66.2	50.0	23.8	13.5	9.8	32.7	10.7	11.7	14.5	11.7	11.2	13.4	12.2	22.3
5/52-4/53	43.2	98.0	97.1	57.5	25.2	15.9	56.1	10.7	12.3	11.6	7.1	6.3	8.7	9.1	32.8
5/53-4/54	17.2	42.9	63.9	24.6	11.0	10.0	28.8	9.6	7.0	6.7	8.5	9.3	12.6	9.0	18.9
5/54-4/55	40.8	51.4	41.8	18.3	10.8	7.2	28.9	8.3	8.8	9.9	7.4	7.1	6.9	8.1	18.5
5/55-4/56	21.4	71.5	50.9	21.8	13.6	8.8	32.3	8.1	21.5	21.9	11.1	9.2	12.6	14.6	23.5
Mean	31.1	66.3	57.7	27.5	14.9	9.8	34.6	11.1	11.1	12.5	9.9	8.6	10.9	11.2	22.9

May, 1956, 29.7; June, 1956, 101.3.

per hour. Winds in winter cause the snow to drift over the stream and completely bridge it for varying lengths of time, depending on the severity of the weather. Continuous records of air and water temperatures were maintained by means of a Taylor thermograph. These records are summarized in Tables 2 (air) and 3 (water) for the period of the present studies.

NATURAL POPULATION DENSITY OF WILD BROWN TROUT AND GENERAL METHODS

Prior to reconstruction (1948) and the initiation of the present survival studies (1950), all resident trout were removed from the main stem of the creek within the experimental area. The area had been closed to angling and other uses for a period of seven years and it was important to know the density of the existing, undisturbed population of brown trout in order to form a basis for comparison for the present survival experiments.

Excluding fry and fingerlings of the year, 1,627 trout with a gross weight of 131 pounds were removed from the three-quarter-mile section of stream. On the basis of area, there was an average of one trout per 30 square feet of stream bottom. By weight, density of the recovered population was 120 pounds per acre, and this density was considered to represent the natural carrying capacity of the stream in an undisturbed condition. However, this population density is not in agreement with average densities found by Needham et al. (1945) in open and closed sections of Convict Creek in August in four consecutive years (1939 to 1942). In a stream section 126 feet long, closed to angling, these authors found an average density of 297.1 pounds per acre, whereas in an open section approximately 300 feet long the calculated density was 68.7 pounds per acre. Differences in estimates of population density could easily be accounted for by sizes of sampled areas—75 percent of a mile as compared with single, small sections of 2.4 and 5.7 percent, respectively. Techniques employed in the above population studies were identical: dewatering the stream, pumping pools dry, and recovering all trout alive by hand. This method was used throughout the present survival studies and its efficiency has been successfully tested in all of the experimental stream sections.

All catchable-size, hatchery-reared rainbow trout used in the survival experiments were furnished by the Hot Creek State Fish Hatchery of the California Department of Fish and Game. Wild or resident brown trout of comparable size were captured in open sections of Convict Creek. In each experiment, all trout were individually weighed, measured, and marked by the amputation of single fins. At the conclusion of each experiment the fish were again weighed and measured, and differences in mean weight, length, and condition for the experimental period were calculated. In all of the survival experiments, the only trout present in the experimental areas were the test fish. With the exception of the first year, when yearling rainbow trout of spring-spawning stock were used, all hatchery-reared rainbow trout were the progeny of fall-spawning stocks and were fish of the year, 6 to 10 months old at time of stocking. In contrast with this, brown trout of comparable size used in the experiments were 2 to 3 years old.

TABLE 2

Mean Monthly, Seasonal and Annual Air Temperatures in Degrees Fahrenheit at Convict Creek, May, 1950, to June, 1956

Month/year	May	June	July	Aug.	Sept.	Oct.	Summer mean	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Winter mean	Annual mean	Hours below 32 degrees F.
5/50–4/51	48.4	51.5	62.0	58.5	52.1	49.0	51.1	41.4	35.2	30.1	32.2	37.2	43.5	36.6	45.3	2,064
5/51–4/52	50.0	58.3	63.8	54.5	56.8	43.9	54.6	33.0	19.6	18.6	22.0	25.3	39.7	26.0	40.3	3,372
5/52–4/53	51.2	55.9	63.3	60.4	54.2	48.5	55.6	29.1	22.4	31.0	31.2	36.8	42.7	32.2	43.9	2,750
5/53–4/54	44.5	51.6	64.2	59.4	56.2	44.3	53.8	37.5	31.2	29.1	22.9	29.2	45.8	32.3	43.2	2,621
5/54–4/55	55.6	57.5	62.7	58.6	54.6	46.0	55.8	37.3	22.3	15.9	24.3	33.0	39.0	28.6	42.2	2,991
5/55–4/56	*	--	--	65.5	57.5	50.2	--	39.9	33.8	29.8	25.2	38.4	42.7	34.9		
Mean	49.9	56.2	63.2	59.4	55.2	46.3	54.8	36.4	27.4	25.8	26.3	33.3	42.2	31.8	43.0	

May, 1956, 50.2; June, 1956, 59.0.
* Thermograph being repaired.

TABLE 3

Mean Monthly, Seasonal and Annual Water Temperatures in Degrees Fahrenheit at Convict Creek, May, 1950, to June, 1956

Month/year	May	June	July	Aug.	Sept.	Oct.	Summer mean	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Winter mean	Annual mean
5/50–4/51	47.9	53.0	59.7	59.7	56.3	48.4	51.1	43.6	39.2	34.4	35.5	37.8	44.2	39.4	46.7
5/51–4/52	49.3	55.0	60.5	60.7	58.1	49.2	55.3	41.3	33.3	32.0	33.6	33.6	38.9	35.5	45.4
5/52–4/53	46.8	50.7	55.4	58.7	55.4	52.4	53.2	40.8	35.0	34.6	35.4	37.9	43.3	37.8	45.4
5/53–4/54	45.9	50.9	58.5	59.6	57.3	49.7	53.6	42.5	36.1	32.6	34.7	36.7	45.4	38.0	45.3
5/54–4/55	51.2	53.4	60.1	59.2	55.5	48.4	54.6	42.9	35.6	33.0	34.5	37.9	44.0	37.5	46.4
5/55–4/56	47.3	53.0	63.5	64.6	59.6	52.4	56.7	42.6	37.7	34.9	35.0	39.2	46.3	39.3	48.0
Mean	48.1	52.7	59.6	60.4	57.0	50.0	54.9	42.3	36.1	33.6	34.7	37.2	43.2	37.9	46.2

May, 1956, 52.5; June, 1956, 57.6.

Observation throughout the course of the experiments indicated that predation in Convict Creek was not an important consideration in survival. No evidence was obtained to indicate the presence of mammalian predators, and fish-eating birds are rare visitors to the area.

ACKNOWLEDGMENTS

Sincere thanks are due Bobby D. Combs, John A. Maciolek, and E. Philip Pister,[3] former staff members who participated in the study and whose untiring efforts and keen interest aided in its success. Sincere thanks are also due Paul R. Needham, Professor of Zoology-Fisheries at the University of California, for assistance and active participation in the first winter's work and for providing the services of a student biologist for that period. We are especially indebted to William O. White, Fishery Manager II in charge of Hot Creek Hatchery, for his constant assistance and interest throughout the study and for his complete confidence in our endeavors. We also wish to express our appreciation and thanks to the Mono County Board of Supervisors for the construction and maintenance of the access road from Convict Creek Station to U. S. Highway 395 and for snow removal at critical times during each winter.

COMPARATIVE SURVIVAL OF SPRING-STOCKED, HATCHERY-REARED RAINBOW TROUT AND WILD BROWN TROUT OF CATCHABLE SIZE

The first four years of survival studies were designed to test as many combinations and stocking densities of hatchery-reared, catchable-size rainbow trout and wild brown trout of comparable size as conditions would permit. Rainbow trout of spring-spawning stock were used the first year and those of fall-spawning stocks in the other three years. The spring-spawning trout were hatched and reared from eggs transferred from Mt. Whitney Hatchery and the fall-spawning trout from eggs of brood stocks maintained at Hot Creek Hatchery. The usual plan was to stock one or more stream sections with rainbow or brown trout alone at a certain base density in pounds per acre, and to stock other sections with the two species superimposed at the base density or at double density.

The general schedule followed was to stock the experimental stream sections on May 1, check oversummer survival on November 1, restock the sections, and check overwinter survival the following May 1. These dates are within a week of actual stocking and recovery dates for all test periods. Fish handling and draining of the stream sections required three or four days. The experimental periods correspond with the open and closed angling seasons, as well as with the semiannual climatic divisions hereinafter referred to as "summer" and "winter".

Rainbow trout from the hatchery were handled in accordance with the general technique followed in routine stocking procedures. The test fish were netted at random from production raceways, weighed and counted, and transported four miles from the hatchery to Convict Creek by tank truck. At Convict Creek they were released into previously prepared holding pens in the stream, weighed, measured, marked, and stocked in the sections according to plan. Wild trout

[3] Now with the California Department of Fish and Game.

were seined from open sections of the stream, and test fish in the same length range as the hatchery trout were selected from them. These fish were transported in 10-gallon cans for short distances from the seining sites to the holding pens. With the foregoing exceptions, treatment of the wild brown trout prior to stocking was identical to that given the hatchery rainbow trout.

First Year, Summer Period

Hatchery rainbow trout had a mean total length of 19.4 centimeters (about 7¾ inches) and a mean weight of 81.0 grams (about 2.9 ounces). They were approximately 10 months old at time of stocking, and averaged 5.6 fish per pound. It was intended to stock the stream sections with wild brown trout of comparable total length, but so few could be found that it was impossible to do so. Brown trout had a mean total length of 13.4 centimeters (about 5.3 inches) and a mean weight of 26.3 grams (about one ounce).

Stocking of the two species was based on numerical equality by area, rather than on comparable density by weight. This procedure produced extreme differences in stocking density by weight. In Section 1, rainbow trout were stocked at the rate of 131 pounds per acre, and the superimposed brown trout at 42 pounds per acre made an aggregate total rate of 173 pounds per acre. Rainbow trout alone in Section 2 were at the rate of 214 pounds per acre, in contrast with 50 pounds per acre for wild brown trout alone in Section 3. The weight density of rainbow trout alone in Section 4 was 250 pounds per acre. Table 4 presents the numerical stocking and recovery data for the first six-month period.

Section 4 was stocked with rainbow trout alone to test the problem of fin regeneration and differential survival due to the amputation of single fins. Specific data on this particular experiment and its results are summarized in Table 7.

In this initial experiment wild brown trout had a higher level of survival in competition with rainbow trout than they did alone, and the survival of competitive rainbow trout in Section 1 was superior to that of noncompetitive rainbow trout in Section 2. The average percentages of survival for both species indicated some advantage for the wild brown trout.

Differences in weight, length, and condition of the two species for the experimental period are summarized in Table 5. Both species declined in body condition, but in doing so demonstrated gains in average weight and length. This situation is undoubtedly due to the fact that the smaller individuals of both species, as demonstrated by the recovery of dead fish, succumbed more readily to the vicissitudes of the environment than did the larger fish. The indicated increases in average weight and length would, therefore, be due as much to differential mortality as to real growth. In stream Section 4, the survival of fin-clipped rainbow trout was superior to that of trout in the unclipped control group. Their survival was also superior to that of similarly marked trout in the other experimental stream sections. The control group in Section 4 had the lowest survival rate of all trout in the various experiments except rainbow trout in stream Section 2. No evidence of fin regeneration was observed among the marked fish at the conclusion of the first six-month period of the study.

TABLE 4

Survival and Loss in the Experimental Stream Sections, Summer Period of May 1 to October 31, 1950

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	176	94	53.4	22	12.5	60	34.1	176	108	61.4	22	12.5	45	25.7
2	301	126	41.9	20	6.6	155	51.5							
3	--							251	143	56.3	7	2.7	101	41.0
4	420	249	59.3	32	7.6	139	33.1							
Total or average	897	469	52.3	74	8.3	354	39.4	429	251	58.5	29	6.8	149	34.7

TABLE 5

Lengths, Weights, and Coefficients of Condition of the Trout at Times of Planting and Recovery, 1950-51

Stocking and recovery dates	Hatchery rainbow trout					Wild brown trout				
	Mean total length		Mean weight		Condition factor "K"*	Mean total length		Mean weight		Condition factor "K"*
	(centimeters)	(inches)	(grams)	(ounces)		(centimeters)	(inches)	(grams)	(ounces)	
5/1/50	19.1	7.6	81.0	2.9	1.10	13.8	5.4	27.4	1.0	1.09
11/1/50	20.4	8.0	85.6	3.0	0.99	15.0	5.9	34.0	1.2	0.96
5/1/51	19.5	7.7	65.3	2.3	0.88	16.7	6.6	37.9	1.3	0.90

* Based on total length (tip of snout to end of caudal rays).

There was no initial heavy mortality among the hatchery trout following planting. In fact, no observed losses occurred during the first six weeks of the study. Thereafter, losses of single fish occurred sporadically. The ratio of "known loss" to "unaccounted loss" was about one to five for both species of trout, and it might be argued that some or a large part of the unknown loss occurred during the early weeks of the experiment. It seems more probable, however, that losses in both categories occurred at the same time and at the same rate.

First Year, Winter Period

Survivors from the summer period were returned to their respective stream sections immediately following the midyear check. However, an accident resulted in the loss of some of the oversummer surviving rainbow and wild brown trout in Section 1, and this accounts for the reduced numbers stocked in that section for the winter period. Rainbow trout retained in the holding pool since May 1 were added to the survivors from Section 2, and wild brown trout from the creek were added to the surviving group to restock Section 3. The survivors from Section 4 were retained in that section without additions.

Planting and recovery data for the winter period are summarized in Table 6. It is evident that the average percentage survival of the rainbow trout was approximately equal in summer and winter of this year and that winter survival of brown trout was significantly lower than summer survival. In consideration of these survival levels, it is important to emphasize the fact that the stocking density for the winter period was only slightly greater than 50 percent of the summer rate for rainbow trout in all sections and for the brown trout in Section 1. Brown trout in Section 3 were stocked for the winter period at a density of 100 pounds per acre, compared with 50 pounds per acre for the summer period. The survival of rainbow trout in competition with brown trout in Section 1 was inferior to that of the noncompetitive rainbow trout groups. Competing brown trout exhibited a higher level of survival than the noncompetitive group. However, there is the possibility that differences in total stocking density, regardless of competition, might have contributed to the observed differences in overwinter survival for this species.

Although the winter was relatively mild (Maciolek and Needham, 1952), especially in terms of snowfall, temperatures were low and the formation of various kinds of ice was prevalent for rather long periods of time. Ice and slush conditions in the stream made it virtually impossible to observe losses and this is evident in the high proportion of unaccounted loss in relation to known loss. The heaviest observed mortalities among the rainbow trout began about the middle of March, when ice formation had ceased and stream temperatures were rising. The mortality rate increased slowly but steadily to the termination of the experiment.

Gross examination of the dead rainbow trout disclosed that all had apparently succumbed to a common cause: secondary fungus infection of deep, abraded areas extending dorsally from the tip of the snout to the occipital region. In some cases, the brain was actually exposed. Examination of the survivors indicated that about 70 percent had similar abrasions and that approximately one-half of these were in various

TABLE 6

Survival and Loss in the Experimental Stream Sections, Winter Period of November 1, 1950, to April 30, 1951

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	82	36	43.9	3	3.7	43	52.4	144	77	53.5	4	2.8	63	43.7
2	174	101	59.8	8	4.6	62	35.6							
3	--	--	--	--	--	--	--	426	146	34.3	3	0.7	277	65.0
4	249	113	45.4	35	14.0	101	40.6							
Total or average	505	253	50.1	46	9.1	206	40.8	570	223	39.1	7	1.3	340	59.6

stages of fungus infection. Observations of the behavior of the fish in the stream failed to reveal the cause of the abrasions. None of the brown trout exhibited a similar condition.

In stream Section 4, the percentage survival of fin-clipped trout was lower than of the unclipped control group (Table 7). This is a reversal of position, compared with the levels of survival through the summer period, but the differences are less striking. It is evident that the amputation of either of the ventral fins is in no way deleterious. The survival for the year of marked and unmarked fish in this section was only 27 percent. There was no evidence of fin regeneration among the marked trout at the conclusion of the experiment.

Second Year, Summer Period

The results obtained in the first year's survival experiments were considered to be rather good, especially in view of the fact that the stocking rate in certain instances was in excess of the natural population density found in the stream. Although the survival levels for all trout were promising, it seemed reasonable to suppose that they might have been even better if the stocking density had been lower. Accordingly, stocking for the second year was reduced to a density of 120 pounds per acre and the stream sections were stocked numerically as shown in Table 8, for the summer period. Section 1 was stocked at the rate of 120 pounds per acre (60 pounds per acre rainbow trout and 60 pounds per acre brown trout). The numerical difference in the two species is due to the differences in their weight as shown in Table 9. Sections 2 and 4 were stocked with rainbow trout alone at the rate of 100 pounds per acre in Section 2 and at 120 pounds per acre in Section 4. Section 3 was stocked with brown trout alone at a density of 120 pounds per acre. Average length, weight, and condition for each group of trout at times of stocking and recovery are given in Table 9. The hatchery trout averaged 8.0 fish per pound.

At the conclusion of the summer period the percentage survival of both species was equal, but disappointingly low and well below the level for the first year. Rainbow trout superimposed on brown trout were virtually decimated, while those in noncompetitive status fared considerably better. However, competitive brown trout had more than double the survival rate of the noncompetitive group. The differences in survival levels exhibited by the two species, alone and in combination with each other, cannot be explained. There was nothing to indicate below-average conditions in Sections 2 and 3, the most seriously affected ones, and it is difficult to believe that competition accounted for the low level of survival of rainbow trout in Section 1. Starvation experiments (Reimers, 1957) show that hatchery-reared rainbow trout can withstand prolonged periods without food before sustaining mortality rates as heavy as those observed in this particular section. Furthermore, competition seemed to favor survival in the experiments of the first year, when population densities were greater.

In all cases in which the percentage survival was low, the percentage of unaccounted loss was high, suggesting that escapement of fish from the sections may have contributed to the losses. Identical screens were used to retain fish in all sections, however, and all received the same careful surveillance. There was no screen breakage or loss during the

TABLE 7

Results of Fin Amputation Experiment (Rainbow Trout)

Fin amputated	May 1 to November 1, 1950			November 1, 1950, to May 1, 1951			Percentage survival for the year
	Number planted	Recovered		Number planted	Recovered		
		Number	Percentage		Number	Percentage	
Right ventral	140	92	65.7	92	41	44.6	29.3
Left ventral	140	87	62.1	87	38	43.7	27.1
Unmarked (control)	140	70	50.0	70	34	48.6	24.3
Total or average	420	249	59.3	249	113	45.4	27.0

TABLE 8

Survival and Loss in the Experimental Stream Sections, Summer Period of May 1 to November 1, 1951

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	150	27	18.0	15	10.0	108	72.0	169	109	64.5	1	2.1	56	33.1
2	251	95	37.8	8	3.2	148	59.0							
3	--	--	-	-	-	-	-	416	122	29.3	15	3.6	279	67.1
4	350	176	50.3	23	6.5	151	43.2							
Total or average	751	298	39.7	46	6.2	407	54.1	585	231	39.5	19	3.2	335	57.3

period. Opportunity for escapement was slight, and was certainly equal for all groups of trout.

Second Year, Winter Period

Survivors from the summer period were used to restock the sections for the winter period. Section 1 was stocked at the rate of 120 pounds per acre (60 pounds per acre rainbow trout and 60 pounds per acre brown trout). Section 2 was stocked with rainbow trout alone at a density of 60 pounds per acre, and Section 3 received brown trout alone at 95 pounds per acre. Section 4 was not stocked, and its terminal screens were removed to determine whether or not spawning runs of rainbow and brown trout from Crowley Lake (located approximately five miles downstream), were being blocked by the screen structures. Later observations showed that they were far enough upstream to constitute no serious interference. Numerical stocking of the sections may be examined in Table 10, which also summarizes the results of the experiment. Data on the weight, length, and condition of the trout at times of planting and recovery are summarized in Table 9.

The survival levels for both species of trout, as shown in Table 10, were extremely poor in comparison with survivals for the same period in the preceding year. This poor survival may be accounted for by the weather. The winter was the most severe and prolonged of historical record. The first permanent snow, amounting to two feet on the level, fell on November 19, and this was followed by a succession of storms that extended to the middle of April. By midwinter, these storms and their attendant winds had left a snow cover ranging from 5 to 15 feet in depth over the area. The entire stream was bridged with snow and ice, and remained in this condition for four months. During this period, the maintenance of screens was a matter of arduous labor under extremely trying and difficult weather conditions.

At the conclusion of the winter it was apparent that trout had suffered severe mortality not only in the experimental stream sections but also in the creek outside of the closed area. Observations indicated that the overburden of snow and ice could account for trout losses by several means. Most prominent among these were the collapses of the snow and ice cover into the stream that occurred at various times and places throughout the winter. These collapses were large, and the stream was completely dammed where they occurred. The effect was immediate, and trout could be lost in any of three different ways: (1) crushed and/or suffocated directly beneath the mass of snow and ice; (2) suffocated throughout the length of stream dewatered; and (3) left stranded under the snow when the ponded or flooded area above the snow barrier receded. The insulating snow cover also prevented the formation of various forms of subsurface ice that have been shown (Maciolek and Needham, 1952) to be beneficial in making bottom dwelling organisms available to trout in winter. The snow cover also excluded all light, which resulted in the depletion of bottom organisms (Reimers, 1957). Stream bottom rocks were rough to the touch, and were devoid of the periphytic material that is essential to the macroscopic stream fauna.

Screens that were damaged and broken during the winter were replaced as rapidly as possible, but this replacement sometimes required

TABLE 9

Lengths, Weights, and Coefficients of Condition of the Trout at Times of Planting and Recovery, 1951-52

Stocking and recovery dates	Hatchery rainbow trout					Wild brown trout				
	Mean total length		Mean weight		Condition factor "K"*	Mean total length		Mean weight		Condition factor "K"*
	(centimeters)	(inches)	(grams)	(ounces)		(centimeters)	(inches)	(grams)	(ounces)	
5/1/51	17.2	6.8	56.4	2.0	1.11	16.7	6.6	37.9	1.3	0.94
11/1/51	18.0	7.1	14.5	1.6	0.76	17.5	6.9	15.9	1.6	0.91
5/1/52	19.0	7.5	47.1	1.7	0.69	18.3	7.2	17.4	1.7	0.77

* Based on total length (tip of snout to end of caudal rays).

TABLE 10

Survival and Loss in the Experimental Stream Sections, Winter Period of November 1, 1951, to May 1, 1952

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	140	1	0.7	6	4.3	133	95.0	151	27	17.9	8	5.3	116	76.8
2	140	15	10.7	4	2.9	121	86.4							
3	--	--	--	--	--	--	--	203	51	25.1	4	2.0	148	72.9
Total or average	280	16	5.7	10	3.6	254	90.7	354	78	22.0	12	3.4	264	74.6

several days. Opportunity for escapement of trout from the stream sections existed at these times, but it is believed that actual escapement must have been exceptionally low or nonexistent. This conclusion is based on the findings that no unmarked trout were found in the sections and that there was no evidence of straying between sections. The opportunity for ingress was equal to that for egress and, since ingress did not occur, it is unlikely that escapement was of serious proportions.

The survival of wild brown trout was almost four times as great as that of the hatchery-reared rainbow trout. This suggests that the wild trout possessed physical stamina superior to that of the hatchery trout in coping with extreme environmental conditions, or that the wild trout had a superior aptitude for utilizing effective shelter. Although the survivors of both species showed slight gains in weight and length, their general condition had declined. Percentage reduction in condition was greater among the brown trout for the experimental period.

Third Year, Summer Period

The unprecedented winter of 1951-52 left a record snowpack in the highlands of the Sierra Nevada. Runoff from this snowpack was also of record proportions, and it can be observed from Table 1 that the mean summer flow in Convict Creek was approximately double that of the other years recorded and that heavy runoff characterized the entire summer period. There were drastic fluctuations in flow, and peak flows in excess of 200 c.f.s. were common in the months of June and July. Because of these flow conditions, stocking of the experimental stream sections was delayed until August 1, and even at that late date in the season it was not considered safe to stock more than 2 of the 4 sections.

In consideration of the results obtained in the 1951-52 survival studies, stocking density was further reduced to a base level of 50 pounds per acre. Table 11 summarizes the numerical stocking and the results at the conclusion of 100 days (August 1 to November 8). Section 1 was stocked at the rate of 100 pounds per acre with hatchery-reared rainbow and wild brown trout at 50 pounds per acre each. Section 3 was stocked with rainbow trout only at a density of 50 pounds per acre. Data on the length, weight, and condition of the trout at times of planting and recovery are summarized in Table 12. The hatchery-reared trout at time of planting averaged 16.1 and 8.0 fish per pound for the two size classes used.

The survival of hatchery-reared rainbow trout in this experiment was considered to be phenomenal. A higher survival rate (96.8 percent) occurred in the group in competition with wild trout than in the group stocked alone at lower density. The survival of 80.6 percent of the noncompetitive group of rainbow trout must also be considered excellent.

The low level of survival among the wild brown trout resulted from an epizootic to which the hatchery trout were not susceptible. Dead and dying brown trout in unusual numbers were first noticed about the middle of August. Observation indicated that brown trout were dying in the open sections of Convict Creek, as well as in Section 1. The condition prevailed for about two weeks and disappeared as rapidly as it had begun. Numerous moribund and dead trout taken from Section 1 and from the stream outside the closed area were examined during the outbreak. General external condition of all trout examined appeared

TABLE 11

Survival and Loss in the Experimental Stream Sections, Summer Period of August 1 to November 8, 1952

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	95	92	96.8	1	1.1	2	2.1	87	32	36.8	4	4.6	51	58.6
3	242	195	80.6	5	2.1	42	17.3							
Total or average	337	287	85.1	6	1.7	44	13.2	87	32	36.8	4	4.6	51	58.6

to be excellent, but gross post-mortem examination revealed the coagulation of the entire blood supply. The condition was a progressive one, with coagulation first appearing in the gills. Several hours elasped between the time of first distress and death. At time of death, blood could be squeezed from the gills as a firm, nonliquid mass.

In terms of the total brown trout population in Convict Creek, it was impossible to estimate the extent of the epizootic. It was certain, though, that all sizes of trout were susceptible and that none of the infected trout recovered. Microscopic examination of blood specimens failed to reveal the cause of the condition.

Third Year, Winter Period

Survivors from the summer period were returned to their respective sections and additional stream-conditioned trout were added to bring the stocking density to 100 pounds per acre (rainbow and brown trout) in Section 1 and to 50 pounds per acre in Section 3 (rainbow trout only). Numerical stocking of these stream sections is summarized in Table 13, together with data on survival and loss. Data on the mean weight, length, and condition of these trout at times of planting and recovery are summarized in Table 12.

The winter was considered average for the area. General conditions may best be described as being about midway between the mild winter of 1950-51 and the record winter of 1951-52. Snow depth averaged from two to five feet, and the entire stream was bridged with ice and snow for approximately two months. Once again, the maintenance of screens and the operation of the stream sections was a difficult and arduous task.

The overwinter survival of the test fish was excellent, especially in comparison with survivals for the two preceding winters. It is remarkable that the percentage survival of hatchery-reared rainbow trout virtually equaled that of the wild brown trout and that the survival levels for both in competition were superior to that of the noncompetitive rainbow trout group at one-half the population density. Loss in condition was slight for both species. The noncompetitive rainbow trout showed slightly improved body condition.

Extended Observation of Third-year Survivors (Rainbow Trout)

Because the survival of hatchery-reared rainbow trout was so good during the year, the survivors were held in the creek an additional 18 months. The history of this group of trout for 27 months in Convict Creek is summarized in Table 14. Survival of this group of trout during the first year was excellent, as previously noted, but the survival rate in the second year dropped to less than one-half the first year's level. The few second-year survivors passed through the third summer with a survival rate approximately equal to that of the first year. After the first year, these fish were held continuously in Section 2, and as mortality continued their density per unit area decreased. It is, therefore, apparent that the carrying capacity of the stream had nothing to do with the survival of these trout. It is equally evident that continuous natural mortality is indeed high among members of an animal group characterized by short life spans. The trout used in this experiment

TABLE 12

Lengths, Weights, and Coefficients of Condition of the Trout at Times of Planting and Recovery, 1952-53

Stream section number	Period	Hatchery rainbow trout: Mean total length (centimeters)	Hatchery rainbow trout: Mean total length (inches)	Hatchery rainbow trout: Mean weight (grams)	Hatchery rainbow trout: Mean weight (ounces)	Hatchery rainbow trout: Condition factor "K"*	Wild brown trout: Mean total length (centimeters)	Wild brown trout: Mean total length (inches)	Wild brown trout: Mean weight (grams)	Wild brown trout: Mean weight (ounces)	Wild brown trout: Condition factor "K"*
1	Planted 8/1/52	16.2	6.4	57.3	2.0	1.351	18.8	7.4	62.6	2.2	0.926
	Recovered 11/8/52	18.1	7.1	57.9	2.0	0.971	20.1	8.0	81.0	2.9	0.949
3	Planted 8/1/52	13.2	5.2	28.1	1.0	1.226					
	Recovered 11/8/52	15.1	5.9	31.0	1.1	0.887					
1	Planted 11/10/52	17.5	6.9	53.4	1.9	0.965	17.3	6.8	50.5	1.8	0.929
	Recovered 4/29/53	18.1	7.1	52.9	1.8	0.866	18.3	7.2	56.3	2.0	0.902
3	Planted 11/10/52	15.0	5.9	31.1	1.1	0.896					
	Recovered 4/29/53	15.2	6.0	31.4	1.2	0.932					

* Based on total length (tip of snout to end of caudal rays).

TABLE 13

Survival and Loss in the Experimental Stream Sections, Winter Period of November 8, 1952, to April 29, 1953

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	102	86	84.3	7	6.9	9	8.8	108	92	85.2	0	0.0	16	14.8
3	209	151	73.7	7	3.3	48	23.0							
Total or average	311	240	77.2	14	4.5	57	18.3	108	92	85.2	0	0.0	16	14.8

TABLE 14

Survival History of Hatchery-reared Rainbow Trout Originally Stocked August 1, 1952

Period	Number planted	Survival		Known loss		Unaccounted loss		Progressive survival (percentage)
		Number	Percentage	Number	Percentage	Number	Percentage	
8/1/52–11/ 8/52	337	287	85.1	6	1.8	44	13.1	85.1
11/8/52– 4/29/53	311	240	77.2	14	4.5	57	18.3	66.5
5/1/53–11/ 1/53	206	82	39.8	13	6.3	111	53.9	29.6
11/1/53– 5/ 1/54	79	25	31.7	9	11.4	45	57.0	9.1
5/1/54–11/ 1/54	24	18	75.0	2	8.3	4	16.7	6.6

were 33 months old from time of hatching to the termination of this experiment.

The sex ratio of the 18 terminal survivors was one to one and they were all in good condition (K=0.798). All males were in various stages of sexual maturity, but none of the females had attained any noticeable degree of sexual development.

Fourth Year, Summer Period

Because of the rather confused results obtained during the summer period of the second year and the excellent results of tests in the third year, a base stocking density of 75 pounds per acre was selected to represent an intermediate level for the fourth year. Section 1 was stocked with hatchery-reared rainbow trout and wild brown trout, each at the rate of 75 pounds per acre. Section 2 carried holdover rainbow trout from the third-year survival group. Section 3 was stocked with rainbow trout only of the size (average total length) used in Section 1 and at a density of 75 pounds per acre. Section 4 was stocked with rainbow trout alone at a density of 75 pounds per acre, but these trout averaged 20 percent larger (total length) than those used in Sections 1 and 3.

Numerical stocking of the sections and the results obtained are summarized in Table 15, and data on the weight, length, and condition are summarized in Table 16. At the time of stocking, rainbow trout averaged 14.3 and 6.8 per pound for the two size classes used. In this experiment, the survival of competitive rainbow trout was definitely inferior to that of the noncompetitive groups and inferior to that of wild brown trout with which they were stocked at double density. There was no difference in percentage survival between the two size classes of rainbow trout, and both of these groups exhibited survival levels slightly greater than that for the competitive brown trout. The survival levels in all cases were approximately 50 percent higher than for the comparable period in the second year. Although evidence is inconclusive, this seems to be the only instance in which interspecies competition appeared clear and detrimental to the hatchery-reared trout. Even so, the survival level of the competitive rainbow trout was equal to or greater than that of noncompetitive groups in some of the preceding experiments for an equivalent period of time.

There was no initial heavy mortality among the hatchery trout immediately following planting. Losses, consisting of single fish, were first observed after four weeks and continued sporadically to the close of the experimental period. With the exception of a few emaciated individuals, all dead trout recovered appeared to be in good physical condition and the cause of death could not be determined.

Survival of rainbow trout held over from the third-year experiments was definitely inferior to the survival of the rainbow trout freshly stocked from the hatchery.

Fourth Year, Winter Period

Only two of the four experimental sections were used over the winter. Section 2 continued to carry the hold-over rainbow trout from the third-year experiments, and Section 4 carried its survivors from the summer period at a density of 52.2 pounds per acre. Numerical stock-

TABLE 15

Survival and Loss in the Experimental Stream Sections, Summer Period of May 1 to November 1, 1953

Stream section number	Hatchery rainbow trout							Wild brown trout						
	Number planted	Recovered		Known loss		Unaccounted loss		Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage		Number	Percentage	Number	Percentage	Number	Percentage
1	260	125	48.1	74	28.4	61	23.5	177	134	75.7	17	9.6	26	14.7
2*	206	82	39.8	13	6.3	111	53.9							
3	312	239	76.6	13	4.2	60	19.2							
4	155	118	76.1	1	0.6	36	23.3							
Total or average	727	482	66.3	88	12.1	157	21.6	177	134	75.7	17	9.6	26	14.7

* Hold-over rainbow trout from third year not included in summary of totals and averages.

TABLE 16

Lengths, Weights, and Coefficients of Condition of the Trout at Times of Planting and Recovery, 1953-54

Stream section number	Period	Hatchery rainbow trout					Wild brown trout				
		Mean total length		Mean weight		Condition factor "K"*	Mean total length		Mean weight		Condition factor "K"*
		(centimeters)	(inches)	(grams)	(ounces)		(centimeters)	(inches)	(grams)	(ounces)	
1	Planted 5/1/53	14.2	5.6	31.6	1.1	1.096	17.1	6.7	46.3	1.6	0.916
	Recovered 11/1/53	15.7	6.2	30.2	1.1	0.773	17.8	7.0	51.1	1.9	0.793
3	Planted 5/1/53	14.2	5.6	33.0	1.2	1.153					
	Recovered 11/1/53	16.5	6.5	35.8	1.3	0.792					
4	Planted 5/1/53	17.8	7.0	66.3	2.3	1.218					
	Recovered 11/1/53	19.9	7.8	61.8	2.2	0.739					
4	Planted 11/1/53	19.9	7.8	61.8	2.2	0.739					
	Recovered 5/1/54	20.5	8.1	57.3	2.0	0.666					

* Based on total length (tip of snout to end of caudal rays).

ing and results for the period are summarized in Table 17 and data on the weight, length, and condition of the trout in Section 4 are summarized in Table 16.

TABLE 17

Survival and Loss in the Experimental Stream Sections, Winter Period of November 1, 1953, to May 1, 1954

Stream section number	Hatchery rainbow trout						
	Number planted	Recovered		Known loss		Unaccounted loss	
		Number	Percentage	Number	Percentage	Number	Percentage
2*	79	25	31.7	9	11.4	45	57.0
4	115	46	40.0	38	33.0	31	27.0

* Hold-over trout from third year.

Winter conditions, with regard to severity and duration, were very similar to those that prevailed during the previous year. Snow depth averaged from two to five feet and the stream was bridged with ice and snow for about two months.

Survival of the hatchery-reared rainbow trout in Section 4 was only 40 percent, in comparison with the survival of 73.7 percent of the rainbow trout stocked in the same section at a density of 50 pounds per acre the preceding winter. However, the third-year trout entered the winter of 1952-53 at an average condition of 0.896, in comparison with 0.739 for the present group. These differences in condition could account for the differences in survival levels for the two groups. It is also important that the overwinter survivors of the third year apparently gained in condition to 0.932, whereas the survivors of the fourth winter reduced in condition to an average of 0.666.

The survival of rainbow trout through their second winter in the stream was relatively low at 31.7 percent, but was surprisingly high in comparison with the survival of only 40 percent of the current year group. It is evident that the condition of trout has a rather considerable bearing on ability to survive, but it is equally clear that certain environmental conditions, as yet undetermined, must be of critical significance.

SUMMARY OF FIRST FOUR YEARS

In the preceding sections the results of comparative survival trials on a seasonal basis have been presented, and the trends of events for each test period have been briefly described. During the four years, weather conditions were represented by a mild winter, by the most severe winter of record, and by two average years. Stocking density of trout ranged from 50 to 250 pounds per acre (initial spring stocking). Competitive stocking at various levels was tested in seven of the eight six-month test periods. The existence of interspecies or intraspecies competition was not demonstrated and survival was not indicated as being influenced by differences in stocking density. In one instance, the full impact of an unknown epizootic was sustained by brown trout alone. In another instance, the partial impact of a fungus infection was felt by rainbow trout alone. Except in those cases where infections were prominent, observed losses of trout were sporadic and without pattern in all experimental periods. There was never a case of high initial mortality among the planted trout.

The gross average percentages of survival for each test period for each species of trout are summarized in Table 18. The resident wild

TABLE 18

Percentage Survival of Hatchery-reared Rainbow Trout and Wild, Resident Brown Trout of Comparable Size for Four Years

Year	Summer period		Winter period	
	Rainbow trout	Brown trout	Rainbow trout	Brown trout
1950-51	52.3	58.5	50.1	39.1
1951-52	39.7	39.5	5.7	22.0
1952-53	85.1	36.8	77.2	85.2
1953-54	66.3	75.7	40.0*	(none used)
Averages	60.8	52.6	44.3	48.8

* Not included in calculation of averages for this column to avoid bias in comparison with percentage survival of brown trout. Average winter survival of rainbow trout for four years was 43.2 percent.

brown trout exhibited better survival than did hatchery rainbow trout in two of three winter periods and in two of four summer periods. The only instance in which hatchery rainbow trout were superior was through the summer period of the third year, when brown trout were decimated by an epizootic to which the rainbow trout were immune. In the summer period of the second year, average survival of the two species was indicated as equal. The grand seasonal averages for the four years, however, indicate slightly superior survival of the rainbow trout through the summer season as compared with superior survival of brown trout through the winter. The average of summer and winter survivals over four years of study was 52.5 percent for hatchery rainbow trout and 50.7 percent for wild brown trout. The interpretation of annual survival was not attempted with the present data of semiannual or shorter periods, since handling losses and other accidental losses sustained in the draining operations at the end of each seasonal period are difficult if not impossible to reconcile on an annual basis. Because gross survival levels of the two species and types of trout were so nearly identical, it is apparent that these trout must be of nearly equal physical vitality and hardiness, at least for the experimental periods considered.

SURVIVAL OF FALL-STOCKED, HATCHERY-REARED RAINBOW TROUT OF CATCHABLE SIZE

The fifth and sixth years of the study were concerned with the survival of hatchery-reared, catchable-size, fall-spawning rainbow trout stocked in the fall. These experiments were restricted to rainbow trout and the stocking density in both years was 120 pounds per acre. Trout were stocked on or about August 1, September 1, October 1, and November 1 and the experiments were terminated in June of the following year in both cases. Trout were obtained from the hatchery in the usual manner, but were selected for uniform total length.

Fifth Year

The experimental stream sections were stocked at monthly intervals beginning August 2, 1954, and the experiment was terminated June 7 to 10, 1955. Stocking and recovery data are summarized in Table 19, and data on the weight, length, and condition of the trout at times of planting and recovery are summarized in Table 20. The various lots averaged 6.2 fish per pound.

In this experiment, as in all previous trials, there was no mortality immediately following planting of the various lots of trout. Losses consisting of individual fish were first observed about 10 days after planting and continued sporadically throughout the experimental period, except in that heaviest losses in Section 3 were coincident with extreme winter conditions during late December and through the months of January and February. Snowfall and duration of snow cover was about average for the area, but temperatures were lower than usual. Ice formations were heavier and persisted longer than in previous years, excepting the record winter of 1951-52. The stream was bridged with ice and snow for about nine weeks.

The percentage levels of survival attained by these fall-stocked trout are considered to be excellent, especially in view of the widespread acceptance of the concept that trout stocked at such a time have a very low survival rate and that the procedure is a wasteful one. Actually, the percentage survival of the lots stocked September 3 and November 1 (66.5 and 64.0 percent) is greater than the four-year average summer survival of 60.8 percent for hatchery rainbow trout during periods between May 1 and November 1. The average overwinter survival of stream acclimated rainbow trout (survivors of summer periods) for the previous four years was 43.6 percent, which is a significantly lower rate than for the trout stocked directly from the hatchery in the present experiment. In an earlier experiment, hatchery-reared rainbow trout stocked August 1, 1952, had a survival of 66.5 percent on April 29, 1953 (272 days). This may be compared with the identical survival rate of 66.5 percent for the lot stocked on September 3, 1954, and recovered on June 9, 1955 (280 days), in the present experiment. Of interest in this comparison is the fact that stocking of the trout planted August 1, 1952, was at an average rate of 75 pounds per acre, whereas the stocking density in the present experiment was 120 pounds per acre.

The average survival of the four lots of trout for the experimental period was 54.0 percent. The poorest survival (37.7 percent) was experienced by the lot stocked in Section 3 on October 1. The heavy losses sustained in this stream section were coincident with extreme winter conditions and, although no quantitative evidence has been obtained, the explanation of the disproportionately low recovery of trout is thought to lie in the relative exposure of the section to certain

TABLE 19

Survival and Loss in the Experimental Stream Sections for Fall-stocking Experiment, 1954-55
(Hatchery-reared, Catchable-size, Fall-spawning Rainbow Trout)

Stream section number	Planted		Recovered			Known loss		Unaccounted loss	
	Date	Number	Date	Number	Percentage	Number	Percentage	Number	Percentage
1	9-3-54	200	6-9-55	133	66.5	37	18.5	30	15.0
2	11-4-54	161	6-10-55	103	64.0	26	16.2	32	19.8
3	10-4-54	228	6-8-55	86	37.7	58	25.5	84	36.8
4	8-2-54	234	6-7-55	122	52.1	37	15.8	75	32.1
Totals or averages		823		444	54.0	158	19.2	221	26.8

TABLE 20

Lengths, Weights, and Coefficients of Condition of Rainbow Trout at Times of Planting and Recovery, 1954-55—
English Equivalents for Centimeters and Grams (Inches and Ounces) in Parentheses

Date	Planted			Recovered					Loss in condition	
	Mean total length (centimeters)	Mean weight (grams)	Condition factor "K"*	Date	Days in stream	Mean total length (centimeters)	Mean weight (grams)	Condition factor "K"*	Amount	Percentage
8/2/54	18.7 (7.4)	68.6 (2.4)	1.031	6/7/55	310	19.8 (7.8)	54.9 (1.9)	0.700	—0.331	32.1
9/3/54	19.2 (7.6)	70.4 (2.5)	0.992	6/9/55	280	19.5 (7.7)	54.7 (1.9)	0.724	—0.268	27.0
10/1/54	19.6 (7.7)	71.4 (2.5)	0.940	6/8/55	251	19.9 (7.8)	54.7 (1.9)	0.690	—0.250	26.6
11/1/54	20.7 (8.1)	81.7 (3.0)	0.939	6/10/55	222	20.7 (8.1)	59.6 (2.1)	0.673	—0.266	28.3

* Based on total length (tip of snout to end of caudal rays).

critical winter conditions. It is unlikely that the trout stocked in Section 3 were of inferior physical vitality. All trout used in the experiments were drawn from the same group in the hatchery, and the individuals obtained for stocking the other sections were all in good condition, as evidenced by their survival levels.

The condition of the trout (as measured by their coefficient of condition) at times of planting and recovery is summarized in Table 20. There was a small but general decline in plumpness of the successive lots of trout as they were received from the hatchery. All of the trout except those stocked November 1, 1954, made slight growths in length but all sustained considerable loss in weight and consequently declined in coefficient of condition. The most significant point concerning weight loss is that all four groups of trout, regardless of initial condition, time of planting, and period of residence in the stream, reduced to a common weight level. Among the four lots of trout, the length of residence in the creek ranged from 222 to 310 days, a difference of 88 days. Therefore, nearly all weight loss must have occurred during the initial four-month period following planting. It was further indicated that body weight was maintained after it had reached a certain level. However, the actual and percentage losses in condition indicated a progressive decline in relation to time.

Hatchery-reared trout that are introduced into rapidly flowing waters characteristic of mountain streams have many adaptations to make in order to survive. It appears that one of these is streamlining, especially among trout that are as plump as those produced at Hot Creek Hatchery. The importance of such streamlining or reduction in weight was demonstrated in preliminary experiments designed to test the rates of exhaustion of various trout. Plump rainbow trout fresh from the hatchery, hatchery-reared rainbow trout that had been in residence in the stream for 100 days, and wild brown trout of comparable size that had spent their lives in the creek were compared. The test fish were placed in a metal trough, 20 feet long and 16 by 20 inches in cross section, in which the velocity of the water could be controlled from 0 to 3.5 feet per second. The fish were kept moving by motions of the observers or by agitation of the water. A terminal screen prevented escapement. A test fish was considered exhausted when it could no longer maintain its position in the current and was carried onto the screen. At a current velocity of 3.0 feet per second, fresh hatchery trout reached the point of exhaustion in 5 to 10 minutes, stream-conditioned (100 days) hatchery trout in 20 to 30 minutes, and wild brown trout in 45 minutes to an hour. When disturbance was not maintained, brown trout immediately sought out resting areas of dead water at the corners of the trough, but rainbow trout did not. All test fish recovered quickly after being returned to quiet water. It is obvious that the wild trout exhibited greated stamina. It is equally evident that several months of stream residence are required to enable freshly stocked, hatchery-reared trout to approach the level of fitness of the wild trout.

Sixth Year

The experimental stream sections were stocked at the same monthly intervals as in the preceding year, but the pattern of distribution was changed. Each monthly lot of trout was distributed among the four stream sections, rather than being planted in an individual section. Thus, at the conclusion of the four monthly stocking periods each stream section contained an equal density by weight of each lot of trout. This method was designed to test the degree of relationship between stream quality and overwinter survival, as well as to test the general overwinter survival of trout stocked in the fall.

Stocking and recovery data are summarized in Table 21, and data on the weight, length, and condition of the trout at times of planting and recovery are summarized in Table 22. The four lots of trout averaged 5.2 fish per pound at time of planting. As shown in Tables 20 and 22, the average lengths of the trout used in the two years were the same (19.5 cms. or 7.7 inches), with more variation in the fifth-year fish. The trout used in the current experiment, however, were considerably heavier at time of planting (87.2 grams or 3.1 ounces in comparison with 73.8 grams or 2.6 ounces), with consequent higher average coefficients of condition (1.160 in comparison with 0.975).

Winter conditions were milder than in the preceding year and air and water temperatures were generally higher. Snowfall averaged one to two feet on the level and the stream sections were partially bridged with ice and snow for less than one month.

The overwinter survival of the test fish, as shown in Table 21, may only be described as phenomenal. It is apparent that the high levels of survival were undoubtedly due to the mildness and short duration of the winter and to the physical condition and vitality of the test fish. The average survival of all lots of trout (81.2 percent) was 27.2 percent higher than in the preceding year. The disparity between the percentage survival of the August 1 lot and that of the three later groups indicates that time or period of residence in the stream was not necessarily the sole determinant of loss over the experimental period. Circumstantial evidence indicates that high water temperatures during a short period after planting may bring about heavy later mortality, probably due to an early radical loss of body condition. The mean monthly water temperature for August, 1955, in comparison with the lower temperatures for September, October, and November (Table 3), is suggestive of the probable influence of temperatures near 65 degrees F. on higher mortality of the trout stocked on August 1. Highest water temperatures in Convict Creek are reached in early August and are normally sustained throughout the month.

All lots of trout declined drastically in condition during the experimental period, from an initial average of 1.160 to a terminal average of 0.761. These losses in condition were related to decreases in weight much more than to increases in length and were proportional to the respective periods of residence in the stream. The average percentage loss in condition was 34.4, in comparison with 28.5 percent for the previous years' survivors. However, the terminal coefficients of condition for the fifth- and sixth-year survivors were similar (0.697 and 0.761). This further confirms the assumption made at the conclusion of the fifth-year experiments that reduction in weight of plump hatchery trout is a necessary consequence of exposure to a stream environment.

In the fifth year, heaviest losses were sustained in Section 3, coincident with severe winter conditions, suggesting that this section was in

TABLE 21

Survival and Loss in the Experimental Stream Sections for Fall-stocking Experiment, 1955-56
(Hatchery-reared, Catchable-size, Fall-spawning Rainbow Trout)

Lot number	Planted		Recovered			Known loss		Unaccounted loss	
	Date	Number	Date	Number	Percentage	Number	Percentage	Number	Percentage
1	8/1/55	174	6/4-6/56	110	63.2	17	9.8	47	27.0
2	9/1/55	179	6/4-6/56	152	84.9	6	3.4	21	11.7
3	10/1/55	169	6/4-6/56	150	88.7	2	1.2	17	10.1
4	11/1/55	158	6/4-6/56	140	88.6	4	2.5	14	8.9
Totals or averages		680		552	81.2	29	4.3	99	14.5

TABLE 22

Lengths, Weights, and Coefficients of Condition of Rainbow Trout at Times of Planting and Recovery, 1955-56—English Equivalents for Centimeters and Grams (Inches and Ounces) in Parentheses

Lot number	Planted				Recovered					Loss in condition	
	Date	Mean total length (centimeters)	Mean weight (grams)	Condition factor "K"*	Date	Days	Mean total length (centimeters)	Mean weight (grams)	Condition factor "K"*	Amount	Percentage
1	8/1/55	19.4 (7.6)	85.1 (3.0)	1.156	6/6/56	311	21.0 (8.3)	66.5 (2.4)	0.711	0.445	38.5
2	9/1/55	19.1 (7.6)	82.6 (2.9)	1.112	6/6/56	281	20.6 (8.1)	63.9 (2.3)	0.709	0.403	36.2
3	10/1/55	19.6 (7.7)	88.1 (3.1)	1.156	6/6/56	250	21.3 (8.4)	77.6 (2.8)	0.801	–0.355	30.7
4	11/1/55	19.7 (7.8)	93.3 (3.3)	1.217	6/6/56	220	21.3 (8.4)	80.7 (2.9)	0.825	–0.392	32.2

* Based on total length (tip of snout to end of caudal rays).

some way inferior to the others as a habitat for trout. A detailed survey indicated similarity of pool quality among the sections, but considerable variation in numbers of pools in relation to stream length. Stream Section 3 had 0.61 pools per 100 feet, in comparison with 0.71 in Section 1, 1.35 in Section 2, and 0.87 in Section 4. In the sixth year, differences in overwinter survival among the stream sections were small and did not conform to the indicated differences in stream quality as measured by pool numbers (Section 1, 77.5 percent survival; Section 2, 84.0 percent; Section 3, 87.1 percent; Section 4, 74.9 percent). The highest level of survival among the sections occurred in stream Section 3, where the lowest survival was found in the fifth year. The comparison of survival results in Section 3 between the two years is not a sound one, owing to differences in winter conditions, yet it is apparent that the superior shelter in Sections 2 and 4 did not result in higher sixth-year survival in these sections. These results suggest that the shelter qualities of a small stream probably influence first-winter survival of hatchery trout under stringent winter conditions, but not in milder circumstances.

CONCLUSIONS

It is evident from these experiments that rainbow trout hatched and reared to catchable size at Hot Creek Hatchery, of both fall-spawning and spring-spawning stock, exhibited an ability to survive equal to that of resident wild brown trout of comparable size. It is also clear that the hatchery trout were capable of competing with wild brown trout of the same size, even though the hatchery fish were compelled to make rather drastic adaptations to the wild and entirely foreign environment. There was no evidence to indicate that the survival of the hatchery trout was influenced by the absence of the processes of natural selection during early life stages in the hatchery. If the hatchery trout possessed abnormal physical condition due to fish-cultural techniques, and to stocking practices and methods, their abnormalities evidently were not critical factors in their ability to survive.

If it is true that hatchery trout are generally inferior to wild trout, then it is only reasonable to infer that the rainbow trout produced at Hot Creek Hatchery are demonstrably superior in quality and that the reason or reasons for this superiority must be found in the hatchery and its operational procedures. Further tests are planned to determine whether trout of identical genetic stock and hatching origin, reared at Hot Creek and at other California hatcheries, exhibit similar or different survival rates after being stocked in the stream.

Differences in stocking density within the range tested seemed to have little or no effect on survival, which suggests that our knowledge of stream carrying capacity and the factors that influence that capacity is indeed scant.

It was demonstrated beyond reasonable doubt that mortality in small streams is indeed high among wild trout, as well as among hatchery-reared trout. However, were the observed losses "high" or were they normal for the test periods in consideration of the species and origins of trout utilized? We have no answer to this question, but the experimental evidence indicates that time is the grim reaper—that mortality progresses with time and that the mortalities experienced in the trials are probably within the yearly expectation of natural death. It is therefore of paramount importance that hatchery-reared trout of catchable size be stocked immediately prior to and during the open season in areas of heavy angling pressure in order to realize greatest benefits. This is in confirmation of generally accepted practice, but the concept that hatchery trout so stocked would not be available to anglers a few weeks after stocking is untenable. Equally untenable are the concepts that overwinter survival of hatchery-reared trout is always poor, and that these trout suffer heavy mortality immediately after planting or during short periods following planting. Actually, fall-stocked trout exhibited higher survival levels than those stocked in the spring, considering equal periods of residence in the stream. However, in winters where conditions are extreme and protracted, mortality is exceptionally high and more drastic among hatchery-reared trout than among wild trout.

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SOME ASPECTS OF THE RELATION BETWEEN STREAM FOODS AND TROUT SURVIVAL[1]

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It is known that large losses of both wild and hatchery trout may occur in winter, particularly in smaller streams exposed to severe weather conditions, but there is little established knowledge of the factors responsible for the bulk of such mortality. Continuous direct observation of the natural stream environment or of the fish themselves is impossible in the critical periods. The carcasses of trout, when they can be found, seldom show reliable evidence of the cause of death. Although diseases, predation, and various minor accidents always contribute to the mortality, the influence of these factors in most winter stream situations is too small to account for the heavy losses experienced in many areas. There follows the assumption that winter trout mortality in small, exposed streams is related primarily to lack of nourishment, to severely damaging physical changes in the habitat, or to a combination of the two. Needham and Slater (1944) and Needham, Moffett, and Slater (1945) suggested the probable importance of cold water, ice, and snow conditions as agents of winter trout mortality in streams. The work of Maciolek and Needham (1952) at Convict Creek, California, suggested that further exploration of the winter food problems of trout might clarify the causes of mortality.

The present study was conducted to obtain more information on (1) winter trout food and feeding, (2) the speed and effectiveness of trout digestion at various water temperatures, and (3) the effects of prolonged starvation on the condition and viability of trout in various seasons. These three aspects of the food problem were studied in the stream sections and small experimental hatchery at the Convict Creek Experiment Station of the United States Fish and Wildlife Service. The station is located in Mono County, California, on the eastern slope of the Sierra Nevada, at an elevation of 7,200 feet.

Convict Creek in the area of study is 6 to 15 feet wide, has a bottom of gravel and rubble with frequent long riffles but few deep pools, and follows a relatively straight course on a grade of about 2 percent. The creek is typical of many alpine trout streams, and of streams at lower elevations in regions of severe winters, in that it is exposed nearly every winter to snow and ice cover, long periods of very low water temperature, and radical changes in rate of flow within the daily cycle.

The period of study extended from April, 1952, to June, 1956. Stream food observations were made in April, 1952, and in February and March, 1953, to represent late winter stream conditions in the respective

[1] Submitted for publication August, 1956.

years. Additional postwinter samples were taken in April, 1956. Resident brown trout were taken for stomach analysis in February, 1953. Digestion experiments were conducted when stream temperatures were in the desired ranges, between October, 1954, and February, 1955. Starvation trials with brown and rainbow trout began in December, 1953, and were repeated as other stream work permitted until June, 1956.

The assistance of Fishery Research Biologists H. D. Kennedy, B. D. Combs, and E. P. Pister[2] in winter sampling, care of experimental fish, and other field work leading to the preparation of this report is gratefully acknowledged. Special thanks are extended to Reed S. Nielson, Chief of California-Nevada Inland Fishery Investigations, United States Fish and Wildlife Service, for advice and assistance throughout the study. Rainbow trout were obtained from the Hot Creek State Fish Hatchery through the cooperation of the California Department of Fish and Game.

WINTER FOOD AND FEEDING

Because nearly all semiaquatic insects overwinter in immature aquatic form, the winter half of the year is often thought of as the season of abundant food for trout in streams. In many situations it might be possible to demonstrate greater per-unit-area abundance of stream-bottom organisms in winter than in summer. Reduced stream flow would contribute to the indication of abundance, however, and the lessened accessibility of many food forms at low or partially ice-bound water stages might result in the suggestion of a nonexistent food advantage for trout. It should not be inferred, particularly where the winters are long and cold, that available trout foods in a stream are most abundant in winter. The supply may be better or poorer than in summer, depending on the extent to which the physical agents of winter affect the stream.

The effect on the stream bottom of prolonged surface ice or snow cover is to reduce light, periphytic algae, and grazing organisms of food importance. Anchor ice, which forms in cold weather on the bottoms of trout streams in many localities, usually dissipates each day and in doing so may increase the temporary availability of bottom organisms by dislodging them and setting them adrift. However, repeated anchor ice formation in a small stream also results in bottom scouring by sudden releases of water, with the bottom fauna of affected riffle areas inevitably reduced as the season progresses. Ice and slush dams formed by the accumulation of released anchor ice further deteriorate the stream bottom habitat by exposing areas to partial drying, freezing, and rewatering. The total effect is a gradual depletion of available trout food through the winter.

Bottom Foods

To continue the pattern of sampling done in the relatively mild winter of 1950-51 (Maciolek and Needham, 1952), a series of square-foot riffle bottom samples was taken in Convict Creek at the end of an extremely severe winter (1951-52) and in the second half of an intermediate or average winter (1952-53). Results are presented as coarse indications of comparative productivity, with the realization that an expression of the general abundance of stream bottom foods that is

[2] Now with the California Department of Fish and Game.

based on a few samples is inadequate, however carefully the sampling areas may be chosen or the measurements made. The tests conducted by Needham and Usinger (1956) established that quantitative estimates of invertebrate productivity in a stream section are statistically unreliable unless they represent impractically large numbers of bottom samples.

In 1952, from early January to mid-April, the entire width of the creek in most of the study area was bridged by snow and ice. The bridges were caused by heavy drifts of snow which filled and covered the stream channels, and by slush or ice dams which subjected stream areas to surface freezing. Occasionally such covers collapsed under the weight of new snow, forming backwaters that froze to strengthen or create other bridges upstream.

In the darkness under the bridges, rock became devoid of algal growth, the basic food supply of larger bottom organisms. Anchor ice did not form, but surges of water and slush accomplished the same effect on some parts of the stream bottom as would anchor ice. Although they were more extensive than usual at Convict Creek in 1952, these bridging formations are common on northern or alpine inland trout streams and warrant consideration as an influence on bottom food abundance. The deleterious effects of these conditions on the trout food fauna may be seen in the results of a weight analysis of 12 bottom samples taken under and at the edges of ice bridges on April 17. These samples indicated a standing crop of 21.4 pounds (blotted wet weight) of organisms per acre (36 organisms per square foot), which is meager when compared with 134 pounds per acre (373 organisms per square foot) for five samples in February, 1942, and 109 pounds per acre (organisms per square foot not available) for a five-year average of 225 May-to-September samples (Maciolek and Needham, 1952). The average of 12 samples taken in open riffles on April 25, 1952, a week after the stream had begun to clear of ice, yielded a slightly improved estimate of 32.4 pounds per acre (41 organisms per square foot).

The same groups of insects were dominant in the winter bottom samples of all years for which data are available (Table 1), and a comparison of average numbers per square foot may be made. Between January 1 and March 31, 1951, the stream was largely open and was subjected frequently to the influence of anchor ice and frazil ice (floating ice crystals). Riffle bottom samples within this period yielded an average of 107 organisms per square foot. In mid-April, 1952, when sections of the stream first became accessible for sampling, numerical abundance of all food organisms was very low. The average number per square foot was 36. By April 25, when the water had begun to warm and stream ice formations had largely disappeared, samples indicated an average of 41 organisms per square foot. In early 1953, periods of partial stream bridging alternated with periods of open water and extensive anchor ice formation. Samples taken in February and March, 1953, indicated standing crops of 139 and 162 organisms per square foot of riffle bottom.

With respect to snow and the bridging of the stream, the months of January, February, and March, 1953, were considerably less severe than the same months in 1952 but somewhat more severe than those months in 1951. However, the bottom fauna crop during this period

TABLE 1

Comparison of the Numbers and Percentages of Riffle Bottom Organisms From Convict Creek in 1942,* 1951,* 1952, and 1953

Group of organisms	1942 February 9 and 10		1951 January 15 to March 22		1952 April 17		1952 April 25		1953 February 3		1953 March 9 to 12	
	Number† and stage	Percentage	Number and stage	Percentage	Number and stage	Percentage	Number and stage	Percentage	Number and stage	Percentage	Number and stage	Percentage
Ephemeroptera	995 (n)	53.4	258 (n)	21.8	13 (n)	10.0	59 (n)	11.9	580 (n)	31.7	591 (n)	30.4
Trichoptera	237 (l) 1 (p) 1 (a)	12.8	316 (l) 1 (p)	29.3	170 (l) 19 (p)	14.0	147 (l) 6 (p)	30.9	378 (l)	22.6	603 (l)	31.1
Diptera	351 (l)	18.8	140 (l) 2 (p) 5 (a)	12.1	91 (l)	21.2	104 (l)	21.0	297 (l) 2 (a)	17.9	323 (l) 8 (a)	17.1
Coleoptera	162 (l) 18 (a)	9.7	151 (l) 39 (a)	16.0	2 (l) 1 (a)	0.7	6 (l) 2 (a)	1.6	82 (l) 21 (a)	6.1	77 (l) 13 (a)	4.6
Plecoptera	10 (n)	0.5	37 (n) 1 (a)	3.2	3 (n)	0.7	12 (n)	2.5	18 (n)	1.1	12 (n)	0.6
Oligochaeta	79	1.2	139	11.7	81	18.8	149	30.1	265	15.8	304	15.7
Miscellaneous	11	0.6	67	5.6	20	1.6	10	2.0	30	1.8	10	0.5
Totals	1,865		1,186		130		495		1,673		1,941	
Average number of organisms per square foot	373		107		36		41		139		162	
Number of samples	5		11		12		12		12		12	

* Data from Maciolek and Needham (1952).
† Abbreviations used: l—larvae; n—nymphs; p—pupae; a—adults.

appeared greater in 1953 than in 1951. If anything may be said about these differences in food abundance, beyond the observation that they may be within a range of population fluctuation not controlled by physical conditions of the season, it is that populations of bottom dwelling organisms in a small stream are apparently harmed less by partial snow and ice cover than by repeated exposure to the radical changes in flow that accompany subsurface ice action.

Drift Foods

Drift net samples, obtained by anchoring the square-foot sampler in the current for 15-minute periods at various times and points in the stream, yielded results for February and March, 1953, that were comparable to those for the same months of 1951. The similarity of taxonomic groups composing the drift foods in all sampling periods is evident in Table 2. Immature forms of Ephemeroptera, Trichoptera,

TABLE 2

Numbers and Percentages of Organisms Taken From Convict Creek in 36 Drift Net Samples, February 4 Through March 27, 1953

Group of organisms	February 4 to 6, 1953		March 12, 1953		March 27, 1953	
	Number	Percentage by number	Number	Percentage by number	Number	Percentage by number
Ephemeroptera	108	63.2	93	62.0	99	41.6
Trichoptera	30	17.5	17	11.3	21	8.8
Diptera	24	14.0	36	24.0	102	42.9
Coleoptera	2	1.2	4	2.7	5	2.1
Plecoptera	1	0.6				
Oligochaeta	5	2.9	--	--	1	0.4
Miscellaneous	1	0.6	--	--	10	4.2
Totals	171		150		238	
Average number of organisms per 15-minute drift	14.2	--	12.5	--	19.8	
Number of 15-minute sampling periods	12	--	12	--	12	

and Diptera were dominant. These formed 80 to 97 percent in the aggregate of drift foods available during the 1951 and 1953 sampling periods, and they were set adrift in rough proportion to their abundance on the stream bottom (Table 1). Drift nets could not be fished in early 1952, but the paucity of bottom organisms in April of that year suggests that drift foods were also scarce during much of the $3\frac{1}{2}$-month period that the stream was covered.

Between February 19 and March 8, 1951, the average number of drifting organisms collected per 15-minute drift net sample was 14.4 (Maciolek and Needham, 1952). The average 15-minute yield of 36 drift net sets made in three periods between February 4 and March 27, 1953, ranged from 12.5 to 19.8 organisms (Table 2), with a mean of 15.5 organisms. Weather in February and March of the two years was roughly similar, although 1953 was characterized by more snow, as mentioned previously, and by slightly lower temperatures.

Bottom and drift foods were sampled again in April, 1956, to obtain an estimate of drift food abundance in relation to quantity of bottom foods at a time after all winter disturbances had passed, but before the advent of increased spring runoff and prior to the appearance of leaves on insect-harboring streamside trees. The average yield of six drift net samples at this time was only 7.3 organisms per 15-minute set, although the average yield of six riffle bottom samples (137 organisms per square foot) indicated a supply of bottom foods equal to that found in early February (139 organisms per square foot).

Twelve drift net samples (February 4 to 6, 1953) were divided into four sets during increased flow following the dispersal of anchor ice and slush, and eight sets at times in the afternoon when the flow was free but not influenced by ice dispersal. This division resulted in an indication of slightly increased drift food availability during higher water (17 organisms per 15-minute set) over that found in normal flow (13 organisms per set), but the indication of feeding advantage is less dramatic than what may be gained by observing trout in the stream at such times. As noted by Maciolek and Needham (1952), trout react strongly to increases in flow and drifting particles. During observations in February, 1953, trout fed avidly among clumps of ice in the surges of water, but remained in hiding at times of lower water. As will be shown by analysis of stomach contents, however, there was little selectivity in such feeding. Many of the available drifting organisms were missed while the trout were attacking bits of debris.

The foregoing figures for winter drift food availability may not be protracted over 24 hours or even 12 hours per day, since disturbance of the stream bottom is limited to daylight hours when ice is in motion. At other times the flow is usually reduced and the fish must forage for their food. Frequently in winter these small numbers of drifting bottom organisms are the main source of food for trout in the stream, for when ice in its various forms is present the fish are free to move about in only a fraction of the normal time and area.

Feeding

One occasionally hears the opinion that, due to lowered metabolism, trout existing in a seasonal state of extremely cold water become torpid, or at least inactive and indifferent to food, depending on the habitat. The observations reported by Maciolek and Needham (1952) and subsequent winter observations in the same area indicate that activity of acclimated trout does not decline appreciably with the seasonal reduction of stream temperature, and that the trout feed whenever food is available—even when the water runs at freezing point and is filled with ice spicules. Reduced winter feeding among healthy stream dwelling trout should be attributed for the most part to scarcity or unavailability of food, not to lack of interest in food.

Winter food conditions of Convict Creek for critical parts of three winters have been cited and described in foregoing sections. The evidence of actual availability and utilization of this food must be found in the stomachs of the trout. In 1952, no resident trout could be found until the latter part of April, too late for an analysis of stomach contents to be representative of feeding in the icebound stream. On February 17, 1953, 66 brown trout were netted from open, "natural" sections of the creek (i.e., sections that were not being used to support other experimental fish). At this time, the stream had been subjected to snowstorms and low temperatures, resulting in ice and snow bridging and disturbance by anchor ice cycles, for well over a month and the ice conditions still prevailed. The results of an analysis of stomach contents of these fish are presented in Table 3.

TABLE 3

Stomach Contents of 66 Brown Trout Taken From Convict Creek, February 17, 1953 *

Classification of food item	Number	Percentage by number	Volume in cubic centimeters	Percentage by volume
Ephemeroptera	314	42.8	0.7	6.9
Trichoptera	123	16.8	1.3	12.9
Diptera	246	33.5	0.5	4.9
Coleoptera	38	5.2	0.4	4.0
Plecoptera	5	0.7	0.6	5.9
Other organisms	2	0.3	0.1	1.0
Trout eggs	5	0.7	0.4	4.0
Debris†	--		6.1	60.4
Total	733	--	10.1	
Average per stomach	11.1		0.16	

* Trout averaged 17.2 cm. (6.8 in.) and ranged from 11.6 to 22.6 cm. in total length (tip of snout to end of caudal rays).
† Sand, pebbles, pine needles, leaf ribs, twigs, bark, and other dead plant parts.

The 66 stomachs contained 733 organisms or 11.1 per fish, compared with 14.5 per fish in 40 brown trout caught during the first three months of 1951. As would be expected in view of their relative abundance in the bottom fauna, immature forms of Ephemeroptera, Diptera, and Trichoptera predominated numerically among ingested foods. Oligochaetes were indicated as highly inaccessible. Although they formed 15.8 percent of the number of organisms found in bottom samples in the same month (Table 1), only a fragment of one of these worms was found in one out of 66 stomachs. Trout eggs were indicated as a casual food. The five eggs listed in Table 3 were found in two stomachs. The average volume of stomach contents was 0.16 cc. per fish, which is only 55 percent of the average stomach volume noted in 1951 (0.29 cc.). Two of the 66 stomachs were empty, but none was filled or even half-filled except by virtue of containing one or two large organisms.

The outstanding feature of the food analysis was the large proportion of nonnutritious material found in the stomachs. By volume, 60.4 percent of all material ingested consisted of indigestible debris (Table 3), so that the average stomach contained only a little over 0.06 cc. of actual food. Feeding by this group of trout prior to capture was limited by ice to times when water releases made drift foods available. The amount of debris in stomachs indicates that there was little or no discrimination between food and nonfood particles in such feeding. The relatively insignificant volume of organisms per stomach further indicates that food was not easily obtained, even though the trout actively sought it.

DIGESTION EXPERIMENTS

The ability of trout to digest and utilize winter food was studied as a factor that could bear on the problem of survival in relation to food. Leonard (1941) suggested the possibility that trout may derive little nourishment from natural feeding in cold weather, and that food supplies during the coldest part of the year, therefore, may not be a critical factor in the success of trout. Hess and Rainwater (1939) attempted to test the relative digestibility of several natural trout food organisms by estimating the percentages of single organisms that remained in trout stomachs at various times after feeding. They demonstrated incidentally that low water temperature has a marked inhibitive effect on the rate of digestion.

The principal objective of the present experiments was to determine the extent to which digestion of natural food organisms is impeded by low water temperatures. It was considered that the time required for complete digestion of a standardized meal would provide the most informative measure of digestive efficiency at a given water temperature.

Preliminary feeding trials in 1953 resulted in the selection of three easily available and readily ingested organisms to represent soft-bodied, intermediate, and hard-bodied natural stream food forms. The aquatic oligochaete *Helodrilus tetraedrus* is common in Convict Creek and has a soft integument that is almost devoid of chitinous substance. An amphipod (*Gammarus lacustris*) is abundant in nearby Hot Creek. The body of this scud or so-called freshwater shrimp is rendered somewhat more difficult to digest by its covering of delicate chitinous plates. The larva of a locally abundant caddisfly (*Arctopsyche* sp.), with its heavily armored head and thorax and its somewhat leathery abdominal integument, represents a comparatively hard-bodied form. Since individual handling was necessary, size as well as degree of chitinization was considered in the selection of these organisms. Average weight indices of the three organisms were 32, 18, and 16 per gram, respectively.

Simulation of natural feeding was attempted in the 1953 trials. Known numbers and weights of the three types of food organisms were dropped to individual trout in partitioned hatchery troughs from a concealed position in the loft above. Although nearly all of these trout were willing to feed, a few were nervous for hours or days and ignored the items offered. Too much time was involved in bracketing the time required for complete digestion by several fish of a given type meal at the existing stream temperature. The results of the preliminary digestion trials were therefore inconclusive. Feeding was continued at times of various temperature ranges and it was clearly observed that most trout were eager to feed even in such artificial circumstances at water temperatures down to the freezing point. This was true for wild as well as hatchery trout. Condition likewise had little influence.

Beginning in October, 1954, a series of force-feeding experiments was started, again with oligochaetes, amphipods, and caddisfly larvae. Rainbow trout were used as experimental subjects because of their availability in sufficient numbers of reasonably uniform catchable size (5.5 to 8.0 inches, total length). Preliminary trials had not indicated any difference in digestive efficiency between rainbow and brown trout.

Force-feeding was accomplished either by inserting food organisms in the esophagus singly with a round-nosed forceps, or by introducing an entire meal into the stomach with a glass tube and plunger. Standard small meals of 0.5 gram were given in all feedings to minimize the handling time for each fish. Except for temporary respiratory distress, no ill effects among the experimental fish resulted from this method of feeding. Digestion was considered complete when part of the digestate had been eliminated and the balance was found in the lower intestine with no soft tissue remaining. Although this endpoint is coarse, it is recognizable and it takes into account the entire meal. The number of hours required for complete digestion was determined by feeding 20 to 30 trout at one time and periodically examining the digestive tracts of three or four specimens as the expected time approached.

The digestion trials were extended over five months (October to February) to intercept the desired temperature ranges, since water temperatures could not be strictly controlled except by the addition of snow to prolong minimum temperatures. A tendency toward constant temperature in the feeding troughs, caused by tempering of the supply water in over one-quarter mile of four-inch underground pipe, gave some advantage in the selection of feeding periods to include the smallest possible stream temperature fluctuations. Digestion tests were made in four temperature ranges between 32 and 53 degrees F. to represent fall and winter stream conditions. In connection with the lowest range (32 to 33 degrees) it may be mentioned that water in motion begins to freeze at a fraction below 32 degrees F., and that during cold weather Convict Creek sometimes ran for several days at 32 degrees or less, with slight rises to 33 or 34 degrees in late afternoon.

The results of these tests are given in Table 4. At water temperatures near 50 degrees F., catchable-size trout required approximately 12 to 16 hours to digest half-gram meals of the larger stream organisms. Digestion at 35 degrees took roughly two to three times as long as at 50 degrees, depending on the type of food, and complete digestion at a temperature barely above the freezing point took almost twice as long as at 35 degrees. Half-gram meals of hard-bodied caddisfly larvae were digested in 70 hours at 32 to 33 degrees. Experiments with large meals (not tabulated) indicated that trout might feed to satiation in very cold water, but that digestive efficiency is impaired by overfeeding. For example, fish that had gorged themselves on fresh trout eggs were unable to digest their meals in 10 days at 32 to 38 degrees.

It is evident from Table 4 that the speed of digestion is controlled by water temperature, and that the rate decreases sharply in the lower temperature range (below 35 degrees F.). It is possible that regular and moderately heavy feeding in cold water would result in the elimi-

TABLE 4

Results of Experimental Trout Feeding and Digestion Trials at Convict Creek, California, October 5, 1954, to February 28, 1955

Food organism (half-gram meal)	Hours for complete digestion in temperature range*			
	49-53	43-44	35-36	32-33
Helodrilus (soft-bodied)	12	18	25	—
Gammarus (intermediate)	13	18	26	43
Arctopsyche (hard-bodied)	16	21	44	70

* Expressed in degrees Fahrenheit.

nation of undigested food, as suggested by Leonard (1941). In the present trials with single meals, economical assimilation of food appeared to be a normal function in the coldest water. Digestion proceeded steadily though very slowly at 32 to 33 degrees, and examinations of fecal material disclosed that no undigested food organisms were eliminated.

Slow digestion at low temperatures would appear to have a balancing effect on the amount of nourishment taken in winter. Large meals, to be of value, would necessarily be infrequent, whereas small amounts of food could be accommodated almost continuously if available. The inference is that the ability of stream-dwelling trout to pass a cold winter in good nutritional condition is dependent not so much on an abundance of food as on a certain and not necessarily high level of steady food availability.

STARVATION EXPERIMENTS

To provide supplementary information on the importance of nourishment as a factor in seasonal trout survival, experiments were designed to test the vitality and viability of catchable-size trout under the most extreme condition possible: complete lack of food over extended periods. Four separate starvation trials were conducted, the nature of each succeeding one depending primarily on the suggestions of the last. These will be reported in order of occurence. Healthy trout within a size range of 5.5 to 8.0 inches, total length, were selected for all tests. Other than fungus on the extremities of a few individuals, no diseases or morbid conditions were experienced. To minimize disturbance and handling injuries, periodic measurements of body weight were avoided. The differences between initial and final values of the coefficient of condition (K), together with K values for trout at times of death, were used as indices of depreciation in body weight.

Winter, 1953-54

The first experiment began in December, 1953, and was terminated in April, 1954, after 120 days. Resident brown trout of normal early winter condition were used as subjects, since the purpose of this first test was to distinguish between mortality resulting from malnutrition following a normal autumn existence and winter mortality resulting from additional causes.

Two groups of trout were starved at the same water temperatures, the daily averages of which ranged from 32 to 41 degrees F. The control group was held indoors in hatchery troughs, while the other group was exposed to winter stream conditions in a food-tight outdoor enclosure. Degree of exposure was the only variable between the groups. Particulate food was excluded from the hatchery troughs by straining the supply water through a 40-meshes-per-inch screen at the intake and through layers of cheesecloth at the trough heads. Food organisms were excluded from the outdoor enclosure by applying layers of cheesecloth over the 4-meshes-per-inch hardware cloth walls and, later, over the cover. The indoor group was limited by available space to 100 fish (reduced to 97 by eliminating fungused, debilitated, or otherwise unsuitable individuals). The outdoor group, which comprised the remainder of the brown trout available at the time, was more than twice as large (266 fish, reduced to 254). Space per fish in relation to volume of flow was more than adequate for both groups of trout. Current in the outdoor enclosure was equalized with the slight current in the troughs by deepening the penned water and bypassing the surplus.

Neither group of trout was given any food in 120 days. Mortalities were recorded as they occurred, and are represented in a synopsis of the course of the test (Table 5). Nearly all mortalities in both groups

TABLE 5

Mortality Record of Two Groups of Brown Trout Held Without Food in Exposed and Sheltered Situations at Convict Creek, California, December 10, 1953, to April 9, 1954

Days from entrance	Cumulative mortality of brown trout in:			
	Exposed group (254 fish)		Sheltered group (97 fish)	
	Number	Percentage	Number	Percentage
30	9	3.5		
45	18	7.1	1	1.0
60	22	8.7	4	4.1
75	42	16.5	9	9.3
90	42	16.5	9	9.3
105	44	17.3	9	9.3
120	45	17.7	9	9.3

occurred in the first two-thirds of the test period, which suggests that some of these wild fish were not in sufficiently good nutritional condition to withstand 2 to 3 months of fasting. Later tests (1954-55, 1955-56) demonstrated that many individuals of normal hardiness can live for at least seven months without food if the temperature remains low. Most of the 120-day survivors were active and in fair physical condition, which also suggests that the mortality attributable to lack of food resulted from a prior physiological weakness (shortage of reserve nutrients), aggravated by malnutrition. The depletion of reserve nutrients in the absence of food has been shown by Phillips et al. (1953), who reported conspicuous reductions in the riboflavin, biotin, pantothenic acid, and fat content of trout livers as a result of 14 weeks of starvation.

Differential mortality between groups is most evident for the months of December, January, and February, the period of severe winter conditions. During this time the trout in the outdoor situation were subjected to as many of the natural vicissitudes of winter stream life as their enclosure would permit: the water was often filled with abrasive snow and slush or frazil ice; the flow was frequently reduced by upstream stoppages; and surface ice with an overburden of snow occasionally collapsed into the enclosure. Surface ice also formed in the indoor troughs, but did not constitute a danger to the occupants. At the conclusion of the test period the mortality in the exposed outdoor group was 17.7 percent and the mortality in the sheltered indoor group was 9.3 percent. The significantly higher percentage mortality in the stream group is offered as a positive indication that such observed hazards to winter survival as exposure to ice, slush, collapsing snowbanks, and fluctuating flow are of considerable influence in winter trout losses.

Fall, Winter, Spring, 1954-55

The second starvation experiment was conducted to determine (1) the losses that might be expected among catchable-size trout starved through the entire coldwater season, beginning in the fall, and (2) the ability of survivors to live and recover body condition when fed. In this test, 50 hatchery-reared rainbow trout and 60 resident brown trout were held in the food-free hatchery troughs for comparison of viability under starvation conditions. A local comparison of hatchery trout and wild trout necessarily involves these two species, which are commonly considered to compete with one another in streams. Brown trout populate nearly all streams of the area, whereas catchable-size rainbow trout are planted from the hatchery to meet heavy angling demands and are not available as wild stream fish.

Food was withheld from both groups until rainbow trout mortality had reached 50 percent and brown trout mortality had reached 61.7 percent, a period of 248 days or a little over eight months (October 15, 1954, to June 20, 1955). At this point, 23 survivors of each group were placed on a diet of amphipods (*Gammarus* sp.) to initiate the feeding phase. Moderate daily feeding was continued until termination of the experiment on September 15, at which time only three rainbow trout remained alive.

Early mortalities were few, possibly because trout of normal condition and healthy appearance were carefully selected for both groups. After 180 days of starvation, only five trout of each species had died. Beyond the six-month point, mortalities became more frequent and the death rate increased slowly (Table 6). Associated with the increased mortality was the steady spring rise of stream temperatures (Table 7). At seven months, 84 percent of the rainbow trout and 80 percent of the brown trout still survived. Comparable results were obtained in a similar experiment in Michigan (Adelman, Bingham, and Maatch, 1955), in which 90 percent of 5.5-inch brook trout and 75 percent of 7.5-inch brook trout survived seven months of starvation at 45 degrees F.

TABLE 6

Mortality Record of 50 Rainbow Trout and 60 Brown Trout Held Without Food at Convict Creek, California, October 15, 1954, to June 20, 1955

Days from entrance	Hatchery rainbow trout				Wild brown trout			
	Cumulative mortality		Mean condition factor (K)*		Cumulative mortality		Mean condition factor (K)*	
	Number	Percentage	Mortalities†	Survivors	Number	Percentage	Mortalities†	Survivors
0	--		-	0.940				0.793
60								
90	2	4.0		0.821				
120	4	8.0			1	1.7		
150	5	10.0			5	8.4		
180	5	10.0			5	8.4		
210	8	16.0			12	20.0	0.628	
230	11	22.0	0.608		21	35.0	0.589	
240	15	30.0			27	45.0	0.600	
245	21	42.0	0.576		32	53.3	0.517	
248	25	50.0	0.513	0.646	37	61.7	0.571	0.609

* Based on total length (tip of snout to end of caudal rays).
† Mortalities during period enclosed by braces.

TABLE 7

Summary of Air and Water Temperatures at Convict Creek, California, January, 1953, Through June, 1956

Month	1953 Air	1953 Water	1954 Air	1954 Water	1955 Air	1955 Water	1956 Air	1956 Water
	Temperature in degrees Fahrenheit* (given in order under each heading are: mean monthly temperature, maximum temperature, and minimum temperature)							
January	31.0 52.0 4.0	34.9 41.5 32.0	29.1 58.0 −2.0	35.3 38.0 32.0	15.9 40.0 −22.0	33.4 37.0 32.0	29.8 52.5 −18.0	34.9 40.0 32.0
February	31.3 57.5 5.0	35.4 43.0 32.0	22.9 50.0 1.0	34.8 42.0 32.0	24.3 55.0 −2.0	34.8 43.0 32.0	25.2 52.5 −5.0	35.0 41.5 32.0
March	36.9 66.0 0.0	38.6 49.5 32.0	29.2 54.0 −5.0	36.9 46.0 32.0	33.0 63.5 2.5	38.0 49.5 32.0	38.4 71.0 4.5	39.2 51.5 32.5
April	42.8 82.0 3.5	43.3 58.0 32.0	45.8 78.0 11.0	45.4 59.5 32.0	39.0 66.0 10.0	41.0 55.0 32.0	42.7 72.0 9.5	46.3 60.5 33.5
May	44.5 74.0 16.5	45.9 55.5 48.5	55.6 85.0 37.0	51.3 59.0 37.0	† -- -	47.3 58.0 34.5	50.2 84.0 20.0	52.5 64.0 41.5
June	54.6 85.0 21.0	50.9 58.5 41.0	57.5 93.0 19.0	53.4 62.5 41.0	 -- --	53.0 62.0 43.0	59.0 93.0 28.0	57.6 64.5 49.0
July	64.2 88.0 34.5	58.5 65.0 50.0	62.7 88.0 36.5	60.4 69.0 51.0	- 87.5 37.5	58.6 70.0 49.0		
August	59.4 85.5 34.0	59.6 66.0 51.5	58.6 87.0 29.5	59.2 68.5 45.0	65.5 91.5 30.5	64.6 72.5 56.0		
September	56.2 84.5 26.5	57.3 65.0 49.5	54.6 82.0 26.0	55.5 66.0 45.0	57.5 91.5 22.0	59.6 71.5 49.0		
October	41.3 72.5 18.0	49.7 60.0 41.5	46.0 84.0 10.5	48.4 58.0 36.0	50.2 78.0 15.0	52.4 63.0 41.5		
November	37.5 66.0 7.0	42.4 50.5 33.5	37.3 64.5 −7.0	42.9 49.5 33.5	39.9 77.5 5.0	42.6 55.0 32.5		
December	31.2 62.0 −2.0	36.3 45.0 32.0	22.3 46.5 −12.5	35.6 41.0 32.0	33.8 63.5 −5.0	37.7 46.0 32.0		

* Compiled from recording thermometer hourly chart readings.
† Thermograph out for repairs.

In the last month of the starvation phase, maximum daily water temperatures ranged from 49 to 62 degrees F., and these higher temperatures undoubtedly produced unfavorably high metabolic rates in the weakened fish. After 248 days of total starvation, most survivors were in such poor condition that their recovery seemed unlikely regardless of treatment. Coefficients of condition had dropped 31 percent for the rainbow trout and 21 percent for the brown trout, to averages of 0.646 and 0.609, respectively. Condition factors as low as 0.439 were noted among brown trout in June.

From November 1, 1954, to June 10, 1955, catchable-size rainbow trout were confined in one of the quarter-mile experimental stream sections of Convict Creek, at the observed natural density of 120 pounds per acre, as one of several experiments to measure overwinter survival and loss of condition among trout in the natural stream environment (Nielson et al., 1957). Being from the same size-selected lot, these trout and the rainbow trout held without food were initially identical and their fates could therefore be compared for nearly all of the starvation period (222 out of 248 days). The stream-stocked trout could not be regarded as controls for the experimentally starved trout, as it could not be presumed that the trout in the stream were feeding regularly while the experimental group starved.

Aside from the nourishment factor, the stream-stocked trout were exposed to the natural snow and ice conditions previously shown to influence winter mortality, while the starving trout were not. Nevertheless, it is revealing to compare the two groups as to mortality and loss of condition. After 222 days from the respective dates of entry (November 1 and October 15, 1954), the stream-stocked trout had suffered 36 percent mortality and the starving trout had suffered only 18 percent. The doubled mortality in the group that underwent natural stream life is reminiscent of the results of the 1953-54 starvation trial with brown trout, and is again evidence that the physical stream conditions of winter constitute a potent factor in trout losses. The average condition factor (K) of the stream-stocked trout declined 28 percent (0.939 to 0.673) in 222 days. When this is compared with the similar 31 percent loss in condition by the starving trout in 248 days, and when the foregoing differential survival in favor of starving trout is considered, it is evident that liberty in the stream and access to a limited food supply afforded no survival advantage to the stream-stocked trout during the winter period.

Beginning on June 21, natural food organisms (*Gammarus* sp.) were offered to 23 survivors of each species in quantities sufficient to provide one full meal per fish per day. Reactions of these emaciated trout to the sight of food were varied. Some fed so avidly as to suffer temporary losses of equilibrium, others fed sparingly, while still others remained in a lethargic state and took no notice of the food or the activity around them. The appearance of normal feces in the troughs within a few hours of the first feeding indicated that the digestive function had not been impaired by the long fasting period.

Data on mortality and condition of trout through the feeding phase are presented in Table 8. No radical changes in mortality rates were noted following the initiation of feeding, and no other evidence of injurious effects of unaccustomed food was observed. Brown trout main-

TABLE 8

Mortality Record of 23 Rainbow Trout and 23 Brown Trout Fed Natural Food * Daily Following a Starvation Period of 248 Days (Feeding Period: June 21, 1955, to September 15, 1955)

Days from entrance	Hatchery rainbow trout				Wild brown trout			
	Cumulative mortality		Mean condition factor (K)†		Cumulative mortality		Mean condition factor (K)†	
	Number	Percentage	Mortalities‡	Survivors	Number	Percentage	Mortalities	Survivors
0				0.646	-			0.609
10	5	21.7	0.621		4	17.4	0.572	
20	13	56.5	0.584		12	52.2	0.546	
30	14	60.9	0.538		20	87.0	0.587	
40	17	73.9	0.778		21	91.3		
50	19	82.6	0.480		23	100.0		
60	19	82.6						
70	19	82.6						
80	19	82.6						
86	20	87.0		0.808				

* Amphipods (Gammarus sp.).
† Based on total length (tip of snout to end of caudal rays).
‡ Mortalities during period enclosed by braces.

tained about the same average body condition as when first fed, but all died within 50 days. Of the rainbow trout for which accurate condition factor data could be obtained at time of death, most declined gradually from an average condition factor of 0.646 for the first 50 days of feeding. The four rainbow trout surviving at 50 days gradually improved in condition and took on a more healthy appearance. After 86 days of feeding, the average coefficient of condition of these survivors was 0.808.

The first six months of the 1954-55 starvation trial included the entire coldwater season as indicated by air and water temperatures (Table 7). At the end of six months, mortality was still so light that serious loss due to malnutrition probably could have been avoided by feeding. In view of the high mortality rate experienced in the last part of the starvation phase (230 to 248 days, Table 6), and in the early part of the feeding phase (Table 8), it is considered that feeding began too late to result in a fair test of the ability of starved trout to recover with the aid of nourishment.

Summer, Fall, Winter, 1955

The main purpose of this trial was to discover the effect of summer and fall stream temperatures on mortality among starving trout, it having been observed in the previous trial that mortality rates rose with the late spring rise in water temperatures. A secondary purpose was to observe mortality among survivors of these summer-starved trout during the following period (November to December), when stream temperatures fall to winter levels.

One hundred hatchery rainbow trout (in duplicate groups of 50 each) and 50 wild brown trout were starved in the cheesecloth covered outdoor pens, built into one of the concrete water-control structures in the stream, beginning on July 1, 1955. Complete screening of the enclosures was necessary at this season to prevent ingress of aerial as well as aquatic food forms. The experiment was terminated on January 4, 1956, (187 days), at which time snow and stream ice threatened the shelter.

Daily records indicated that the first 120 days of the experiment were characterized by minimum stream temperatures above 40 degrees F. and that the first minimum below 40 degrees occurred on November 2 (123 days). Stream temperatures then continued to decline in November and December, as indicated by the monthly averages (Table 7). Since the 40-degree level appeared to be near a natural temperature division between seasons both in spring and in fall (Table 7), the first four months of starvation were regarded as a period that represented summer-fall temperature conditions. The mortality and condition records of the three lots of trout starved through this period may be reviewed in Table 9 (0 to 120 days). Most striking was the early onset of heavy mortality among the brown trout. Within 60 days of entry 32 percent of the brown trout had died, whereas neither group of rainbow trout had suffered any mortality. At 90 days, brown trout mortality had reached 56 percent and only one rainbow trout had died. At the 120-day point no further rainbow trout mortality had occurred, but brown trout losses stood at 82 percent.

Survival of brown trout was markedly improved in the fall and early winter (120 to 187 days, Table 9). Mortality during this period

TABLE 9

Mortality Record of 100 Rainbow Trout (in Two Groups of 50 Each) and 50 Brown Trout Held Without Food at Convict Creek, California, July 1, 1955, to January 4, 1956

Days from entrance	Hatchery rainbow trout—group A				Hatchery rainbow trout—group B				Wild brown trout			
	Cumulative mortality		Mean condition factor (K)*		Cumulative mortality		Mean condition factor (K)*		Cumulative mortality		Mean condition factor (K)*	
	Number	Percentage	Mortalities†	Survivors	Number	Percentage	Mortalities†	Survivors	Number	Percentage	Mortalities†	Survivors
0	--	--	--	1.068				1.068				0.808
30												
45									7	14		
60									16	32	0.510	
75	--	--	--	--	--	--			19	38		
90					1	2	0.686		28	56	0.494	
105					1	2			34	68	0.513	
120‡	-	--		0.789	1	2			41	82	0.551	0.649
150	6	12	0.567		3	6	0.606		43	86	0.555	
180	13	26	0.591		10	20	0.702		46	92	0.556	
187	14	28	0.616	0.725	13	26	0.637	0.719	46	92	--	0.559

* Based on total length (tip of snout to end of caudal rays).
† Mortalities during period enclosed by braces.
‡ Dividing line between summer-fall and winter starvation periods.

amounted to only 10 percent of the initial number of trout, whereas losses amounting to 50 percent had occurred in an equivalent earlier period (60 to 120 days). Although the number of fish remaining was too small to permit any definite conclusions, such an improvement in survival rate appears to reflect a downward adjustment in metabolism as effected by the seasonal decline of stream temperature. An alternative view, that the few surviving brown trout were possibly the hardiest individuals in the original lot and were therefore able to resist starvation longer, is contradicted to some extent by the extremely low average condition factor (0.559) of four survivors at the end of the experiment. The majority of brown trout had perished earlier, at approximately the same level of condition.

The rainbow trout entered the experiment in relatively good body condition and evidently did not become critically wasted during the first four months, even though their loss of condition was more rapid in this time than in the final weeks of the experiment. The beginning of a definite mortality pattern in both groups of rainbow trout followed closely after the 120-day point (Table 9). Any favorable effects of cold-hardening on the viability of the starving rainbow trout were largely obscured by this mortality, which was probably due more to the accumulation of ill effects with time than to changes in the environment.

It is certain that summer water temperatures, which ranged up to 72.5 degrees in August, accelerated catabolic processes leading to early and severe malnutrition in the brown trout. Weight loss as indicated by reduction of average coefficient of condition (K) was even more pronounced in rainbow trout (1.068 to 0.789 = 26 percent loss) than in brown trout (0.808 to 0.649 = 20 percent loss), but the loss of condition in the first 120 days obviously did not reduce the average hatchery rainbow trout to the point of imminent death. The average condition of the rainbow trout after 120 days of starvation was not markedly lower than the average initial condition of the wild brown trout. The lower-than-average condition factors of brown trout that died during this period are also significant (Table 9). Evidently, the less robust members of the group were more quickly susceptible to the effects of summer starvation.

In considering the effects of temperature on reduction of body condition it is pertinent to compare the above percentages with those experienced in the previous 248-day starvation trial (rainbow trout: 31 percent reduction; brown trout: 21 percent reduction). In terms of temperature units[3] used as summations of heat (Reimers and Combs, 1956), the 248-day period was characterized by a water temperature total that was only 61 percent of that of the 120-day summer-fall period (1,952 and 3,166 temperature units). In one-half the time, but associated with over one-and-a-half times as many thermal units, there was approximately the same percentage loss of body condition in the trout starved through summer and fall as in the trout starved through fall, winter, and spring.

It is suggested that the ability of a trout to endure withdrawal of food for any reason (e.g., seasonal food scarcity; isolation from normal habitat; aestival inertia; suspension of feeding while adjusting to new habitat) is dependent more on its body condition at the time than on

[3] Degrees F. per day in excess of 32 degrees.

its origin. A reserve of body tissue and essential nutrients is a definite asset to the trout that must withstand a fasting period. In the present test, hatchery rainbow trout in their initial season of natural surroundings demonstrated summer vitality superior to that of wild brown trout in a stream situation that has generally been thought to favor wild or resident trout.

Fall, Winter, Spring, 1955-56

In the previous long-term starvation trial (1954-55) it was found that an amazingly large percentage of trout could exist without food for six or seven months, through the colder seasons, in a situation uncomplicated by severe winter stream conditions. Indications were that continued lack of food at higher temperatures resulted in excessive mortality and loss of the capacity to recover weight and strength when food was again made available.

In the present experiment trout were held 180 days without food during a period that corresponded to the first six months of the previous overwinter trial (October to April), and survivors were then fed to observe recovery. The 180-day point (April 12, 1956) occurred at a time when stream food availability would normally begin to increase after the winter season. In this regard, the test of ability to recover from a starved condition was initiated at the normal seasonal point, with respect to rising water temperature and the resumption of regular feeding by trout in the stream.

As in the previous overwinter starvation test, survival through 180 days was excellent (rainbow trout: 98 percent: brown trout: 92 percent). From the standpoint of body condition the hatchery rainbow trout did not reach a starved or emaciated state, but the wild brown trout were thin and weak as the result of a 19.7 percent reduction in coefficient of condition (Table 10).

Feeding began with live food (*Gammarus* sp.), but a shortage of these organisms dictated the use of a regular hatchery diet after two weeks. Daily feeding of surviving brown trout and one group of surviving rainbow trout continued for 56 days, after which time it was apparent that a recovery had been made. Rainbow trout gained slightly in body condition (+ 1.0 percent) during the feeding period. Brown trout improved markedly in condition (+ 10.2 percent), presumably because of an excess of food in relation to average body weight. Both groups improved in general appearance, and in vitality as indicated by increased activity and stamina. One feeding rainbow trout and three feeding brown trout died during the 56 days.

The second group of rainbow trout, which had continued to starve as a control, lost only one member but reduced drastically in body condition (— 17.0 percent) during the feeding phase. This group lost 32.6 percent of initial body condition over the entire 236 days of starvation.

In conjunction with the starvation trial, 100 catchable-size rainbow trout were held in a pool adjacent to the creek for an approximately corresponding six-month period (November 3, 1955, to April 30, 1956). The purpose of this test was to determine overwinter survival of the trout in a situation where food was available in some slight degree but where current did not demand normal stream activity of the subjects and where ice action did not create conditions detrimental to survival.

TABLE 10

Mortality and Condition of 100 Rainbow Trout (in Two Groups of 50 Each) and 50 Brown Trout Held at Convict Creek, California, October 14, 1955, to April 12, 1956 (Without Food) and April 12, 1956, to June 7, 1956 (Brown Trout and Group-A Rainbow Trout Fed Daily)

Days from entrance	Hatchery rainbow trout—group A				Hatchery rainbow trout—group B				Wild brown trout			
	Cumulative mortality		Mean condition factor (K)*		Cumulative mortality		Mean condition factor (K)*		Cumulative mortality		Mean condition factor (K)*	
	Number	Percentage	Mortalities†	Survivors	Number	Percentage	Mortalities†	Survivors	Number	Percentage	Mortalities†	Survivors
0	--			1.135				1.136				0.852
30											0.833	
45									2	1	0.818	
60					1	2			3	6		
120			1.135		1	2			3	6	0.720	
150	1	2			1	2			3	6		
180‡	1	2		0.900	1	2		0.921	4	8	0.613	0.684
210	1	2	1.001		1	2			7	14		
236	2	4		0.909	2	4		0.765	7	14		0.754

* Based on total length (tip of snout to end of caudal rays).
† Mortalities during period enclosed by braces.
‡ Began daily feeding of survivors (rainbow trout Group A, and brown trout).

The pond was roughly 1,200 square feet in surface area and had a mean depth of about one-and-one-half feet when filled. Water level and circulation were maintained through screened channels connected with a primary stream section. The pond had been maintained for several years, with occasional temporary occupation by trout, and it could be assumed that a small supply of natural food was in existence at the time of the trial reported here. Although surface ice with a cover of snow was present on the pond for at least half of the six-month period, its only discernible effect on the habitat was to reduce light.

After the light losses experienced in two six-month starvation tests of these rainbow trout it came as no great surprise, on draining the pond at the end of April, to learn that all 100 fish had survived. The average condition factor declined 22 percent (1.091 to 0.855) during the test period. By comparison, loss of body condition among rainbow trout in the concurrent starvation trial averaged 20 percent. It will be recalled that rainbow trout stocked in the natural stream sections the previous November (1954) suffered 36 percent mortality and lost 28 percent of their body condition in 222 days. Rainbow trout similarly stocked in November, 1955, suffered only 11 percent motality but lost 32 percent of their body condition in 218 days.

This combination of tests provides further evidence that food is not a critical factor in overwinter survival of trout in sheltered water of the area studied. Loss of body condition through the coldwater season was similar in sheltered groups of trout, whether starved or exposed to a minimum food supply, but was somewhat greater in the stream, where food was also available in minimum quantities. Survival of starved trout was far greater than that of trout at liberty in the stream. The importance of snow, ice, current, and exposure conditions as mortality agents in the stream is emphasized by the comparison of survival rates between groups of trout held in pond (lentic) and open stream (lotic) situations.

TROUT SURVIVAL IN RELATION TO FOOD AND EXPOSURE

As pointed out by Hazzard (1941), the severity of weather and ice conditions determines the damage that may be done to stream bottom food supplies by the loosening, scouring, and molar actions of anchor ice, accelerated current, and solid ice. Although the findings are somewhat in conflict, it appears that the amount of damage from anchor ice may be less in larger streams. Anchor ice was observed to serve as a means for downstream dispersal of bottom organisms in the Pigeon River, Michigan, but depletion and physical damage to the stream bed were considered negligible (Benson, 1955). O'Donnell and Churchill (1954) described extensive scouring and movement of bottom materials as a result of frequent anchor ice dam releases in the Brule River, Wisconsin. On the basis of sampling over several weeks they reported 4,440 to 16,560 (average of 9,480) aquatic organisms per hour being carried past a given point by released anchor ice, and they concluded that the total disturbance to the bottom environment could reach such proportions as to be a limiting factor to the trout populations. A study of the effects of ice in the West Gallatin River, Montana (Brown, Clothier, and Alvord, 1953), disclosed little or no depletion of bottom fauna by anchor ice, although masses of freed anchor ice were observed to dislodge and transport organisms. These authors found, however, that freezing of the stream bottom near the shore annihilated the organisms present.

Small streams of moderate to steep gradient, with many riffle areas, are more susceptible to depletion in prolonged cold weather because of greater exposure of sections of the bottom to freezing and sudden scouring in anchor ice cycles. Damage to the bottom and banks of Convict Creek by increased flow and anchor ice release occurred in early 1951. Long-term blanketing of stream areas by snow and ice cover rendered the stream bottom almost sterile in the early spring months of 1952. Anchor ice repeatedly disturbed bottom areas, dislodged organisms, and subjected riffle sections to partial drying and freezing in early 1953. Midwinter food intake by stream-resident trout was so low as to suggest very low availability of the food organisms that were present.

The winter stream conditions described for Convict Creek are common to many small trout streams in the alpine west and in other localities of similar climate, and the bottom food crops of such streams must be similarly depleted or unavailable to trout in winter and early spring. However, it is obvious from the results of tests described in foregoing sections that scarcity of food during winter months cannot by itself be a limiting factor in the survival of trout in any single year. Although an abundance of stream food is undoubtedly an important asset to the growth and success of a trout population, it seems clear that the impact of seasonal food scarcity on survival rates for a given winter is felt only when the physical conditions of the environment are barely tolerable to trout. Trout that must maintain normal stream activity during a season of relative famine, when their energy output should be low, must suffer from starvation in proportion to the rigors of the environment. In a single winter, the effect of food shortage alone is indicated as temporary debility, not mortality, for a large majority of the trout.

It was demonstrated in the starvation experiments that the ability to fast is an adaptation that serves to assist the fish through a difficult season in terms of food, but it was also made clear that the results of tests in sheltered situations cannot be applied directly as expectations for the exposed winter stream. Scarcity of food, unavailability of food, and inability to assimilate normal quantities of food must therefore be listed as contributory in some degree to winter trout mortality in swift streams that are exposed to rigorous winters. Physical deterioration of the habitat is indicated as the primary agent of winter mortality in such streams. The most important single cause of death is probably suffocation, following exhaustion, as a result of one or more forms of exposure.

In view of the present findings on coldwater digestion and the ability of healthy trout to withstand several months of fasting, the question of the importance of winter food to trout survival may be approached with the quality and vitality of the trout, rather than the quality of the food supply, as the main point of reference. In starvation trials in all seasons, well-nourished hatchery rainbow trout demonstrated better survival qualities than did stream-conditioned wild brown trout. The results of the feeding phase of the final starvation experiment indicated that overwinter fasting or partial fasting should not be harmful to the majority of catchable-size trout in sheltered situations, provided that the spring rise in water temperature is accompanied by an increase in the food supply. Clearly, superior body condition and a supply of reserve nutrients were advantageous to the hatchery trout in these experiments. It is logical to assume that the excess weight which results from forced growth in the rearing of most stocked trout is beneficial to survival through the first year, particularly in small streams that are incapable of providing sufficient food for hatchery trout superimposed on wild trout populations.

The excellent survival of hatchery trout in starvation periods of four months during summer and fall (99 percent) and six months overwinter (average of 95 percent for three groups of fish in two tests) raises the question of the importance of competition for food among these trout, and between them and trout that are established in the streams that are stocked. Information on the effect of competition may be drawn from the data of six years of survival experiments at Convict Creek (Nielson et al., 1957). No convincing evidence of decreased annual survival as a result of increased trout density was found at stocking rates from 50 to 250 pounds of trout per acre, although with this much variation in fish density it must be assumed that the available food per fish also varied radically. The above applied to both hatchery rainbow trout and wild brown trout. Within the same group of experiments, rainbow trout held in an isolated section of the stream for 27 months incurred no survival benefits during the second year as a result of decreased density and wider foraging opportunity following the first year's mortality. Survival in the second discrete year (12.1 percent) was much lower than in the first (66.5 percent), presumably because of increased age and or differential exposure between years.

The main purpose of stocking catchable-size trout in streams is to alleviate angling pressure in the season of planting or in the season that follows fall stocking. Since the present ideal in the management of such stocking programs is a complete harvest within the year, the problem of intraspecific food competition among the hatchery trout during the expected period of usefulness would appear to be a small one in terms of quantitative survival. Similarly, food consumption by resident trout would have little to do with survival of superimposed catchable trout in the year of stocking. It is possible that put-and-take stocking far in excess of carrying capacity, as understood in terms of natural food production, may be practiced repeatedly without significant nutritional mortality of hatchery trout prior to capture. However, the lower vitality of stream-conditioned wild trout in the absence of summer food, demonstrated in the 1955 starvation trial, indicates that such stocking practices may have sufficient effect on the food fauna of a small stream to limit the success of the resident trout.

SUMMARY

During the period April, 1952, to June, 1956, when suitable conditions prevailed, experiments and observations bearing on the general problems of winter trout food availability, trout vitality, and trout survival as related to food were conducted at Convict Creek Experi-

ment Station, Mono County, California. This U. S. Fish and Wildlife Service fishery research unit is located at an elevation of 7,200 feet on Convict Creek, a small stream on the eastern slope of the Sierra Nevada.

Stream bottom sampling immediately after the dissipation of prolonged ice and snow cover in April, 1952, demonstrated that a severe winter in this area reduces the bottom fauna of a swift stream drastically below the normal winter condition, to a point where the intake of food by trout must be limited. Analysis of the stomach contents of 66 trout taken from the stream in February, 1953, indicated an extremely low intake of food in a critical winter month. Sampling indicated that drift foods are more abundant relative to the bottom food supply in February and March, when ice action prevails, than later in the spring, but the food analysis demonstrated that lack of feeding selectivity reduces any advantage the trout might gain from such increases in drift foods.

The question of the digestive efficiency of rainbow trout at various water temperatures was explored through controlled feeding of soft-bodied, intermediate, and hard-bodied natural food organisms. Digestion was found to proceed slowly but steadily at temperatures closely approaching the freezing point. Time required for complete digestion of half-gram meals ranged from 12 hours for the soft-bodied food organisms at 49 to 53 degrees F. to 70 hours for hard-bodied insects at 32 to 33 degrees F. From results of the low temperature digestion trials it may be deduced that the amount of nourishment trout can obtain from available food in extremely cold water is controlled primarily by the rate of assimilation, so that the low food supply associated with severe winter stream conditions cannot by itself be regarded as a crucial factor in trout survival.

Trials to determine the effects of prolonged starvation were conducted with several lots of trout at various times, and results indicated that survival without food is favored by low water temperature and high initial condition of the fish. Higher mortality (17.7 percent) among trout starved for 120 days in an outdoor stream enclosure than among those of a control group starved indoors at the same low water temperatures (9.3 percent) emphasized the importance of such physical factors as abrasion by slush and ice, collapse of snow and ice bridges and snowbanks, and fluctuating flow (with stranding and restrictions on movement) in winter trout survival.

Groups of hatchery rainbow trout and wild brown trout were held without food for a total of 248 days through fall, winter, and spring months with mortalities of 50 and 62 percent. Only slight recovery was made among survivors fed natural food. Summer-fall starvation trials resulted in decimation of wild brown trout (82 percent mortality in 120 days), but negligible loss of super-nourished hatchery rainbow trout (2 percent mortality in 120 days). Disease was not a factor in the mortalities. In a fourth experiment, mortality after 180 days of overwinter starvation was 2 percent among hatchery rainbow trout and 8 percent among wild brown trout. Feeding initiated at 180 days revitalized and improved the body condition of both species, and mortality rates remained low through 56 days of feeding. In an associated experiment, 100 percent overwinter survival of hatchery rainbow trout was obtained in a small pond that provided a little natural food and a sheltered habitat. Survival of rainbow trout held in the open stream for comparable periods ranged from 64 to 89 percent.

The results of the starvation trials point to the following conclusions: (1) healthy trout are adapted to and are capable of long periods of fasting, particularly in cold water; (2) planted trout need not make immediate heavy demands on the environment; and (3) competition for stream foods among catchable-size planted trout, or competition between these and resident wild trout, may be largely disregarded as a critical factor in survival of planted trout to the creel of the year. Present data also support the more general conclusion that overwinter losses of catchable-size trout in small streams exposed to severe winter conditions result primarily from adverse and exhaustive physical conditions in the stream, and that food is a secondary and qualitative factor in survival.

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A WATERFOWL NESTING STUDY IN THE SACRAMENTO VALLEY, CALIFORNIA, 1955[1]

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INTRODUCTION

An evaluation of waterfowl production in any given area must of necessity be computed from the results of two separate types of investigations. First, an inventory must be made to determine the approximate number of breeding pairs existing in the area, and second, a nesting study should be conducted to appraise the hatching success and brood survival of these nesting birds.

The California Department of Fish and Game, through Pittman-Robertson Project W-30-R, has conducted annual inventories of all major breeding grounds within the State for a number of years. Aerial surveys have proved to be the most reliable. However, it has become increasingly evident that figures derived from these surveys must be supplemented by regional studies of breeding conditions.

A thorough, comprehensive nesting study is, understandably, a tedious undertaking, requiring as much personnel as can be spared from other activities if a large area is to be sampled. It is believed that regional studies made at intervals of several years in each locality should be sufficient to yield adequate information regarding the effects upon waterfowl production of possible changes in the environment during the intervening years, such as modification in land use, fluctuation in predator populations, and amount and distribution of precipitation.

The present report covers a nesting study which was conducted in the Sacramento Valley during the 1955 breeding season of ducks and coots.

ACKNOWLEDGMENTS

On the average, four men per day were engaged in the field work. Other assignments necessitated some shifting of personnel; in fact, the writer alone was able to remain with the field study from start to finish.

Frank M. Kozlik and A. W. Miller provided guidance and assistance in the field work and advice in the preparation of the manuscript. Robert LeDonne compiled the weather statistics used in the report. Assisting with the field work were Philip Arend, Warren Rienecker, William Hines, Gene Wilson, William Forward, and William Burgen.

[1] Submitted for publication July, 1956. Federal Aid in Wildlife Restoration Act, Project California W-30-R, "A Study of Waterfowl in California".

A study of this nature could scarcely be accomplished without the help and cooperation of a good many individuals not directly participating in the assignment. The writer wishes to express his appreciation to land owners and ranch managers for permission to carry on the field work on the various properties.

Special thanks are extended to John Cowan of the Department of Fish and Game and his staff for assisting with brood counts, to Chester M. Hart, also of the Department of Fish and Game, for loan of the camera used for predation photography, to Lee Baldock and other personnel on the Conaway Ranch for help and numerous courtesies, and to Vernon Ekedahl and David Marshall of the United States Fish and Wildlife Service for assistance with photography of nest predation.

PREVIOUS NESTING STUDIES IN THE SACRAMENTO VALLEY

During the spring and summer of 1948 an investigation of mallard production was conducted on the 19,000-acre Conaway Ranch in Yolo County by John Earl (1950). Wilbur W. Mayhew (1955) repeated studies on the same ranch during the years 1949 through 1953, with entirely different results from those of the previous investigation.

Another nesting study was carried on in Butte County and northern Sutter County by A. W. Miller and James Blaisdell of the Department of Fish and Game during 1949 and 1950.

The methods used by Earl and Mayhew to evaluate production were based to a large degree on a ground census of mallards which were assumed to be breeding pairs, taken before nesting began, and on an aerial census which was then assumed to indicate the number of mallards produced on the area, taken in midsummer of the total population on the ranch. However, Earl determined the fate of 60 mallard nests through periodic visits until the time the nests were terminated.

The Miller-Blaisdell studies are most suitable for direct comparison with the one covered by this report, since the methods used to arrive at production data are essentially the same.

HISTORY

Comparatively little authentic information is available concerning waterfowl abundance in the Sacramento Valley during the days of the early settlers. Although existing reports seem extravagant, without a doubt the natural marshes of those days furnished a haven for waterfowl which will never again be equalled.

Since the advent of intense agriculture, most of these marshes have been drained or materially reduced in extent; at the same time, there are certain compensating factors. Much of the drained land area is devoted to the growing of field crops which even after being harvested help sustain waterfowl through waste and spillage left in the fields.

The most important of these crops from the standpoint of waterfowl habitat restoration is rice. Commercial production of rice in California began in 1912, when 1,400 acres were planted. In 1949 the area had been increased to 290,000 acres. Rice acreage in California reached its peak in 1954, with a total of nearly 430,000 acres.

Due to a decline in the foreign markets for American rice, the 1955 allotment of rice acreage to California growers was reduced by more than 100,000 acres. However, the total allotment for seven Sacramento Valley counties in 1955 was 264,276 acres.

As long as rice is grown in the Sacramento Valley on a large scale, and harvesting methods do not become overly efficient, the waste grain from this crop will constitute an important source of food for wintering waterfowl. Since land sown to rice must be inundated for a period of from 90 to 140 days during spring and summer, it also forms excellent habitat for a breeding population of ducks and coots. True, the rice does not ripen until September, but rice fields are often weedy, and though the numerous plant species regarded as weeds are a nuisance to the grower, they are usually of value as duck food, much of which is available during the nesting season.

PROCEDURE

The techniques employed and materials used by the Waterfowl Project in conducting a nesting study have been described in detail in previous reports (e.g., Miller and Collins, 1954), so that it is probably sufficient here to outline the most important principles involved.

Study plots on which an effort is made to locate as many nests as possible are selected. The nests are revisited once every 7 to 10 days and the history recorded on nesting cards until the ultimate fate of each nest has been determined.

The nesting card used in this study was devised by A. W. Miller for the Tule Lake-Lower Klamath Study in 1952. It was illustrated and described in the report of that study (Miller and Collins, 1954) and is mentioned at this time merely to reiterate the fact that this card is still being reproduced in its original form, and has proved to be an invaluable tool in the analysis of nesting study data.

The Sacramento Valley contains about 2,400 square miles. Although permanent natural lakes and ponds are all but gone, a network of canals and ditches combines with the Sacramento River and its tributaries and the flooded rice fields to make the valley quite attractive to nesting ducks, especially mallards (*Anas platyrhynchos*). The project's 1955 breeding ground survey indicated a nesting population of 23,720 pairs of ducks, of which 22,320 were mallards, 200 pintails (*Anas acuta*), 280 gadwalls (*Anas strepera*), and 920 cinnamon teal (*Anas cyanoptera*) (Miller et al., 1956). The survey also showed an estimated 4,760 pairs of coots (*Fulica americana*).

As duck nests were for the most part scattered thinly over the greater portion of this immense area, and it was considered desirable to locate a fairly large sample of nests, it was necessary to select the study plots in places which were assumed to be reasonably productive.

Three of the study plots were located within the boundaries of Federal and State waterfowl management areas, because of convenience of access. The emphasis in the management of these areas is placed on accommodating winter populations of waterfowl, and Table 6 indicates that the average nesting success in these plots was about the same as the over-all average.

The plots were chosen in widely separated parts of the valley, as well as in divergent types of habitat (Figure 1 and Table 1).

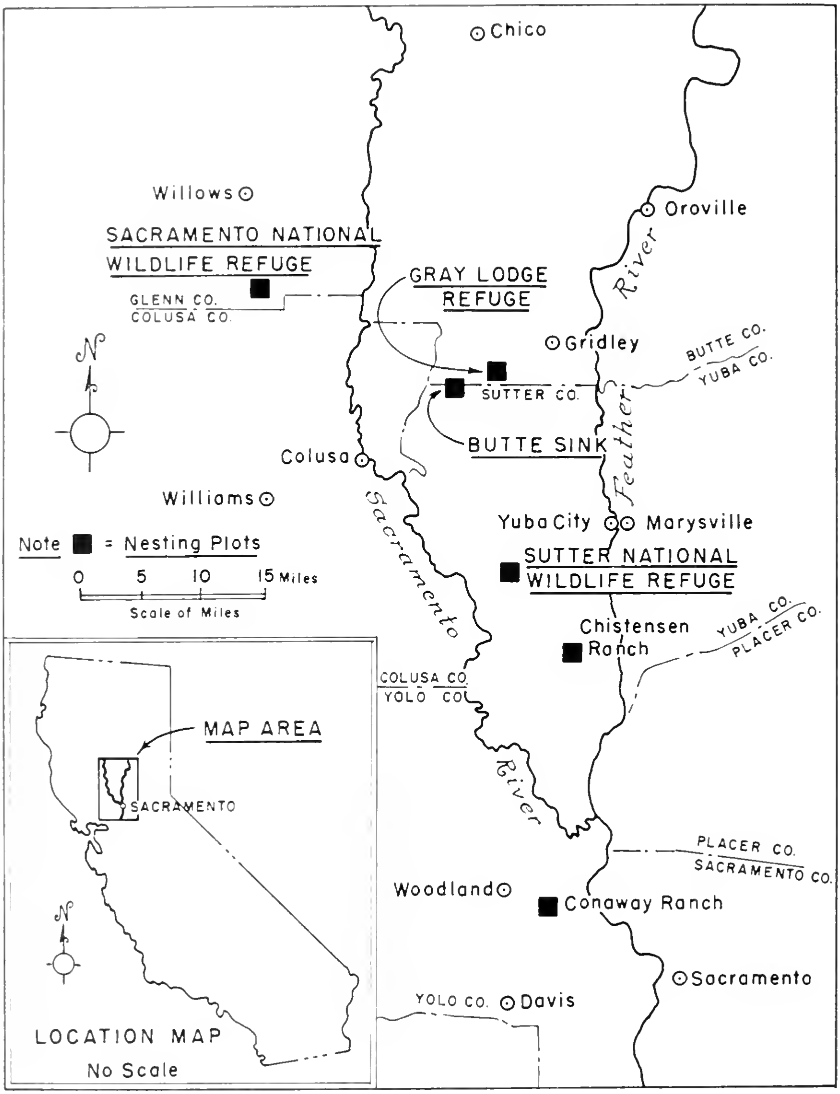

FIGURE 1. Waterfowl nesting study plots in the Sacramento Valley, 1955. *Drawing by Cliffa Corson.*

DESCRIPTION OF STUDY PLOTS

1. Gray Lodge Waterfowl Management Area, Butte County. This plot consisted of 100 acres of marsh located in the original part of the area and 100 acres of marsh and 200 acres of standing barley in the new "Rising River" section.

2. Butte Sink. This plot consisted of portions of several adjoining gun clubs, flooded during the waterfowl hunting season but becoming progressively drier during the spring and summer months. The clubs

TABLE 1

Type of Habitat on the Study Plots

Type	Acres	Percentage
Wasteland, dry marsh	1,790	50.3
Rice field	1,330	37.4
Newly harvested barley	240	6.7
Standing barley	200	5.6
Totals	3,560	100.0

included in this plot were the Wild Goose Gun Club, Butte County, 60 acres of pastured marsh; the Berry Patch Gun Club, Sutter County, 200 acres of marsh; and the Greenhead and Live Oak Gun Clubs, Sutter County, 200 acres of marsh. The predominant cover on this plot was wire rush (*Juncus balticus*) and sedge (*Carex* sp.).

3. Sacramento National Wildlife Refuge, Glenn County. This plot consisted of 100 acres of marsh and 400 acres of rice with old check dams.

4. Sutter National Wildlife Refuge, Glenn County. This plot consisted of 1,000 acres of marsh grown to sedge, wire rush, and various coarse grasses.

5. La Croix Ranch, Glenn County. This plot was situated about four miles west of the Sacramento National Wildlife Refuge and consisted of 20 acres of harvested barley.

6. Christenson-MacIlenry Ranch, Sutter County. This plot consisted of 640 acres of rice with old check dams supporting an excellent growth of volunteer barley, plus 10 acres of barley stubble.

7. Conaway Ranch, Yolo County. This plot consisted of 200 acres of barley stubble, 140 acres of rice with old check dams supporting a variety of vegetation including mustard (*Brassica campestris*), vetch (*Vicia* sp.), and various grasses, and 100 acres of rice with sparse cover on the check dams.

8. Cassady Ranch, Butte County. This plot was located adjacent to the Gray Lodge Waterfowl Management Area and consisted of 10 acres of barley stubble.

9. Lambert Area, Glenn County. This plot was located just east of the Sacramento National Wildlife Refuge and consisted of 50 acres of rice and 30 acres of marsh.

The marsh areas indicated in the above listed plots are wet during the spring period and become progressively drier during the advancing nesting season.

The study plots were thus located in four Sacramento Valley counties (Figure 1), and Table 1 gives the total acreage of each type of nesting habitat included in the study. Because of the understandable objection of permitting personnel to walk through standing grain crops, this phase of nest hunting was possible only on Gray Lodge Waterfowl Management Area. In the case of the privately owned fields it was necessary to wait until the grain had been harvested before obtaining a sample of nests in this habitat type. Since harvesting operations did not take place until well after the normal peak of hatch, only very late nests were broken up by the equipment. Generally this type of damage was easily recognized by the crushed or scattered eggs the contents of which had not been devoured by predators.

The study was begun on May 3, after mallard nesting was well under way. The last two active nests, those of a mallard and a cinnamon teal, were found to have hatched about the middle of August.

NESTING PERIOD

Table 2 indicates, by 10-day periods, when the nests were located and shows that the peak of activity lasted from May 1 until toward the end of June. The peak of hatch (Table 3) occurred between late May and mid-July. Both of these tables take into account only active nests and do not include nests which were either hatched or found destroyed at the time of the first visit. It may reasonably be assumed that the nesting period was prolonged considerably, due to predation and subsequent renesting attempts by the victimized hens.

TABLE 2

Period in Which Active Nests Were Located

Species	Apr. 23	May 2	May 12	May 22	June 2	June 12	June 22	July 2	July 12	July 22		Totals
Mallard	1	1	38	9	26	19	32	10	6	2	--	144
Gadwall	--	--	1	--	--	--	1	--	--	--	--	2
Cinnamon teal	--	--	1	--	2	3	2	1	--	1	--	10
Totals	1	1	40	9	28	22	35	11	6	3	--	156

TABLE 3

Hatching Period of Nests

Species	May 22	June 2	June 12	June 22	July 2	July 12	July 22	Aug. 2	Aug. 12	Aug. 22		Totals
Mallard	1	18	18	14	11	16	3	3	1	--	--	85
Gadwall	--	--	--	--	1	1	--	--	--	--	--	2
Cinnamon teal	--	--	2	2	--	2	--	--	--	1	--	7
Totals	1	18	20	16	12	19	3	3	1	1	--	94

NEST SITES

The nest sites all came under one of five categories, as follows:

1. *Dike, ditch bank, roadside, or similar situation.*

2. *Rice check.* The check dams or low levees generally built on contours and separating rice paddies. Since newly prepared rice fields were

without good cover until the nesting season was well under way and used only by late nesters, nearly all fields included in the study were those which had also been planted to rice the previous year and supported rank vegetative cover on the check dams (Figure 2).

3. *Pasture.* Any habitat type where grazing of livestock was included in the land use, either intentionally or accidentally.

4. *Grainfield.* Either standing or freshly mowed grains, invariably barley in the study plots of this investigation.

5. *Wasteland, marsh, and fields which were not utilized for stock grazing during the study.*

FIGURE 2. A portion of the Christenson-MocHenry rice fields. *Photograph by author.*

Table 4 compares nesting success in the different types of nest sites. A comparison of Table 1 with Table 4 demonstrates the attractiveness of rice checks as nest sites, especially considering the small amount of dry land involved.

FATE OF DUCK NESTS

Table 5 shows the fate of all duck nests included in the sample. A total of 333 nests was located, of which 38.4 percent hatched, 9.3 percent were deserted, and 52.3 percent were destroyed. Of the 174 destroyed nests, 82.7 percent were known to have been victimized by predatory mammals.

Table 6 compares the nesting success in nine different plots. Three of these yielded such small samples that the results may be considered insignificant.

The highest rate of success was enjoyed on the Christenson-MacHenry Ranch, where 72.7 percent of all duck nests hatched and only

TABLE 4

Fate of Nests by Nest Sites

Site	Destroyed		Deserted		Hatched		Total nests in each side	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Dike	12	44.4	2	7.4	13	48.2	27	8.1
Rice check	65	54.6	14	11.8	40	33.6	119	35.8
Pasture	6	85.7	1	14.3	0	0.0	7	2.1
Grainfield	33	51.6	5	7.8	26	40.6	64	19.2
Wasteland	58	50.0	9	7.8	49	42.2	116	34.8
Totals	174	52.3	31	9.3	128	38.4	333	100.0

TABLE 5

Fate of Nests by Species

Species	Destroyed		Deserted		Hatched		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Mallard	161	53.0	26	8.6	117	38.5	304	100.0
Gadwall	2	33.3	1	16.6	3	50.0	6	100.0
Cinnamon teal	11	47.8	4	17.4	8	34.8	23	100.0
Totals	174	52.3	31	9.3	128	38.4	333	100.0

TABLE 6

Fate of Nests by Study Plot

Study plot	Destroyed		Deserted		Hatched		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Gray Lodge Area—400 acres	17	27.0	8	12.7	38	60.3	63	100.0
Butte Sink—460 acres	22	52.4	2	4.8	18	42.9	42	100.0
Sacramento Refuge—500 acres	35	83.3	1	2.4	6	14.3	42	100.0
Sutter Refuge—1,000 acres	38	57.6	6	9.1	22	33.3	66	100.0
La Croix Ranch—20 acres	4	100.0	0	0.0	0	0.0	4	100.0
Christenson Ranch—650 acres	5	9.1	10	18.2	40	72.7	55	100.0
Conaway Ranch—440 acres	49	92.5	3	5.7	1	1.9	53	100.0
Cassady Ranch—10 acres	2	40.0	0	0.0	3	60.0	5	100.0
Lambert Area—80 acres	2	66.7	1	33.3	0	0.0	3	100.0
Totals—3,560 acres	174	52.3	31	9.3	128	38.4	333	100.0

9.1 percent were destroyed. The balance, 18.2 percent (10 nests), were deserted before incubation was completed. The exceptionally low incidence of predation on this plot was rather surprising, since no effort had been expended on predator control in recent years, according to the owner's statement. However, nearly all the nests were located on the check dams separating the rice paddies in 540 acres of this crop. It is possible that the extremely long check dams or levees, some of them $1\frac{1}{2}$ miles in length, only a foot or two in width, and without cross levees, may have discouraged predatory mammals from traveling on them.

In direct contrast was the absolute nesting failure in rice fields on the Conaway Ranch and on the Sacramento National Wildlife Refuge, where check dams were short and connected with cross levees. Under these conditions, nests were easily accessible to predators.

The relatively high hatching success on Gray Lodge Waterfowl Management Area of 60.3 percent may, in all probability, be attributed to a prenesting trapping program which had been carried on for several years.

On the Sutter National Wildlife Refuge and the Butte Sink study plot, where 33.3 percent and 42.9 percent, respectively, of the nests hatched, most of the nests were located in the midst of extensive, dense stands of wire rush and sedges. Raccoon hunting with hounds has been practiced by some of the gun clubs, notably the "Berry Patch." There is no doubt that this practice has helped to control the raccoon population and benefited nesting ducks.

Of all the destroyed nests, 6.9 percent were ruined by livestock or human activities, mostly the latter. This loss appears to be an unavoidable one, and it is fortunate that it is relatively low. Most of this destruction occurred to late nests, which were broken up by harvesting equipment.

Only one duck nest bore evidence of having been damaged by a bird, probably a crow (*Corvus corax*).

The cause of destruction of 9.8 percent of the nests in the destroyed category could not be determined. Most of these nests were found empty, without any trace of eggshells in the vicinity. There is a possibility that the eggs were swallowed by large snakes. Gopher snakes (*Pituophis catenifer*) are quite common in the Sacramento Valley. However, some mammals occasionally transport eggs a considerable distance from the nest site.

Predation by mammals constituted by far the greatest loss, 82.7 percent of all destroyed duck nests. Therefore, some effort was made to determine which of the various species of mammals, native or introduced into the Sacramento Valley, were the worst offenders. Since the Conaway Ranch had proved to be one of the trouble spots, State trapper Walter Frazier was assigned to operate there for a period of two weeks in late June, to obtain a sample of the predators in this area. His catch consisted of one raccoon (*Procyon lotor*), one red fox (*Vulpes fulva*), 14 striped skunks (*Mephitis mephitis*), one spotted skunk (*Spilogale gracilis*), 18 feral house cats, and one stray dog. Mr. Lee Baldock accounted for two additional striped skunks.

This list of predators certainly points to a large skunk population on the Conaway Ranch, one large enough to raise havoc with the duck nests. Feral house cats, though not known to be habitual egg eaters, are a menace to young ducks and are believed to have killed incubating ducks and coots on their nests. It is believed that if some smaller traps had been used, or more sensitive sets put out, so as to obtain a more complete sampling, more information would have been gained by this trapping experiment.

On the Sacramento National Wildlife Refuge all duck nests were destroyed on the check dams of a 400-acre rice field, in spite of the fact that a Federal trapper, operating on the refuge during March and April of 1955, had taken 9 raccoons, 10 red foxes, 23 striped skunks, 6 spotted skunks, 54 feral house cats, and 2 dogs.

FIGURE 3. Camera ready for predation photography. *Photograph by author.*

By July 11 the routine field work of the nesting study had slackened sufficiently to allow time for predation photography. This had proved to be a practical means of securing indisputable evidence in a previous nesting study on the grasslands of Merced County, California (Anderson, 1956).

A camera was set up on a rice check on the Sacramento Refuge (Figure 3). The camera, equipped with synchronized shutter and flash, was focused on a "dummy" nest from which a switch was connected with each individual egg in such a manner that a slight pull exerted on any of the eggs would automatically create a photographic exposure. Since duck eggs were difficult to obtain, chicken eggs were substituted. It was considered a foregone conclusion that any animal which would rob a simulated nest containing chicken eggs would likewise destroy a real duck nest.

These photographic experiments were carried on in four different locations, one-quarter mile or more apart, and by July 31 a series of 13 photographs had been obtained. Five of these pictures showed Norway rats (*Rattus norvegicus*) in the act of nest predation; the remainder showed spotted skunks removing eggs. In most instances, all of the eggs were destroyed by the following morning. In a few cases, some eggs were left intact, but invariably these were devoured during the following night (Figures 4 and 5).

It would surely be a mistake to conclude from these experiments that Norway rats and spotted skunks are the only nest predators in the Sacramento Valley. Striped skunks and Virginia opossums (*Didel-*

FIGURE 4. Spotted skunk robbing nest. *Photograph by author.*

FIGURE 5. Nest predation by Norway rat. Photograph by author.

phis virginiana) were photographed in the act of devouring or removing eggs from duck nests in the northern San Joaquin Valley in 1953 and 1954. Striped skunks are abundant in the Sacramento Valley and opossums are present, though thus far in smaller numbers than on the San Joaquin Grasslands. Raccoons, coyotes (*Canis latrans*), and stray dogs are also known to eat eggs. The experiments did lend support to the opinion, expressed above, that trappers often miss many of the small nest predators by neglecting to set some small traps. The fact that 8 out of 13 instances of predation were committed by skunks, even in competition with Norway rats, demonstrates graphically the appetite of these animals for eggs.

Of late years, Norway rats have invaded the Sacramento Valley, until they are now a serious pest. According to the Maxwell Tribune, April 20, 1955, eight boys had killed 96 rats in four hours on the local air strip a few days earlier. Lee Baldock stated that a muskrat trapper on the Conaway Ranch complained because he caught Norway rats instead of muskrats during the previous winter.

On July 25, the activities of two turkey vultures (*Cathartes aurea*) were investigated when the birds were seen in a field of mowed and

TABLE 7

Fate of Eggs in Hatched Nests

Species	Hatched		Dead embryos		Destroyed		Infertile		Missing		Dead in nest		Totals	
	Number	Percent-age	Number	Percent-age	Number	Percent-age	Number	Percent-age	Number	Percent-age	Number	Percent-age	Number	Percent-age
Mallard	616	83.4	37	5.0	4	0.5	27	3.7	52	7.0	3	0.4	739	100.0
Gadwall	20	95.2	0	0.0	0	0.0	1	4.8	0	0.0	0	0.0	21	100.0
Cinnamon teal	47	73.4	3	4.7	2	3.1	6	9.4	6	9.4	0	0.0	64	100.0
Totals	683	82.9	40	4.9	6	0.7	34	4.1	58	7.0	3	0.4	824	100.0

baled barley straw in Sutter County. They were found to have been feeding upon the eggs left in a deserted pheasant (*Phasianus colchicus torquatus*) nest. It is not known if the efforts of these birds were confined only to eggs which had already been broken by farming equipment. For lack of evidence to the contrary, it is considered unlikely that vultures present a factor in destruction of active pheasant or duck nests.

FATE OF EGGS IN HATCHED NESTS

Table 7 shows the fate of individual eggs in successfully hatched duck nests. Thirty-four nests which were not discovered until after they were hatched are not included in this table, because rodents or insects were found to have devoured some of the membranes, so that it was impossible to determine the original clutch size. Dead ducklings found in a nest were not considered successfully hatched and, therefore, are included in a separate column.

A total of 824 eggs was accounted for in 94 nests, for an average clutch size of 8.8 eggs. Six hundred and eighty-three eggs hatched successfully, for an average of 7.3 per nest.

COVER TYPE AND DISTANCE TO WATER

Though availability, no doubt, is an important factor in the choice of nesting cover, it appears safe to assert that ducks breeding in the Sacramento Valley showed a preference for reedy or coarse grass-like growths. Table 8 shows that one-third of all duck nests were located in barley cover. Perhaps the flourishing stand of volunteer barley on the check dams of the Christenson-MacHenry rice fields played an important role in attracting many nesting pairs of ducks to this area. Wire rush and sedge were also heavily utilized, while a tangled growth of vetch on the checks of another rice field was devoid of nests, and stands of tall mustard were only slightly more popular. The average height of nesting cover was about two and one-half feet.

The distance to water, as given in Table 9, shows the distance to the nearest water at the time the nest was found. There was no indication that distance from water was an important factor in influencing the

TABLE 8

Fate of Nests by Cover Type

Cover	Destroyed		Deserted		Hatched		Total nests in each type	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Wire Rush	19	57.6	2	6.1	12	36.3	33	9.9
Sedge	31	55.3	1	7.2	21	37.5	56	16.8
Grasses	46	74.2	6	9.7	10	16.1	62	18.6
Barley	36	32.4	15	13.5	60	54.1	111	33.3
Cattail	2	28.6	1	11.3	4	57.1	7	2.1
Thistle	10	55.6	1	5.6	7	38.8	18	5.4
Others	30	65.2	2	4.3	14	30.5	46	13.9
Totals	171	52.3	31	9.3	128	38.4	333	100.0

chance for a successful hatch. It is of interest to note that about 25 percent of all located nests were more than 100 yards from any water; those out in the middle of barley fields were sometimes one-quarter mile away. The number of newly hatched ducklings that managed to make the formidable journey across the dry, cracked ground to the dubious safety of the nearest ditch is a matter for conjecture. No evidence to support Mayhew's (1955) theory that lack of humidity is a relevant factor in reducing the hatchability of duck eggs under natural conditions was found in this investigation.

TABLE 9

Fate of Nests in Relation to Distance From Water

Distance	Destroyed		Deserted		Hatched		Total nests in each class	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Up to 3 yards	74	55.6	13	9.8	46	34.5	133	40.0
4 to 50 yards	32	46.4	7	10.1	30	43.5	69	20.7
51 to 100 yards	26	54.2	2	4.2	20	41.7	48	14.4
Over 100 yards	42	50.6	9	10.8	32	38.6	83	24.9
Totals	174	52.3	31	9.3	128	38.4	333	100.0

DUCK BROODS

Lack of open water areas, coupled with the dense vegetative growth in the rice fields, made brood observations rather difficult. However, with the cooperation of the personnel at Gray Lodge Waterfowl Management Area, a total of 101 duck broods was counted. Eighty-five of these were mallard broods. Gadwall and cinnamon teal broods were not found in sufficient quantities to draw any conclusions from the observations.

TABLE 10

Duck Brood Counts

Species	Age of brood	Number of brood	Average number of young
Mallard	1 week	23	6.1
	2 weeks	24	5.1
	3 weeks	16	3.8
	4 weeks	8	3.5
	5 weeks	7	3.7
	6 weeks	4	4.5
Gadwall	1 week	3	10.3
Cinnamon teal	1 week	11	5.5
	2 weeks	1	3.0
	3 weeks	1	2.0

Table 10 shows that one-week old mallard broods averaged 6.1 young, and that the number of young seems to have regressed to 3.5 by the time the broods had reached the age of four weeks. After that age there appears to be a tendency for the broods to group together. It is also quite likely that some broods of only one or two ducklings were not reported, with consequent possible distortion of the figures.

COOTS

The unpopularity of the coot in California results because it is not considered particularly palatable by the general public, competes with more valuable waterfowl species in its feeding habits, and does considerable damage to crops and pastures. In other words, as long as the coot is regarded as a nuisance, rather than a resource, its management will be approached with a widely different attitude from that toward the management of ducks and geese.

In most parts of its breeding range, the coot anchors its nest to cattail (*Typha*) or bulrush (*Scirpus*) stems directly over water. Here it is far safer from nest predators than are ground nesting ducks. Therefore, it enjoys a higher nesting success than do ducks (Miller and Collins, 1954; Hunt and Naylor, 1955).

In the Sacramento Valley the situation was found to differ somewhat, in that the bulk of the coot population nested on rice checks, where they were quite as vulnerable to predator interference as were the ducks.

A total of 105 coot nests was located, all on two study plots and confined to rice fields. Table 11 compares the fate of coot nests on these two plots, the Conaway Ranch and the Christenson-MacHenry Ranch. Of the sample obtained, 41 percent hatched, 54.3 percent were destroyed, and 4.8 percent were deserted. On the Conaway Ranch all coot nest predation was attributed to mammals, while on the Christenson-MacHenry Ranch six nests had evidently been broken up by crows or yellow-billed magpies (*Pica nuttalli*).

Though coot nests hatched from late May to early July, 23 out of 36 nests hatched between the dates of June 12 and June 22. In the 27 active nests, where the eggs could be counted, a total of 247 eggs

TABLE 11

Fate of Coot Nests

Plot	Destroyed		Deserted		Hatched		Total	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Conaway Ranch	45	91.8	1	2.0	3	6.1	49	100.0
Christenson Ranch	12	21.4	4	7.1	40	71.4	56	100.0
Totals	57	54.3	5	4.8	43	41.0	105	100.0

was laid, for an average of 9.1 eggs per nest. The average number of eggs hatched was 7.9 (Table 12).

Sixteen groups of young coots of various ages were counted. These averaged four young per group. However, since both parents assist in caring for the young, the groups may not have represented complete broods.

TABLE 12

Fate of Eggs in Coot Nests

	Number of eggs	Percentage
Hatched	213	86.2
Dead embryos	19	7.7
Destroyed	5	2.0
Infertile	9	3.7
Dead in nest	1	0.4
Totals	247	100.0

RESULTS COMPARED WITH PREVIOUS STUDIES

In comparing the duck production figures of the Miller and Blaisdell studies in 1949 and 1950 with those of 1955, Table 13 brings out the interesting fact that there was a greater contrast between the results of the two successive seasons of 1949 and 1950 than between those of 1950 and 1955. A possible explanation lies in the following circumstances. The 1949-50 studies were confined to three study plots in the northeastern part of the Sacramento Valley, including Gray Lodge Refuge and the nearby "Berry Patch" or Tobin Gun Club. Intensive predator control had been carried on at Gray Lodge Refuge during the three winters preceding the 1949 breeding season. It is even possible that this may have affected the results on the "Berry Patch". During the winter of 1949-50, predator control efforts were relaxed on Gray Lodge Refuge, but have since been put back into practice (Table 14).

Earl (1950) located 60 duck nests on the Conaway Ranch during 1948, of which 52 percent hatched, 25 percent were destroyed by predators, 8 percent were destroyed by livestock, 12 percent were deserted,

TABLE 13

Fate of Nests in the Present Study (1955) Compared With the Miller-Blaisdell Studies (1949-1950)

Year	Percentage destroyed	Percentage deserted	Percentage hatched
1949	17.0	13.0	70.0
1950	48.3	5.7	46.0
1955	52.3	9.3	38.4

TABLE 14

Fate of Nests on Gray Lodge Waterfowl Management Area in the Present Study and in the Miller-Blaisdell Studies

Year	Percentage destroyed	Percentage deserted	Percentage hatched
1949	14.0	17.0	69.0
1950	61.0	1.0	35.0
1955	27.0	12.7	60.3

and 3 percent were flooded. During the next five years Mayhew (1955) failed to experience a recurrence of a comparable hatching success on the Conaway Ranch, and it may be assumed that the nesting success of 1948 was exceptionally favorable, rather than typical, for the Sacramento Valley.

Most writers agree that predation is the major cause of loss in waterfowl production in the Central Valley. There is little doubt that heavy rainfall and floods immediately prior to the nesting season would, at least temporarily, tend to reduce the predator population in the lowlands. Such weather conditions prevailed in 1948.

The Appendix shows precipitation and temperatures for January through August, 1955, at three localities in the Sacramento Valley. Although over two inches of rain fell in April, precipitation was light during March and May.

DISCUSSION

The Sacramento Valley nesting study during the breeding season of 1955 showed a duck nesting success of 38.4 percent. According to brood observations, it is not likely that more than three young from each successful nest survived to early autumn. If these figures are applied to the estimated breeding population of 23,200 pairs, it would indicate a production of approximately 26,700 young ducks and a total fall population of 73,100 local ducks.

Assuming that all unsuccessful hens made a second attempt at nesting and that 38.4 percent of these succeeded in rearing three young, there would be an additional production of about 16,400 young ducks, which would bring the total fall population up to 89,500. No allowance has been made for mortality among the adult population.

The study showed a nesting failure of 52.3 percent, but only 6.9 percent of this loss was attributable to unavoidable human activities. On the other hand, almost all this destruction was caused by small mammalian predators, including the Norway rat. These same predators and other species, including the feral house cat, may be blamed to a notable degree for the sharp decline in brood size from 7.2 at hatching time to 3.5 at the age of four weeks.

The enormous production potential wasted through predation is easily recognized, but a practical method of control has not been attained. Since it is no longer profitable to trap small fur bearers for their pelts, virtually the only trapping done, except for muskrats, is on State and Federal management areas, and even it is considered too expensive to be practiced on a large scale.

The use of poisons is generally opposed because of the possible danger to innocent species and even to human life. Nevertheless, poisoning will probably have to be used if the Norway rat is to be controlled. Since this animal is proving costly to the farmers and, indeed, a serious threat to human health, the biologist and game manager are not alone in their concern over this pest. It is not unreasonable to suppose that poison could be used safely in many places for the control of other species. However, such a program would have to be planned with intelligence and with every known precaution taken in selecting the kind of poison as well as the kind of bait and method of application. Poison stations would have to be plainly posted and a fixed minimum distance from human habitation. A time limit for the removal of the poison could be required.

It is suggested that an experiment of this kind be tried in a limited area, where it could be closely watched and the results measured. If it proved to be practical from the standpoint of safety, economy, and effectiveness, the program could be expanded to cover other areas.

SUMMARY

1. A waterfowl nesting study was undertaken in the Sacramento Valley, California, during the breeding season of 1955, by Pittman-Robertson Project W-30-R of the California Department of Fish and Game.

2. Nine study plots, ranging in size from 10 acres to 1,000 acres, with a combined area of 3,560 acres, were selected in different sections of the valley, in order to obtain representative results.

3. A total of 333 duck nests was located and studied. About 93 percent of these were nests of mallards and the remainder were nests of cinnamon teal and gadwall. Of these nests, 38.4 percent hatched, 9.3 percent were deserted, and 52.3 percent were destroyed.

4. The peak of hatch occurred between May 20 and July 10. The last two nests, one mallard and one cinnamon teal, hatched after August 1. The average number of eggs hatched was 7.2 per successful nest.

5. Predation by mammals, chiefly striped and spotted skunks, Norway rats, and racoons was the principal cause of nesting failure. Some nests were destroyed by harvesting operations and other human activities.

6. A total of 85 mallard broods was counted. These averaged 6.1 young in the one-week-old broods and appeared to diminish to an average of 3.5 young by the time the broods were four weeks old.

7. One hundred and fifty coot nests were found and studied. These were all located on the check dams of rice fields, where 41 percent hatched, 4.8 percent were deserted, and 54.3 percent were destroyed by predators. The average number of eggs hatched was 7.9 per successful nest.

8. It seems that the key to increased production of ducks in the Sacramento Valley is more intensive predator control. Since trapping of predators has become too costly to receive widespread application, it is suggested that more effective means of control be given serious consideration. It is further suggested that judicious use of poison be

attempted on a small scale, until sufficient experience may warrant a gradual expansion of such a program.

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APPENDIX

Precipitation and Temperatures, Sacramento Valley, January Through August, 1955

Month	Total precipitation in inches	Av. high temp. in degrees F.	Av. low temp. in degrees F.	Av. temp. in degrees F.
Willows				
January	1.80	50.8	32.2	41.5
February	0.23	59.4	34.8	47.1
March	0.67	67.0	40.1	53.6
April	2.32	66.3	41.0	53.7
May	0.03	81.7	53.2	67.5
June	0.04	87.7	57.7	72.7
July	0.00	92.2	59.2	75.7
August	0.00	96.3	58.5	77.4
Gridley				
January	2.85	50.0	33.8	41.9
February	1.05	60.3	34.8	47.6
March	0.31	69.5	39.0	54.3
April	2.53	66.3	41.8	54.1
May	0.01	81.7	51.8	66.8
June	0.03	88.1	55.5	71.8
July	0.00	93.0	58.3	75.7
August	0.00	96.9	56.0	76.5
Woodland				
January	2.75	50.9	35.1	43.0
February	1.74	61.4	37.5	49.5
March	0.40	68.9	41.4	55.2
April	2.12	68.0	42.6	55.3
May	0.43	82.2	52.2	67.2
June	Trace	88.4	54.0	71.2
July	0.00	92.5	55.2	73.9
August	0.00	96.9	54.3	75.6

THE BREEDING SEASON OF SOME CALIFORNIA DEER HERDS[1]

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INTRODUCTION

The deer of California include six subspecies of the species *Odocoileus hemionus* (Cowan, 1936). These deer are divided into two broad groups: the Columbian black-tailed deer (*O. h. columbianus*) and five subspecies of mule deer. The home ranges of these deer are characterized by a diversity of soil and vegetative types as well as of climates. The deer themselves exhibit corresponding differences in habits, breeding seasons, and migrations.

During the past several years, considerable attention has been devoted to the deer of California because of the need for better management. Extensive studies have been made of range condition in relation to deer and livestock and of habitat improvement, herd numbers, and herd composition. Physical and biological data on the deer themselves, however, are limited. This has been true with respect to information on breeding seasons.

Only a few reports on breeding periods of California deer based on embryo ages have been published. Chattin (1948) reported that in the Interstate herd 88 percent of the does were bred during the period November 15 to December 6 and 12 percent from December 18 to January 3. Lassen et al. (1952), in studies on the Lassen-Washoe herd, found the breeding season to start the third week of November and to continue until the last week of December. Leopold et al. (1951) estimated the breeding period for the Jawbone herd to extend from the second week of November to the fourth week of January. These reports were all on mule deer. Taber (1953), working with black-tailed deer on Cow Mountain, Lake and Mendocino counties, stated that the peak of conception in 1949 occurred about the last week in October and during the first two weeks of November.

Knowledge of the breeding seasons of deer is a valuable tool of management, particularly in the establishment of hunting seasons. In order to obtain data from as many herds as possible, the Fish and Game Commission authorized a number of special collections to obtain breeding dates and other data. Figure 1 shows the general localities where these collections were made.

[1] Submitted for publication September, 1956. This report has been made possible through Federal Aid in Restoration Project W-52-R, "Wildlife Investigations Laboratory".

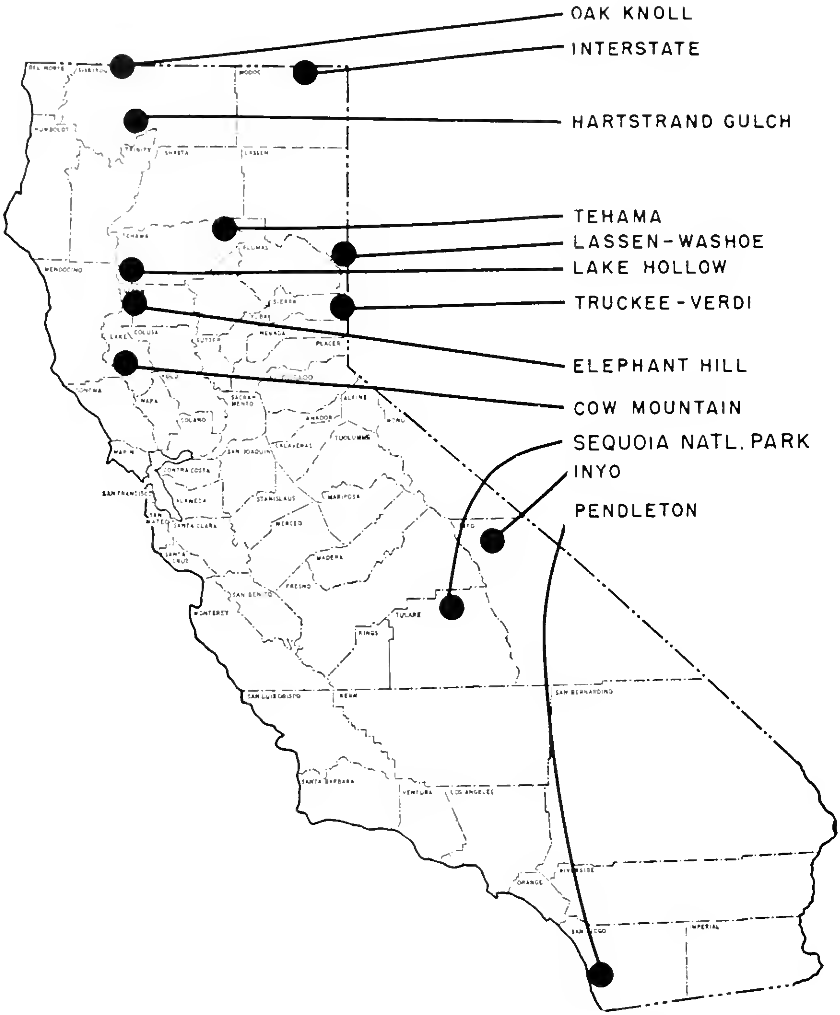

FIGURE 1. Map of California, showing general locations of the deer herds studied for breeding data. *Drawing by Cliffa Corson.*

ACKNOWLEDGMENTS

Special note is made of the cooperation of the Nevada Fish and Game Commission in allowing collections from the Lassen-Washoe herd in Nevada. The personnel of the U. S. Marine Corps, Camp Pendleton, worked closely with the Department in gathering data during the special hunts held there. Mr. E. L. Sumner, Park biologist of Sequoia National Park, was instrumental in gathering data in the Park. Numerous personnel of the Department not directly connected with the Laboratory aided in collecting data.

MATERIALS AND METHODS

In this study the breeding season was established by aging embryos according to the method described by Armstrong (1950) and determining the conception date by back calculation. Since it is not possible to age embryos to the precise day, the earliest age in each range was used. It is possible to determine breeding dates at about 30 days of pregnancy, at which time the embryo becomes grossly visible.

Breeding data were obtained for 427 does, of which 388 were adults and 39 were yearlings. The data were gathered from 12 herds representing five subspecies of deer.

Ninety-four Columbian black-tailed deer were taken from the Tehama, Lake Hollow, Elephant Hill, Oak Knoll, and Cow Mountain herds in northern California.

In addition, data were obtained by Pittman-Robertson Project W-41-R on 31 does, yearling and older, from the Hartstrand Gulch herd. The reported breeding period for the latter herd occurs during December, with a peak from December 22 through 28. (These data are not shown in Figure 2.)

One hundred seventy Rocky Mountain mule deer (*O. h. hemionus*) were examined from the Interstate, Lassen-Washoe, and Truckee-Verdi herds. Sixty-seven deer represented the Inyo mule deer (*O. h. inyoensis*) from the Buttermilk range in Owens Valley. Sixty-seven southern mule deer (*O. h. fulginatus*) were examined during special hunts on Camp Pendleton. Twenty-nine California mule deer (*O. h. californicus*) made up the sample from Sequoia National Park.

Since the samples from individual herds were somewhat limited, no attempt was made to correlate differences in breeding periods with range conditions or population dynamics, although these may be factors. Year-to-year comparisons for individual herds were not possible, so it is not known whether any significant variation occurs from year to year.

Breeding periods for the various herds are shown in Figure 2. It is seen that California deer, as represented by these 12 herds, have breeding periods extending from the third week in Septemeber to the last week in January, a period of four and one-half months.

The black-tailed herds have breeding periods which extend from late October to early January, but the breeding periods of the various herds do not coincide. There is an apparent difference with geographical location. The Cow Mountain and Elephant Hill herds, located to the south of those at Lake Hollow, Tehama, Oak Knoll, and Hartstrand Gulch, have the earliest periods. The latter herds have peak periods approximately one month later.

The mule deer herds also exhibit this type of difference, but in reverse order. The more northern herds tend to have the earlier breeding seasons. The southern mule deer herd is a complete exception, having the earliest as well as the longest breeding season found during this study.

Another method used to determine breeding seasons employes the use of the estimated ages of fawns observed during the fawn drop. Robinette and Gashwiler (1950) used an average gestation period of 202 days, determined from reports in the literature. This method was not

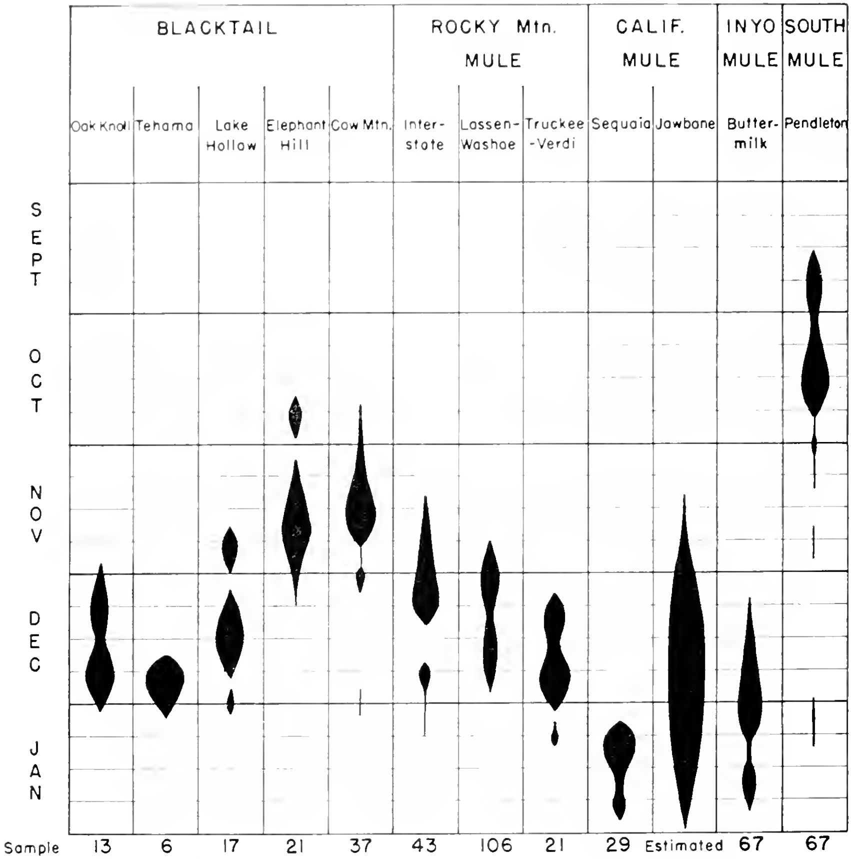

FIGURE 2. Breeding dates of 12 California deer herds. *Drawing by Cliffa Corson.*

used during the present study. However, the following list of observations on fawning periods and notes on the breeding activities of bucks is included. These data are presented in order to give some coverage to the parts of the State not covered in the present study. They are based on observations contained in the files of the California Department of Fish and Game and other sources.

It is a common belief that neck swelling in bucks indicates that the breeding season is under way. Actually, neck swelling precedes breeding activity and indicates the approach of the breeding season. The swollen neck is evident throughout the breeding period.

Hastings Reservation, Monterey County. The main fawning period is from mid-April to the end of June. No pregnant does were seen after June 1. Occasional fawns were dropped after June, one as late as August 8.

Cow Mountain, Lake and Mendocino Counties. The breeding period is generally from November 1 to 15. The peak of the fawn drop occurs in May. The Hopland area is about two weeks earlier.

Huntington Lake, Fresno County. The peak of the fawn drop occurs during the period July 15-30.

Tahquitz Valley, Riverside County. Fawn drop begins early in June, but the peak of the drop occurs in late June and early July. Most bucks have swollen necks by the end of September.

Tepusquet-Labrea, Santa Barbara County. The peak of the fawn drop occurs from May 1 to 7.

Barton's Flat, Fresno County. The peak of the fawn drop occurs during the first week of July.

Capay Valley, Yolo County. Bucks were rutting in September. Assuming that this referred to the appearance of swollen necks, the fawns would be dropped in April.

Marin County. According to Cook et al. (1949) the peak of the breeding season occurs during the month of September, as evidenced by swollen or bloodshot testes and swollen necks. The text states, "Some of the black-tailed bucks apparently were breeding in August, all were breeding in October. By the first of December all activity was over."

Upper Cuyama and Sespe Rivers, Ventura County. Headwaters of Santa Ynez River and Santa Barbara County. Quoting Cook et al., "The height of the breeding activity in the mule deer judged by the condition of the testes and necks also occurred in October."

Yosemite Valley. Quoting J. A. Dixon (1934), "Observations have shown that practically all of the deer in the Yosemite region breed between December 10 and January 27. The peak of the fawn drop was reported for the month of July." "I have never seen other than an occasional spotted fawn before the first of July . . ." ". . . 90 percent of the pregnant does had dropped their fawns by July 30."

Canby Area, Modoc County. McLean (1940) reported that the necks of most bucks were losing their swelling by December 27 and that by January 11 the necks of all bucks were again of normal size

Jawbone, Stanislaus County. Leopold et al. (1951) reported the following observations: "A few fawns were born as early as June 5th." "In the first half of July, 72 percent of the does still carried fawns, but by the end of the month this figure had dropped abruptly to 31 percent." ". . . a second period of fawning in mid-August."

Interstate, Modoc County. Chattin (1948) reported that August 28 was the last date on which a pregnant doe was observed.

DISCUSSION

It is evident that there is considerable variation in the breeding seasons of the various California herds. The estrual period as determined by Cheatum and Morton (1946) is 28 days; if there is breeding failure, as many as three consecutive heat periods may occur. If the rut is disturbed by hunting or some other cause, then a later period of breeding, with subsequent later fawning, may occur.

Recent hunting seasons in California have been divided into two periods: an early coastal season from August to mid-September and a later inland season from approximately mid-September to near the end of October. These seasons, in general, precede the breeding seasons in these two areas, although by the end of each season some breeding may be taking place in some areas.

SUMMARY

A total of 427 does was collected and their embryos aged to determine breeding dates. These represented animals from 12 herds, of which six were black-tailed deer herds and six were mule deer herds. Breeding periods varied from herd to herd and with their geographic locations. Among the black-tailed deer herds studied, breeding occurred from late October to early January. The more southerly herds had the earliest breeding dates. Mule deer herds had breeding periods extending from the third week of September to the last week in January, with the more northerly herds having the earliest breeding dates. An exception to this was the Camp Pendleton deer herd, in which breeding started earlier and extended over a longer period than in any other group.

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NOTES

RECENT OCCURRENCES OF THE RED BROTULA, *BROSMOPHYCIS MARGINATA* (AYRES), IN CALIFORNIA WATERS

The red brotula has been taken only rarely since it was first recorded and described from the San Francisco area 100 years ago. Since 1949, however, 10 specimens have been obtained from the waters of both northern and southern California and an estimated 50 additional specimens, killed as a result of an explosive blast in connection with seismic exploration for oil, were not recovered. While the range of this fish, generally given as southern California to southeastern Alaska, has not been extended by these recent collections, I believe that the catch locations and morphometric data will add much to the knowledge of this colorful little fish.

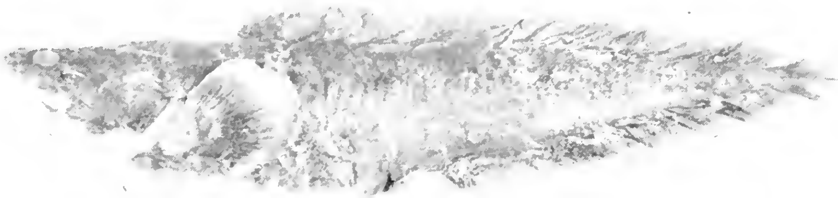

FIGURE 1. Red brotula, *Brosmophycis marginata*, from 140 feet of water off Santa Barbara, May 17, 1949. *Photograph by Al Johns for Vernon M. Haden, San Pedro.*

1. March 24, 1949. Two specimens found floating after a seismic blast in Santa Monica Bay. Depth of water unknown.
2. May 17, 1949. Two specimens found floating after a seismic blast in 140 feet of water, 4 miles SE. of Santa Barbara. Lat. 34° 21′ N., Long. 119° 35′ W. Collector, J. Radovich.
3. June 3, 1949. Two specimens found floating after a seismic blast in 126 feet of water off Santa Rosa Island. Lat. 34° 10′ N., Long. 120° 12′ W. Collector, J. Radovich.
4. June 29, 1949. One specimen found floating after a seismic blast in 129 feet of water off Santa Barbara. Lat. 34° 20′ N., Long. 119° 34′ W.
5. March 13, 1950. One specimen taken on hook and line in 240 feet of water by the vessel COQUETTE, five miles off Tyler Bight, San Miguel Island.
6. December 15, 1953. One specimen taken on hook and line in 300 feet of water from the vessel PIERPOINT fishing off Ship Rock, Santa Catalina Island.
7. February 9, 1956. One specimen found in crab-pot set in 120 feet of water by the vessel JEANNIE MARIE, off the Klamath River.

Measurements and counts were taken only on the three most recently captured fish (Table 1). Although similar data are lacking for the first seven specimens, which were placed in various permanent scientific collections, the brotulas taken May 17 and June 29, 1949, off Santa Barbara were X-rayed for vertebral counts. The abdominal, caudal, and total vertebrae for these specimens were: 17 + 47 = 64, 17 + 48 = 65, and 16 + 47 = 63.

The stomach of the specimen taken off San Miguel Island contained a set of otoliths from a small rockfish (*Sebastodes*), several fish vertebrae, some unidentified crustacean remains, and some unidentifiable shell fragments from a marine gastropod.

I wish to acknowledge the help of John E. Fitch, who suggested this paper and kindly provided the data for the fish collected in southern California.

TABLE 1

Comparison of Three Specimens of Brosmophycis marginata Taken Off California

Measurements and counts	San Miguel Island	Santa Catalina Island	Klamath River
Measurements:*			
Standard length	379	365	376
Total length	1,077	1,079	1,066
Head length	232	251	234
Maxillary length	113	123	117
Snout length	047	051	056
Bony interorbital width	034	032	047
Fleshy orbit	025	025	027
Pectoral length	156	179	162
Pectoral base	058	063	066
Snout to dorsal insertion	303	329	309
Snout to anal insertion	557	574	561
Snout to pelvic insertion	--	197	213
Snout to pectoral insertion	--	249	239
Counts:			
Dorsal rays	--	98	102
Anal rays	--	74	73
Vertebrae	16+18=64	16+47=63	
Functional gill rakers 1st arch	0+1+2	0+1+2	0+1+2
Total gill rakers 1st arch	5+1+15	--	4+1+14
Gill teeth 1st arch	5+21	4+21	5+20
Sex:	Female	Female	--

* Standard length in millimeters; all other measurements expressed in thousandths of standard length.

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—*E. A. Best. Marine Fisheries Branch, California Department of Fish and Game, June, 1956.*

AN EXTENSION OF THE RANGE OF THE LONG-FINNED SMELT

On December 1, 1955, 23 long-finned smelt, *Spirinchus dilatus* (Schultz and Chapman), were taken from a fyke net being fished in the Loleta Bottoms, 4.5 miles upstream from the mouth of the Eel River, Humboldt County, California (Figure 1). This locality is situated within the uppermost limit of tidewater in the Eel River. The fish, probably on a spawning migration, were sexually mature, eggs being extruded from the females at the slightest pressure, and milt flowing freely from the males.

The smelt had become entangled in the wire of a cylindrical fyke net being used by the U. S. Fish and Wildlife Service to tag anadromous salmonids in the Eel River. The fyke net was located approximately 14 feet from the water's edge at a depth of 10 feet when the smelt were trapped.

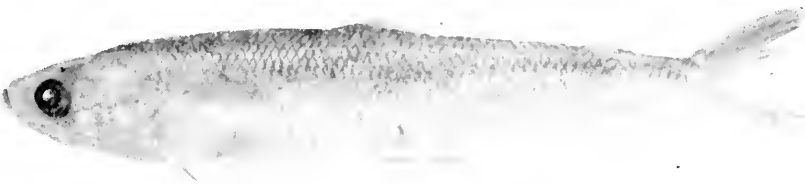

FIGURE 1. Long-finned smelt, *Spirinchus dilatus*, 105 mm. in standard length, taken in the Eel River, California, December 1, 1955. *Photograph by Jack W. Schott.*

Several specimens were examined and identified by Dr. Arthur Welander of the University of Washington. Specimens are now deposited in the U. S. National Museum and at Humboldt State College, Arcata, California.

The previous known southern limit of the range of the long-finned smelt was Tillamook Head, Oregon. Their presence in the Eel River is a southerly range extension of over 400 miles and adds a new species to the fish fauna of California. —*Paul T. Jensen, U. S. Fish and Wildlife Service, Eureka, California, July, 1956.*

THE STATUS OF THE REDEYE BASS IN CALIFORNIA

Forty redeye bass (*Micropterus coosae*) were brought into California for brood stock by the writer from Sheeds Creek, tributary to the Conasauga River in southeastern Tennessee, on November 11, 1953 (Kimsey, 1954). These fish were taken to the California Department of Fish and Game Central Valleys Hatchery, Elk Grove. This note is intended to clarify the present status of the species in California.

The fish were held in a pond of about one surface acre, with a depth of from six inches to five feet, until February 23, 1954, when they were moved to a one-third-acre spawning pond. At this time it was found that 15 individuals from 7.4 to 10.0 inches in fork length had survived. The rigors of procurement and travel are believed to have been largely responsible for the mortality (62.5 percent).

The brood pond sloped gradually in depth from six inches at one end to six feet at the settling basin. Gravel with an average diameter of about two inches was provided in the shallow one-third of the pond. No cover other than aquatic plant growth was present.

The first nests were noted in March and the first fry (about ¼-inch in fork length) in May, 1954. The water temperatures during this period varied from 50 to 62 degrees F.

Forage minnows consisting of golden shiners (*Notemigonus crysoleucas*) and fathead minnows (*Pimephales promelas*) were introduced, but nothing else was done until October 8, 1954, when the brood pond was drained. At that time it was found that the pond had been infested by five additional species of fishes. Nine adult and 10 redeye bass of the year were recovered. The adults ranged from 8.2 to 10.0 inches in fork length and the fish of the year ranged from 2.5 to 3.7 inches. The severe competition offered by the alien species, which included 160 largemouth bass 3.0 to 12.5 inches in fork length, is believed to have been responsible for the poor showing.

The redeye bass and forage minnows were replaced in the pond. The following spring no nest building activity was observed. The pond was drained May 18, 1955, and only three adult redeye bass were found. The pond was again infested with unwanted species. The remaining redeye bass were held at the hatchery until August, 1955, when it was found that none had survived.

No redeye bass were planted in the open waters of the State and none are now present in California.

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—*J. B. Kimsey, Inland Fisheries Branch, California Department of Fish and Game, September, 1956.*

AN OUTRIGGER TYPE DEER FENCE

In the course of game range restoration studies, an outrigger type deer fence was developed for protection of study plots. Ordinary barbed wire fences had proven inadequate. Woven wire fences 8 to 9 feet high usually have been found necessary to keep out big game animals.

The outrigger fence (designed by A. L. Hormay, Figure 1) was built on the theory that a deer must be rather close to the base of a fence in order to jump over it. The outrigger, an extension sloping from the top of the 4½-foot upright structure to a point on the ground 8 feet from the base of the fence, prevents the deer from approaching close enough to jump. This type of construction has been used to exclude deer from study plots on three Sierra deer winter ranges during the past three winters. To date, no deer have crossed any of these fences.

The fence of steel construction, as shown in Figure 1, costs between $1 and $2 per linear foot to construct. This is too expensive for wide-scale use. Costs can be reduced substantially by using wooden posts. Also, it may not be necessary to bury the wire mesh in the ground.

The practical use of such a fence is limited by the cost of construction. The fence does offer possibilities for fencing off deer from hay stacks and other places where extensive fencing is not needed. Also, the

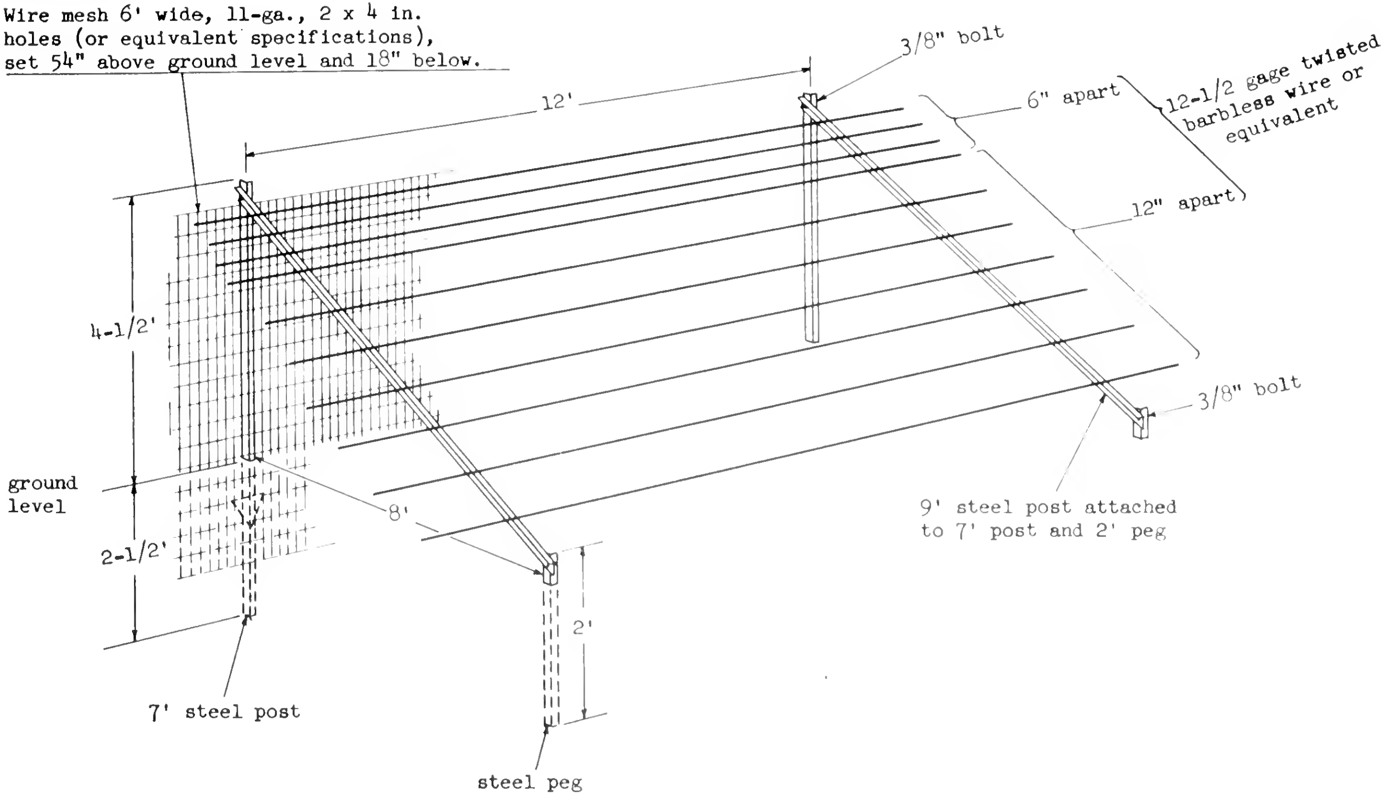

FIGURE 1. Drawing of outrigger type deer fence, showing construction details. *Design by A. L. Hormay.*

outrigger can be added to existing range fences to increase their effectiveness in controlling game animals. *James A. Blaisdell, Game Management Branch, California Department of Fish and Game, and Richard L. Hubbard, California Forest and Range Experiment Station, U. S. Forest Service, Berkeley, California, June, 1956. This work was done in the course of the cooperative investigations of the California Forest and Range Experiment Station and the California Department of Fish and Game, Pittman-Robertson Project W-51-R, "Big Game Studies".*

REVIEWS

The Euphausiacea (Crustacea) of the North Pacific

By Brian P. Boden, Martin W. Johnson, and Edward Brinton; Berkeley, University of California Press, 1955; vol. 6 no. 8, p. 287-400 of the Bulletin of the Scripps Institution of Oceanography. $1.50.

This publication represents the most comprehensive description to date of the euphausiids from the west coast of California. Previously, various papers on west coast euphausiids have described only a few species each, or have confined their descriptions to euphausiids in one small area. This paper describes 55 species belonging to 10 genera found within 500 miles of the coast from the Columbia River southward to below the tip of Lower California.

There is no question that this publication will be a great aid to the identification of these small, shrimplike crustaceans, so common in the diet of fish and other aquatic animals. It fills a long standing need of workers conducting food studies on fish, since it will enable them to make rapid identifications without going through numerous references or spending a great amount of time seeking the advice of euphausiid specialists.—*John Radovich, California Department of Fish and Game.*

The Book of Reptiles and Amphibians

By Michael H. Bevans; Garden City Books, Garden City, N. Y., 1956; 63 p., illus. $2.50.

The author's lifelike illustrations have made what should be a desirable addition to the bookshelf of the scientific youngster. Although the writer has designed the book for young people, the biologist and advanced student should also find at least the illustrations of interest.

A brief introduction describes a few of the characteristics of reptiles and amphibians, and debunks some of the myths about them. The remainder of the book is devoted to descriptions and illustrations of the various species.

Its brevity and emphasis on eastern forms would be the major criticisms of this book.—*John Mahoney, California Department of Fish and Game.*

Aquatic Insects of California, With Keys to North American Genera and California Species

Edited by Robert L. Usinger; University of California Press, Berkeley, 1956; ix + 508 p., 502 text figures. $10.

Dr. Usinger has performed a very worthwhile service to student and professional worker alike by presenting between the covers of this excellent volume information which was previously available only from a wide variety of sources. The book is an outgrowth of a University of California laboratory syllabus, familiar to many students of aquatic entomology, and deals principally with the taxonomy and biology of the various orders of aquatic insects. Each chapter has been written by a recognized authority on the subject covered. Since taxonomy is emphasized, it is very important that the keys were generally found to be easily followed and the drawings and photographs well reproduced. A glossary of technical terms is presented as an aid in this regard. The keys include all known genera from North America, but treatment at the species level is restricted to California and adjacent regions. For the sake of convenience, very complete lists of references to the literature are included at the end of each chapter.

The lengthy introduction begins with the presentation of basic ecological concepts and branches into a discussion of aquatic habitats in California. This section introduces original systems of stream and lake classification, which appear, at least on a local level, to be superior to methods commonly in use. The new system classifies California's streams according to biotic provinces and source and permanence of water. The lakes of the State are classified according to origin. Applied aquatic entomology as related to mosquito and gnat control, man-made impoundments, irrigation, water pollution, pond and game fish culture, and stream and lake management is discussed in some detail, and equipment and techniques commonly used by limnologists and aquatic entomologists are presented.

While this book will be of value principally to students of aquatic biology, anyone with an interest in ecology should find it well worth the price, which is moderate for such a treasure chest of information.

The book is fittingly dedicated to the Department's late Harry P. Chandler, who contributed generously to the text. *E. P. Pister, California Department of Fish and Game.*

Classification of Fishes, Both Recent and Fossil

By Leo S. Berg; J. W. Edwards, Ann Arbor, Michigan, 1947; 430 p., 190 figures, $6.50.

It would probably be well to state at the beginning that this is not a new publication. Those familiar with the fields of ichthyology, comparative anatomy, and paleontology will recognize it immediately as an extract from Volume V, Pt. 2, "Travaux de l'Institut Zoologique de l'Academie des Sciences de l'URSS" (1940). As a result of world conditions at the time of publication, only a precious few copies of this valuable work were received in this country. But for the efforts of Carl Hubbs and Karl Lagler, it could well have been relegated to the status of a rare collector's item. Permission was granted by Dr. Berg in 1941 to republish the work in America. This excellent quality lithoprinted volume is the result.

The addition of an English title page and a foreword by Dr. Lagler are the only deviations from the original. Otherwise, it compares exactly, even to inclusion of the full Russian text, which offers an opportunity to examine both English and Russian versions. Indeed, it also serves as a fine tribute to this great scientist and author.

Though 16 years have elapsed since first publication of this momentous work, it remains the most modern and complete single reference to the classification of fishes. As the title indicates, all of the known fossil records have been included. Countless monographs have been published during this 16-year interval and, as might well be expected, up-to-date knowledge has brought about changes which do not concur with all of Berg's system. In spite of these differences of opinion, this publication stands alone among the classics in the field.

The text deals only with the systematics of the higher taxonomic categories through the level of the family. Brief but good anatomical descriptions, as well as general geographic and geologic ranges, are given for each group. Generic examples are used sparingly in the discussion of each family.

Dr. Berg makes an unsuccessful attempt to standardize the naming of the orders of fishes. He proposes the use of the ending "formes" added to the generic root of the typical family name. This is the method used in forming the ordinal names of birds. To the ichthyologist it would mean the loss of all the names in common usage. Though this system is used throughout, it is fortunate that the familiar synonomic names have been included.

One of the excellent anatomical illustrations did not reproduce well. This, according to a publisher's note, was due to the poor quality of the original. These figures appear only in the Russian section, but the legends are in both languages and are referred to by number and page in the English section.

Also worthy of note is the method of presenting reference material. Footnotes referring to the most up-to-date (at that time) reference on a particular group of fishes are much more convenient to the reader than the usual bibliography at the end of a section or the end of a book.

Definitely this book is not meant for popular consumption, but is a most valuable reference for anyone with interests relative to the systematics of fishes.—*William L. Craig, California Department of Fish Game.*

Lures: The Guide to Sport Fishing

By Keith C. Schuyler; The Stackpole Company, Harrisburg, Pennsylvania, 1955; x + 276 p., illus. $5.

The author's abilities as an angler and a writer have been combined to provide a useful reference for both the novice and expert freshwater angler.

Included in the book are chapters on dry flies, bugs, surface plugs, spoons, trolling lures, and many others. Each type of lure is described, its uses given, and quite often a short story based on the author's experience is woven around it. The relative merits of a large number of "name" lures are discussed with "no punches pulled".

The author's personal philosophy on sport fishing provides a strong background for his material and places the book on a higher level than most of the how-to-catch-a-fish books that have appeared recently. This philosophy can be summed up in the author's own words, "Feast on your sport, but carry a light creel."—*John Mahoney, California Department of Fish and Game.*

The Art of the Aqualung

By Robert Gruss (translated from "Manuel de l'homme sans poids" by Richard Garnett); Philosophical Library, New York, 1956; 66 p., 11 text figs., and 8 black-and-white plates. $2.75.

This short book gives a reasonable description of the physical use of the aqualung and the miscellaneous accessories used in free diving. The 11 figures and eight pages of photographs are excellent, but Chapter 8, "Strict rules for diving", is very incomplete and ignores many of the safety regulations recommended by experts on diving safety.

The book does not adequately describe all phases of the physics and physiology of diving, it does not describe all the safety precautions necessary in handling high pressure air tanks and equipment, and it does not discuss fully the several methods of replacing the mouthpiece (in emergencies) into the mouth and the subsequent clearing of water from the hoses. No mention is made of the various causes of ear drum rupture (explosion and implosion).

For these reasons this book is not recommended for use of the uninitiated, since the diver's well-being, safety, and survival in the underwater world depend upon the extent of his knowledge and training.—*Jack W. Schott, California Department of Fish and Game.*

Seamanship

By T. F. Wickham; Philosophical Library, Inc., New York, 1956; 192 p., 69 figs. $3.75.

This book presents an informative and interesting condensation of the rudiments of seamanship and is well worth reading.

Being British, some of the terms and phraseology are different from those used on American ships; also, the American buoyage system is different. However, the book's marlinspike seamanship, like the Rules of the Road, is international in scope.—*Richard B. Mitchell, California Department of Fish and Game.*

The Deer of North America

Edited by Walter P. Taylor; The Stackpole Co., Harrisburg, Pennsylvania, and The Wildlife Management Institute, Washington, D. C., 1956; xvi + 668 p., 2 color plates by Walter A. Weber, 39 black-and-white plates, drawings by Wallace Hughes, 21 figures. $12.50.

It is seldom that the opportunity arises to review a wildlife text of this stature. This long awaited general deer text has been written by 16 authors, one of whom, Walter P. Taylor, has tied the individual contributions into a volume which is pleasant to read and which contains materials from many of the recent reports of deer investigations. It is arranged so that the reader with a primary interest in black-tailed deer, for instance, is not forced to read all about white-tailed deer. The Wildlife Management Institute is to be congratulated for sponsoring this work, which has been presented in such a manner that the layman, the deer hunter, the game manager, and the biologist all may receive benefit from the volume. Walter A. Weber's color plates are excellent, as wildlifers have come to expect. The use of a black-and-white medium in an unusual manner by Wallace Hughes has produced striking and effective plates.

The historical aspect of deer in relation to the original Americans and to the pioneers is an natural beginning which sets the stage for discussion of the white-tailed deer. This includes descriptions and distributions of 30 races of the white-tail, life history studies, management practices, and hunting methods.

The descriptions and distributions of the mule deer races include the black-tailed deer. However, these coastal deer are treated separately in the last section, as well. Other mule deer sections include life history, productivity, food habits, population estimation, management, and the hunting of this popular game animal.

The experienced biologist will discover some errors in this striking literary effort. For instance, Figure 13 does not depict the distribution of Columbian black-tailed deer south of San Francisco Bay. This lack is known to have been an oversight, for Dr. Cowan went into this distributional phase thoroughly in 1936.

Although the published volume is generous in size and scope, an added chapter on sound management practices and dynamics would have been of immense benefit to the deer manager. For instance, what percentages of fawns and yearlings in the bag would represent a full harvest, without danger of overharvest? Or, to approach the problem from a different angle, is there an average age of bagged deer which represents an optimum harvest? The subject was touched on briefly in the Evaluation of Kill Reports section, but just enough to be tantalizing.

It is unfortunate that deer herd sizes cannot be determined as easily by the pellet group count method as implied, at least on most of California's winter deer ranges. One factor which hinders such determination is the variation of the range perimeter from year to year, and even during a single winter. For this reason, it appears safest to relate deer numbers to that portion of a herd inhabiting a selected key portion of the range, rather than to the entire range of varying character.

The statement that venison is in poor condition and less palatable when taken during the rut was not verified by testing. Cook et al. reported very little variation in flavor or tenderness of venison over the year, despite presence or absence of body fat. Regardless of when a deer is bagged, the fat oxidizes rapidly when stored, developing a strong, unappetizing flavor.

In view of the excellent food habits work which has been done with black-tailed deer in California, tabular food habits errors appear to have resulted from the analyses not reaching the attention of the authors. Important food items incorrectly or incompletely placed in the geographical regions would certainly include Gregg ceanothus. This species does not occur on ranges occupied by black-tailed deer. Snowbrush is taken by these deer inhabiting the western Sierra. Deerbrush is more important to resident deer of the north and south coastal areas than it is in the west Sierra, where it occurs most frequently as a deciduous shrub on winter ranges.

These points are stressed, for they will probably strike the sensitivity of a big game biologist as he encounters them in the text. Actually, the black-tailed deer section is extremely well executed, especially those portions dealing with general behavior, predation, management, and population dynamics.

The volume is very well prepared and will be welcomed by all persons interested in deer. Certain unresolved problems appearing in the text merely add to the vicarious pleasures of the critical biologist. They in no way detract from the interest generated from reading and digesting the contents. It is sincerely recommended for the hunter, as well as the practicing big game manager and wildlife student.—*Henry A. Hjersman, California Department of Fish and Game.*

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printed in CALIFORNIA STATE PRINTING OFFICE

14246 10-56 5,200

STATE OF CALIFORNIA

FISH AND GAME COMMISSION

Notice is hereby given that the Fish and Game Commission shall meet on January 4, 1957, in the State Building, Los Angeles, California, to receive recommendations from its own officers and employees, from public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to fish, mollusks, crustaceans, amphibia and reptiles, or any species or variety thereof, in accordance with Section 15.1 of the Fish and Game Code.

FISH AND GAME COMMISSION
WM. J. HARP
Assistant to the Commission

Notice is hereby given, in accordance with Section 14.2 of the Fish and Game Code, that the Fish and Game Commission shall meet on February 22, 1957, in the State Employment Building, 722 Capitol Avenue, Sacramento, California, to hear and consider any objections to its determinations and proposed orders in relation to fish, amphibia and reptiles for the 1957 angling season, such determinations and orders resulting from hearing held on January 4, 1957.

FISH AND GAME COMMISSION
MONICA O'BRIEN
Secretary to the Commission