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"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

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CASTLE LAKE TROUT INVESTIGATION

FIRST PHASE: INTERRELATIONSHIPS OF FOUR SPECIES[1]

By J. H. Wales

Bureau of Fish Conservation
California Division of Fish and Game

INTRODUCTION

Fig. 27. View from south end of Castle Lake.

In 1938 the California Division of Fish and Game decided to begin an intensive study of a more or less typical mountain lake. It was very evident that the stocking of such waters could not be done intelligently until more information was at hand.

Castle Lake in Siskiyou County was selected for the following reasons: It is fairly typical of the majority of natural lakes in Northern California; it has a road to it and the intensity of fishing is, therefore, above average; all the anglers could easily be checked; and finally the lake was located close to the District Fisheries Headquarters and the State Fish Hatchery in Mt. Shasta.

In Siskiyou and Trinity Counties there is a rugged jumble of mountains whose waters drain into the Klamath, Trinity and Sacramento Rivers. These mountains are much older than the string of extinct volcanoes lying just to the east. In these granitic Klamath mountains lie over 150 small glacial cirque lakes, the furthest east of these being Castle Lake. Although most of them drain into the Klamath and Trinity Rivers there are a few, including Castle Lake, which drain into the Sacramento River. Practically all of the lakes in this area lie near the heads of canyons just below the crests of the ridges. They are formed of melting snow held behind glacial moraines. The bottoms of most have become sealed by fine silt so that the only loss of water after the spring overflow is from evaporation. Many have perennial springs which retard a drop in water level. Most of them are surrounded by a jumble of broken granite and outcroppings of solid stone, though some have meadows or marshes along a portion of their shores. Castle Lake is relatively deep,

[1] Submitted for publication, April, 1946.

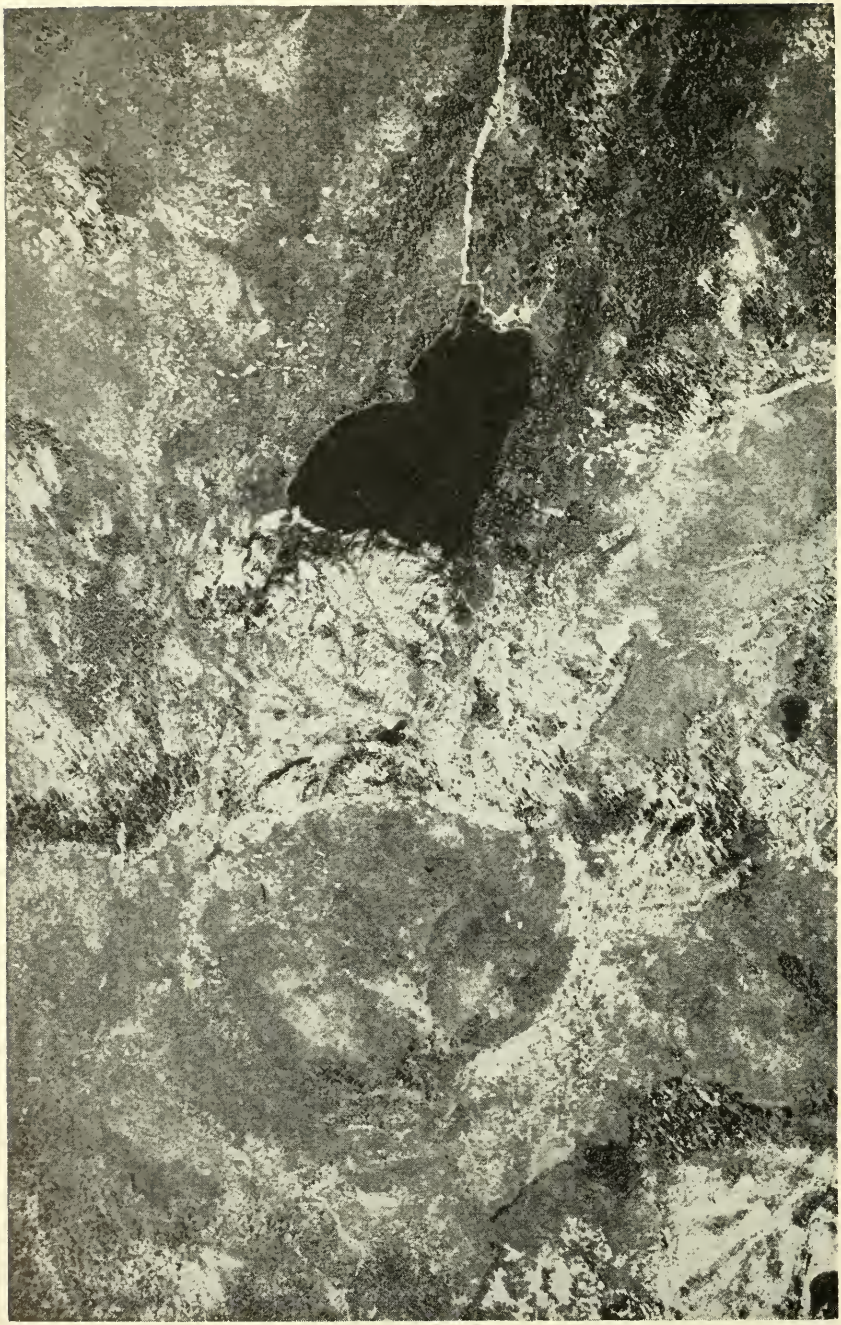

FIG. 28. Aerial photograph of Castle Lake. Note auto road ending at north end of lake and high granite cliffs at south end. Trails lead from road along both sides as far as the cliffs.—Permission of U. S. Forest Service.

120 feet, in fact it may be the deepest of the Klamath Lakes. Most of them are less than 50 feet and a few are shallow, bog lakes. In Castle Lake and in most others the growth of aquatic plants is small; the water tends to be too deep, the bottom too rocky and the wave action too severe. The great majority, like Castle Lake, have neutral or slightly alkaline waters, with small amounts of dissolved minerals. The dissolved organic matter is moderate and the plankton crop is light, in fact the net-phytoplankton is almost nonexistent in Castle Lake. However, the zooplankton is sufficient to form an appreciable part of the fish's diet. As the lakes lie between 5,000 and 8,000 feet elevation, the vegetation around the shore is largely conifers and shrubs. These provide an abundance of insects which are the chief article of trout food.

Ordinarily Castle Lake freezes over in November or December and does not thaw out until early in May. The snow pack has varied from 3 to 12 feet in recent winters. With the melting of the snow and ice the outflow of water reaches about 5 cubic feet per second. In 1945 the lake level reached its low point in September when it was 24 inches below maximum.

In most of the lakes the only fish are trout, though Castle Lake and a few others have some minnows. The natural reproduction of the trout in these lakes tends to be poor or absent. In Castle Lake there are no tributaries in which spawning can take place, and it can be said that for all practical purposes there is no natural propagation except in the mackinaw. In this species the reproduction is great enough to provide some fishing. There is either no reproduction in the cases of the rainbow, brown and brook or so little that the catch of wild fish does not confuse the picture.

SUMMARY OF PERTINENT FACTS

Castle Lake, Siskiyou County, California, T. 39 N., R. 5 W., S. 13.
Tributary to the Sacramento River.
Geological character: granitic, glacial cirque.
Elevation: 5,200 feet.
Surface area: 47 acres.
Volume: Approximately 1,800 acre-feet.
Maximum depth: 120 feet.
Temperature range: 32°–75° F.
Tributaries to Castle Lake: Seasonal; melting snow water.
Water analysis—July, 1944:

Total solids	34 ppm.
Loss on ignition	18 ppm.
Fixed residue	14 ppm.
Total alkalinity as calcium carbonate	23 ppm.
Calcium	4 ppm.

A number of people have aided in the Castle Lake Project. Those to whom we are most indebted are: R. V. Miller, Jr., J. Handley, W. K. Cheney, A. E. Culbertson, Dr. A. B. Murphy, L. Hartley and T. Armstrong, all of whom have served as creel checkers. Floyd Bucklin analyzed the stomach samples taken in 1944 and the plankton samples collected in 1945.

PROGRAM AND METHODS

Program

The objectives of this investigation were to determine the most suitable species of trout to plant in mountain lakes of the class represented by Castle Lake, the optimum size of fish at planting time, and the optimum number to be planted. The original plan was to stock Castle Lake with equal numbers of rainbow, brook and brown trout and determine the one best suited to conditions existing in the lake. After the most suitable species had been chosen it was planned to determine the best size at planting time and then the proper number to be stocked.

TABLE 1

Marked Fish Planted in Castle Lake

	Fish	Size*	Fin removed**
1938			
October 21	7,000 rainbow	9.2 per oz.	Ad.
October 21	7,000 brown	6.5 per oz.	Ad.
October 21	25,000 brook	21.0 per oz.	Not marked
1939			
September 20	6,360 rainbow	7.0 per oz.	L.V.
September 20	7,000 brown	9.5 per oz.	L.V.
August 5	7,000 brook	6.0 per oz.	R.V. & Ad.
1940			
September 9	7,305 rainbow	5.0 per oz.	R.V.
September 10	7,500 brown	9.0 per oz.	R.V.
August 20	7,000 brook	6.0 per oz.	L.V.
1941			
August 29	7,000 rainbow	7.0 per oz.	L.V. & Ad.
September 18	7,000 brown	12.0 per oz.	L.V. & Ad.
August 13	7,101 brook	8.0 per oz.	R.V. & Ad.
1942			
June 11	15,000 rainbow	37.0 per oz.	Not marked
June 11	15,000 brown	31.0 per oz.	Not marked
June 11	15,000 brook	34.0 per oz.	Not marked
June 11	2,000 rainbow	1.4 per oz.	2V.
June 11	181 rainbow	1.1 oz. each	2V. & Ad.
June 11	1,640 brown	1.0 per oz.	2V.
June 11	173 brown	1.5 per oz.	2V. & Ad.
June 11	181 brook	2.7 oz. each	2V. & Ad.
1943			
August 2	5,000 rainbow	17.0 per oz.	Ad.
August 2	5,000 brown	25.0 per oz.	Ad.
July 29	5,000 brook	14.2 per oz.	Ad.
May 27	900 rainbow	11.0 per lb.	R.V. & Ad.
May 27	900 brown	10.6 per lb.	R.V. & Ad.
May 27	900 brook	9.8 per lb.	R.V. & Ad.
May 6-7	148 rainbow	1.4 lbs. av.	½D. & Ad.
May 6-7	75 rainbow	5.0 lbs. av.	½D & Ad.
1944			
July 29	7,000 rainbow	10.9 per oz.	L.V.
August 15	7,000 brown	20.8 per oz.	L.V.
July 29	7,000 brook	12.0 per oz.	L.V.
1945			
July 20	3,500 rainbow	9.6 per oz.	Not marked
July 20	3,500 rainbow	9.3 per oz.	R.V.
August 16	6,000 brown	14.8 per oz.	R.V.
July 20	7,000 brook	12.9 per oz.	R.V.

* Average lengths of fish are approximately:
1½″ at 35 per ounce
1¾″ at 25 per ounce
2″ at 15 per ounce
3″ at 5 per ounce
5″ at 1 per ounce

** Ad.=Adipose.
L.V.=Left ventral.
R.V.=Right ventral.
2 V.=Both ventrals

Five years of creel census have shown that when all three species are planted their interrelationship tends to mask the potentialities of any one alone. It is therefore now planned to pick one species, namely the brook trout, and to plant it only in order to study its suitability for lakes of this type. With no plantings of rainbow and brown they would become extinct in this lake after approximately six years but even then mackinaw would remain. Therefore, it has been decided to eradicate the entire population of the lake at the end of the 1946 season, and to start immediately upon the second phase of the investigation.

Stocking

Because Castle Lake is situated only 11 miles from the Mt. Shasta fish hatchery and because it has always been one of the favorite recreational spots of the area it is natural that fish should have been planted here for many years and in large numbers. It is natural too that most of the available game species should have been tried. Beside the usual rainbow, brown and brook trout, the mackinaw and the Lahontan cutthroat trout were also planted. At some time in the past the western golden shiner was introduced, accidentally or with intention.

Beginning in 1938 all of the fish stocked in Castle Lake have been marked by removal of fins with the exception of the 1942 plant; and these fish could be followed in the catch because they were not marked. Most of the planted fish have been fingerlings but yearlings and older fish were also tried. More emphasis was given the fingerling tests because it is the practice to use trout of this age in stocking most of the California mountain lakes.

Census

Starting in 1941 all of the fish taken from the lake have been recorded. Nearly all of the fish were caught with various types of sport-fishing tackle, but in some years the returns were supplemented by gill-netting. The numbers taken with gill-nets were never large enough to materially effect the sport fishery.

The auto road to Castle Lake is the only route used by fishermen and as this road ends at the lake it is a simple matter to contact all of the fishermen at the close of the angling day. Upon completion of fishing the anglers are interviewed by the creel checker. A special form is filled out for each angler, whether fish have been caught or not. If fish have been caught the checker measures each one on a simple measuring board, recording the length to the next half-centimeter beyond the fork of the tail. Later these measurements are corrected by subtracting $\frac{1}{4}$ cm. from each of the averages. When time permits the fish are weighed in grams on a spring balance. The species and fin mark are, of course, recorded at the same time.

CASTLE LAKE CREEL CENSUS—194

Man:	Woman:	Child:	Fishing from: Shore	Boat	No.
County of Residence:			Weather:	Date:	
Method of Angling:			Fished from	M. to	M.
Name of Angler			No. of hours fished		

Rainbow		Loch Leven		Eastern Brook		Mackinaw	
Length	Mark	Length	Mark	Length	Mark	Length	Mark

Length is from snout to fork in tail. Measure to next larger ½ centimeter. Record sex (M or F) when possible.

FIG. 29. Castle Lake Creel Census Form

Limnological Methods

No really intensive limnological study of Castle Lake has been attempted. Because this was to be a practical fisheries investigation we tried to limit our sampling to features which we believed were necessary to a proper understanding of the ichthyological findings. Following is an outline of the limnological work conducted at Castle Lake during most of the 1941-45 period, the results of which are summarized in the Appendix.

Water Sampling

a. Temperatures—

Taken every two weeks at two stations. In the shallow end of the lake surface and bottom temperatures were taken and in the deep end intermediate samples were taken to locate and characterize the thermocline.

b. Oxygen—

Determinations were made by the modified Winkler method. Samples were taken at the same times and places as the temperatures except that fewer were taken in the thermocline.

c. Hydrogen Ion—

Determined by the Harleco color chart and universal indicator. Usually taken along with the oxygen samples.

Plankton Sampling

The plankton was sampled every two weeks at three stations, using a Birge closing net with #20 silk. At the "shallow end" and "east shore" stations the hauls were made from bottom to top, 10 ft. and 15 ft. long respectively. At the deep end the hauls were made from 100 ft. to 50 ft. and from 50 ft. to 0 ft. All hauls were made in duplicate and the results averaged. Samples were fractioned, and counts made under the microscope on a grid slide.

Bottom Sampling

Bottom samples were taken once a month at four representative stations using a ¼ square foot Eckman dredge. The trout food organisms were grouped, then counted and measured volumetrically.

Food Studies

The food problem in Castle Lake has been attacked in several ways. The study of bottom and plankton samples is important, and the computation of condition factors and growth rates indicates whether the fish have eaten enough to satisfy the needs of work and growth, but the most direct attack on the problem of food eaten is, of course, by the way of stomach analysis. Stomachs have been taken from both hook and line and gill-net captured trout. In 1941-44, inclusive, 790 stomachs were collected and the contents analyzed by volume of food classes. This study has given us a reasonably clear picture of the natural food preferences of the four species of trout in this lake. (See pp., 131 to 135.)

FISH PRESENT

The following species of fish are present in Castle Lake:

1. Brown Trout—*Salmo trutta* Linné.
2. Shasta Rainbow Trout—*Salmo gairdnerii Shasta* Jordan.
3. Eastern Brook Trout—*Salvelinus fontinalis* (Mitchell).
4. Mackinaw Trout—*Cristovomer namaycush namaycush* (Walbaum).
5. Western Golden Shiner—*Notemigonus chrysoleucus auratus* (Rafinesque).
6. Black Dace—*Rhinichthys osculus* (Girard).

Brown Trout

This species had been planted in the lake from the Mt. Shasta Fish Hatchery for many years prior to the present study. It has proven to be very well adapted to the existing conditions in Castle Lake. When planted as fingerlings this species has shown the best survival of the three planted trout. It is felt that the survival rates of the rainbow and brook might not be as low as they are at present if the browns were not in the lake. The brown trout in Castle Lake, living as it does to a greater age (7-8 years) and size than the rainbow and brook, feeds more upon fish

than do the last two species. Thus if the browns were not present in the lake the survival rate of either rainbow or brook might be greater than that of the browns at the present time. This point will be cleared by future experiments but at the present time the brown trout in Castle Lake has a relatively high survival rate.

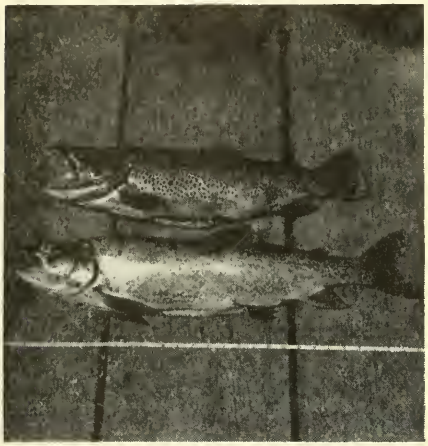

Fig. 30. Brown trout and mackinaw weighing seven and nine pounds respectively. This is the largest brown trout recorded from Castle Lake. Largest mackinaw recorded weighed slightly less than twenty pounds. Photo 1939.

The brown trout makes little use of the plankton in Castle Lake, feeding largely upon insects and to some extent upon young fish. Natural reproduction in this species is ineffective although spawning fish have been found around springs in the lake and in the outlet stream.

Fig. 31 shows clearly that despite nearly equal plants of the three species the fishermen catch many more browns than any of the other species. At present this does not seem to mean that this species is necessarily the best one for Castle Lake. It does mean, however, that with the present mixture of all four species of trout the brown are best able to care for themselves. Although the brown are not quite as gamey as the rainbow they are well regarded by the majority of anglers at this lake.

Rainbow Trout

This species is the only one of the four which is native to the region but it is typically a stream rather than a lake species. Nevertheless it has been planted in all types of lakes in California and has been successful in most. The average survival rate of rainbow fingerlings planted in Castle Lake is not quite as high as that of the brown but it is considerably better than that of the brook trout. When planted as yearlings the survival to the angler is also good. The growth rate of the rainbow is superior to any of the other species in Castle Lake but this is probably due to the fact that the strain of rainbow used is one selected for rapid growth. More young rainbow are caught by fishermen than young brown for the brown is exceptionally wary as a young fish.

The rainbow feed upon plankton (cladocerans and copepods) in Castle Lake far more than do the brown and more than the brook. Insects, however, are their most common food. If this species is cannibalistic in the lake it is to a very slight extent. From this it must not be construed that rainbow are not cannibalistic in other waters. Even in Castle Lake they might become cannibalistic if small fish were more abundant. The rainbow, as a species, is clearly an opportunist.

If rainbow spawn or attempt to spawn in Castle Lake they must do it very rarely for neither spawning fish nor offspring have been observed.

In this particular lake the rainbow seldom live to an age greater than six years.

Ordinarily the rainbow in Castle Lake are more gamey than any of the other species and most discerning sportsmen prefer them. Unlike the brown, whose flesh is white or straw colored, the flesh of the rainbow is usually pink or salmon colored, the depth of color depending upon the amount of copepods recently eaten. The color of the swim bladder is commonly magenta. Because of the reddish oil obtained from the copepods the flavor of the rainbow is usually prized more than the others.

Eastern Brook Trout

The case of this species is interesting. In the majority of the Klamath mountain lakes the brook trout are most successful, in Castle Lake it is the least successful. This appears to be due to the fact that they are preyed upon by the other trout and perhaps other predators, such as snakes, to a greater extent than the rainbow and brown. In most of the Klamath lakes where they do well there are no other species; in Castle Lake the predatory brown and mackinaw have apparently caused the low survival. As a fingerling the brook trout is less wary than either the fingerling rainbow or brown and so far as we know there is no other explanation for its high mortality. This lack of wariness would have little disadvantage if the brook alone were present for the old brook seem to be far less cannibalistic than the brown or mackinaw. Starting in 1946 brook trout alone will be planted and we shall have a chance to see how the single species will do.

At present the maximum age of this species appears to be three years.

In Castle Lake the brook are more omnivorous than the other species. This fact is certainly in their favor.

One reason why the brook trout have been so successful in California mountain lakes is that they spawn commonly in the gravel over springs rising on the lake bottoms and can thus reproduce even where there are no accessible tributary streams. This spawn seems to be reasonably viable and as a result the natural reproduction becomes a most valuable adjunct to hatchery stocking. In Castle Lake mature brook are not abundant but in the fall several pairs can always be seen over the clean gravel of the springs. In the summer, wild brook fingerlings can occasionally be seen in the lake but they are so few and their mortality is so heavy that the number caught by fishermen each year is probably not over six, hardly worth considering.

For the average lake fisherman the brook trout can not be surpassed. It can be caught from shore as well as from boats, an important factor in the inaccessible lakes. In addition, the brook bite more freely than the brown and rainbow commonly do. This is important in the mountain lakes where fishing intensity is light. On the other hand where fishing intensity is heavy the brook might be caught out in greater numbers than it would be economically feasible to plant.

We have some evidence, though insufficient, to show that brook fingerlings tend to move downstream out of Castle Lake, possibly to a greater extent than either the brown or rainbow.

Mackinaw Lake Trout

This species was introduced into Castle Lake probably in 1924. Since then there have been no more put in the lake. In 1941 several old mackinaw were caught which could have been of the original plant. In the last two years none have been caught which were more than three or four years old, although the total number of this species taken was great enough to yield old fish had they been numerous. It seems, therefore, that this species is slowly disappearing and might under normal conditions be rare in a few years. They are probably undesirable as they are too cannibalistic to be profitable in lakes where their diet must be other trout. It is worthy of further emphasis that this one planting of mackinaw made over 20 years ago should have survived, reproduced and appreciably added to the catch whereas the other three species would have died out had they not been planted frequently. Very likely the small mackinaw inhabit a zone in Castle Lake not commonly frequented by large trout. The location of this zone is not known nor do we know where the gravel beds are on which the adults are thought to spawn. The smallest mackinaw recorded from Castle Lake was nine inches long while the largest weighed just under 20 pounds. For the most part the mackinaw seem to range deeper in the lake than other species but they have been caught near the surface both on hook and line and in gill-nets.

Western Golden Shiner

This minnow is not known to occur in any other waters in the northern section of the State. Presumably it was planted in Castle Lake from the Mt. Shasta hatchery about 20 years ago. It has just maintained itself and a small school can always be found among the logs which have drifted into a cove at the north end of the lake, or in the outlet stream just below the lake. A few adults measuring about five inches in length have been taken in gill-nets but it is rare to see them over three inches long. No doubt they contribute to the diet of the trout but on the other hand they might become so abundant that they would seriously compete with the trout for food.

Black Dace

This species was first seen in Castle Lake in 1945 and it is difficult to see how they could have been in the lake long before that without being noted. They are not known to occur in the outlet stream and therefore were probably introduced by fishermen who had used them as bait for mackinaw. In one or more nearby lakes this species has become very abundant and it seems quite possible that they could become a nuisance in Castle Lake.

CATCH

Catch data obtained by the creel census are summarized in Tables 2 to 4 and in Fig. 31.

Survival or Yield

Unquestionably the most important problem which we hope to solve by the Castle Lake experiments is that of survival. Survival figures for planted fish are computed from the number present at planting time to certain definite times in the later history of the fish. In Castle Lake the

TABLE 2

Summary of Angling Data *

	1941	1942	1943	1944	1945
Length of fishing season	6/18–10/31 137 days	5/30–10/31 155 days	5/ 1–10/31 184 days	5/ 1–10/31 184 days	5/ 1–10/31 184 days
Number of angler days	548	555	546	769	489
Total catch	730	1,332	2,136	1,867	1,588
Average catch per day	1.33	2.40	3.91	2.57	3.25
Average hours fished	3.5	5.3	4.0	3.1	3.4
Average catch per hour	0.38	0.45	0.98	0.79	0.95
Angler days from boat	64%	56%	46%	62%	64%
Angler days from shore	36%	44%	54%	38%	36%
Brown trout caught	368 (50%)	612 (46%)	728 (34%)	1,101 (59%)	797 (51%)
Rainbow trout caught	175 (24%)	427 (32%)	1,151 (53%)	399 (21%)	487 (31%)
Brook trout caught	176 (24%)	252 (19%)	258 (12%)	241 (13%)	224 (14%)
Mackinaw trout caught	11 (2%)	39 (3%)	11 (.5%)	126 (7%)	53 (4%)
Total catch	730	1,330	2,148	1,867	1,561

* Gill net catches not included.

TABLE 3

Angling Data by Months

Averages for 1941-1945 Inclusive

Month	Number of angler-days	Man-hours fished	Average hours per angler-day	Number of fish recorded					Average catch		Zero catches	
				EB	RB	Br	Mack	Total	Per angler	Per hour	Number	Per cent
May	42	145	3.3	44	29	42	3	118	2.8	.81	17	40
June	111	467	3.9	57	135	143	16	351	3.2	.75	42	38
July	213	811	3.8	63	171	271	4	509	2.4	.62	96	45
August	123	463	3.9	24	66	81	11	182	1.5	.39	64	52
September	52	187	3.7	24	53	59	15	151	3.0	.81	17	33
October	39	123	3.2	23	54	114	7	198	5.0	1.61	6	15
Totals	580	2,196	3.6	235	508	710	56	1,509	2.6	.69	242	42

TABLE 4

Number of Angler-Days and Individual Anglers

	Angler days	*Individual anglers*
1942	555	334
1943	546	227
1944	769	170
1945	489	140

Travel difficulties and other factors due to the war reduced the number of different anglers who visited the lake but increased the number of "repeaters."

Distribution of Fish Among the Fishermen

1943	15 anglers caught over 50% of the total catch
1944	10 anglers caught over 50% of the total catch
1945	13 anglers caught over 50% of the total catch

Distribution of Catch According to Lure Used

	1943	*1944*	*1945*
Spinner	45%	55%	51%
Bait	39%	19%	29%
Fly	16%	26%	20%

Pounds of Trout Caught Annually
(Averages of 1943-45 Inclusive)

Rainbow	*Brown*	*Brook*	*Mackinaw*	*Total*	*Average per acre*
153	268	32	36	489	10.4

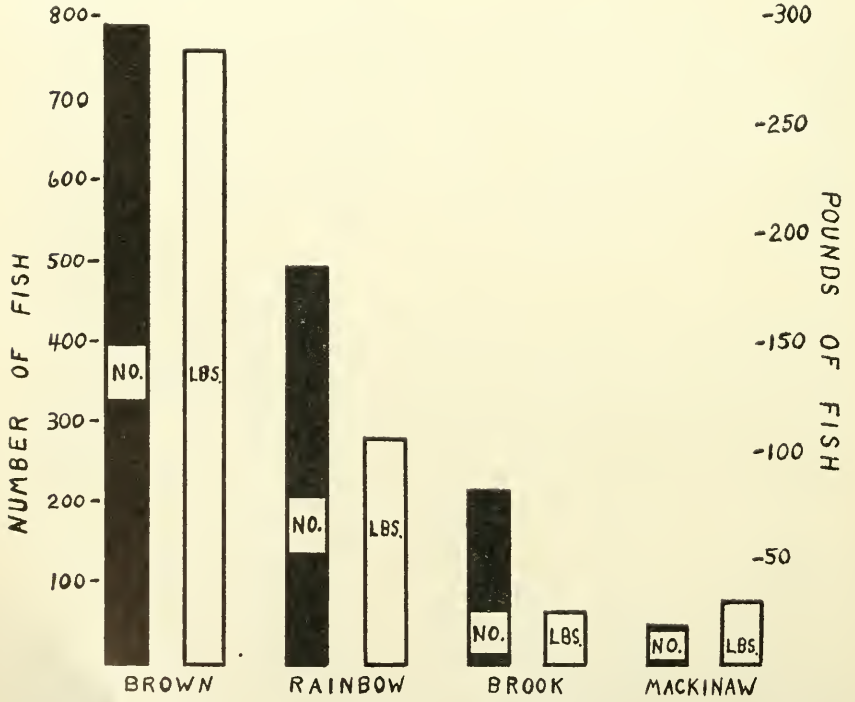

FIG. 31. Anglers' catch in Castle Lake in 1945. Since 1938 the numbers of Brown, Rainbow and Brook trout planted in the lake have been approximately the same. The great differences in catch of these species are due to differences in natural mortality.

survival is computed from the number planted and the number caught and is therefore actually the yield to the anglers. The number which might escape the fishermen and predators and reach spawning age would be of importance in waters where the spawn would result in more fish for the fishermen but in Castle Lake where natural spawn is ineffective the only important figure is the number caught by the anglers.

Thus in lakes which must be planted regularly to maintain fishing it is of prime importance to know the per cent of the different species and of the different sizes (at planting time) which are caught. Of course there are other considerations such as the average size attained by the fish before it is caught, its sporting qualities and its food value. However, if other points are fairly equal the per cent of fish caught is the most valuable index of a group's desirability.

At the start of the Castle Lake study we had no idea which of the three commonly planted species would have the best survival value nor did we know much about the relative survival figures for fish planted as fingerlings and those planted as yearlings. After having planted marked fish for eight years and having recorded the catch for five years we are now in possession of a dependable array of data, although there has been considerable variation in survival among the different year classes.

Lest the following comments on survival be misleading it should be borne in mind that we have been dealing with a mixed population of four cannibalistic species. If the population had had a different composition the results might well have been different.

Survival of Fingerling Brown Trout

The survivals to the angler of brown fingerlings are known, completely or almost completely, for three year classes while the results are at present incomplete for the remaining four. The indications are that the range of survival will lie between 5 and 9 per cent. This relatively high survival rate may be attributed to the observed fact that young browns are extremely wary. Possibly they tend to inhabit less dangerous zones within the lake. Newly planted browns act more like wild fish than do planted fingerling rainbow and brook and as the heaviest loss probably occurs immediately after planting this wariness would seem to account for the good survival. Certainly the good survival can not be attributed to a large size at planting time for the accompanying tables show that the browns are usually smallest when planted. At the same time a study of Table 5 makes it appear unlikely that their good survival could be due to their small size at planting time.

Survival of Fingerling Rainbow Trout

For the rainbow we have complete returns for four year classes, almost complete for a fifth, and considerable information on a sixth. The range of variation in the survival of fingerlings of this species seems to lie between 0.5 and 7.8 per cent with an average of 3.5 per cent. If we disregard the 1939 year-class, whose performance appears to have been distinctly subnormal, fingerling survival ranges from 2.4 to 7.8 per cent with an average of 4.1 per cent. This survival we see is not as high as that of the brown fingerlings. The rainbow have been somewhat larger at planting time but not a great deal. There has also been so much variation in survival from year class to year class in this species that it

TABLE 5

Survival to the Angler—Brown Trout

Planted			Caught							Anticipated catch*			Estimated total per cent of survival
Year	Number	Size (number per oz.)	1941	1942	1943	1944	1945	Total	Per cent survival	1946	1947	Total	
Fingerlings													
1938	7,000	6.5	90	67	44	18	4	223	3.2	0	0	223	**3.2
1939	7,000	9.5	80	129	54	71	33	367	5.2	10	2	379	***5.4
1940	7,500	9.0	27	245	133	139	103	647	8.6	35	10	692	9.2
1941	7,000	12.0	----------	5	106	120	74	305	4.4	40	15	360	5.1
1942	15,000	31.0	----------	----------	92	371	267	730	4.9	----------	----------	----------	----------
1943	5,000	25.0	----------	----------	----------	22	85	107	2.1	----------	----------	----------	----------
1944	7,000	20.8	----------	----------	----------	----------	73	73	0.1	----------	----------	----------	----------
1945	6,000	14.8	----------	----------	----------	----------	0	0	----------	----------	----------	----------	----------
Yearlings													
1942	1,800	1-1.5 per oz.	----------	85	223	161	66	535	30.0	25	5	565	31.4
1943	900	10.6 per lb.	----------	----------	51	165	68	284	31.6	25	5	314	34.9

* Estimated on basis of known yields of the earlier year classes.
** Catches for 1939 and 1940 are not known, and would increase total survival.
* * Catch for 1940 is not known, and would increase total survival.

TABLE 6

Survival to the Angler—Rainbow Trout

Planted			Caught							Anticipated catch*			Estimated total per cent of survival
Year	Number	Size (number per oz.)	1941	1942	1943	1944	1945	Total	Per cent survival	1946	1947	Total	
Fingerlings													
1938	7,000	9.2	34	12	7	8	0	61					
1939	6,360	7.0	6	19	3	3	1	32	0.5	0	0	32	**0.5
1940	7,305	5.0	135	80	29	4	3	251	3.4	0	0	251	3.4
1941	7,000	7.0		61	89	27	4	181	2.6	0	0	181	2.6
1942	15,000	37.0			467	140	27	634	4.2	1	0	635	4.2
1943	5,000	17.0				86	29	115	2.3	5	1	121	2.4
1944	7,000	10.0				32	406	438	6.2	100	10	548	7.8
1945	7,000	9.6					0	0					
Yearlings		Per lb.											
1942	2,180	16-24		239	191	42	4	476	21.8	0	0	476	21.8
1943	900	11.0			299	49	4	352	39.1	0	0	352	39.1
Adults		Lbs. each											
1943	223	1.4 average and 5.0 average			69	2	0	71	31.9	0	0	71	31.9

* Estimated on basis of known yields of the earlier year classes.
** Catch for 1940 is not known, and would increase total survival.

does not seem probable that size at planting time has been the cause of the higher survival of the brown fingerlings. It is generally believed that the larger the fish are at planting time the greater the survival. This principle no doubt holds true in general for all trout species but there seem to be special cases when this is not so. Size is not the only important factor. The health of the fish when planted may be very important and we have some good reasons for thinking that the rainbow fingerlings, and possibly the brown and brook, have varied in health from year to year.

The rainbow fingerlings in Castle Lake seem to be less wary than the browns and it would appear that this fact alone may be sufficient to account for the greater mortality.

Speed of growth is naturally an important factor in determining survival in fishes because the faster a fish grows the sooner it will get out of the dangerous fingerling stage and attain a size which is less vulnerable to cannibalism. The rainbow brood stock is now undergoing selection for speed of growth and the fingerlings planted recently grow more rapidly than those planted early in the Castle Lake study. It must not be lost sight of, however, that selection for such obvious characters as speed of growth, spawning time and egg production may be attended by harmful qualities which might reduce the survival of the fingerlings.

FIG. 32. Castle Lake, looking northeast toward Mt. Shasta.

Survival of Fingerling Brook Trout

The difference between the brown and rainbow fingerling survival, while probably significant, was not great. The survival of the brook fingerlings is definitely lower than the others. The range for five year classes is from 0.4 to about 3.1 per cent with an average of 1.9 per cent. Table 7 indicates some correlation between survival and size at planting time. However, the 1944 plant has already shown good survival and

TABLE 7

Survival to the Angler—Brook Trout

Planted			Caught							Anticipated catch*			Estimated total per cent of survival
Year	Number	Size (number per oz.)	1941	1942	1943	1944	1945	Total	Per cent survival	1946	1947	Total	
Fingerlings													
1939	7,000	6.0	15	1	0	0	0	16	----------	----------	----------	----------	----------
1940	7,000	6.0	152	58	4	1	0	215	3.1	----------	----------	----------	----------
1941	7,010	8.0	----------	118	18	1	0	137	2.0	----------	----------	----------	----------
1942	15,000	34.0	----------	----------	21	66	13	100	0.7	0	0	100	0.7
1943	5,000	14.2	----------	----------	----------	14	7	21	0.4	0	0	21	0.4
1944	7,000	12.0	----------	----------	----------	2	181	183	2.6	40	2	225	3.2
1945	7,000	12.9	----------	----------	----------	----------	0	0	----------	----------	----------	----------	----------
Yearlings		Per lb.											
1942	181	6	----------	57	11	1	0	69	38.1	0	0	69	38.1
1943	900	10	----------	----------	196	149	12	357	39.7	0	0	357	39.7

* Estimated on basis of known yields of the earlier year classes.

may eventually have the highest of the five plants. Thus size at planting time is certainly not the only factor influencing survival though it is probably quite important in this species. The disposition of the brook fingerlings is such that they undoubtedly fall prey to the cannibalistic trout more readily than the other two species. It seems evident, therefore, that when cannibalism is as heavy as it is in Castle Lake the brook should be as large as possible at planting time.

Survival of Yearling Brown, Rainbow and Brook Trout

It will be noted in the preceding tables that there were two plants of yearlings (1942-43) of each of the three species. In 1943 there were 900 yearlings of each species planted and they were very nearly of the same size. The survival to the anglers of these three plants was 34.9, 39.1 and 39.7 for the brown, rainbow and brook respectively. The returns of the 1942 plants were more variable but there was more variation in size at planting time and the numbers planted were so unequal that the results of that year's plants are not as reliable. We are hardly justified in giving a range of survival for the three species because we have insufficient year classes to work with but we can say that there does not seem to be much difference in the three species and that our limited data show a survival of roughly 35 to 40 per cent.

Comparison of Three Species

The survival figures show that the eastern brook trout fingerlings make their most important contribution to the catch the year after planting, after which they drop off rapidly and are negligible by the third year after planting. The brown trout fingerlings make little contribution the year after planting; are most important the second year after planting; and continue to play a significant part through the fifth and sixth years after planting. The rainbow are, like the brooks, the most important the year after planting, but unlike the brooks continue to be significant until at least the third year after planting. Brooks tend to be removed from a lake within two years after planting; browns remain much longer and tend to build up a backlog of older fish; rainbow are intermediate between the two.

SOURCES OF FISH LOSS IN CASTLE LAKE

Following is a list of the known and probable causes of fish loss in Castle Lake:

1. Predatory trout.
2. Predatory birds.
3. Garter snakes.
4. Diseases.
5. Escape by outlet stream.
6. Senescence.
7. Winter-kill.
8. Predatory mammals.

These sources of loss are arranged in order of importance, or as close to it as our limited information will permit. The first six factors are definitely known to exist and the last two are very probable sources of loss.

Predatory Trout

Examinations show that approximately 1 per cent of the 790 trout stomachs taken from fish in Castle Lake contain trout. They have been found only in brown and mackinaw stomachs. Although at first glance it might seem that more stomachs should contain trout it was concluded from computations of the statistical probability that this was a reasonable expectation. It would seem quite reasonable to say that cannibalism causes over 50 per cent of the natural mortality in the lake, and perhaps as much as 75 per cent; we have little evidence of any other great source of loss. Mortality in the lake is highest in the brook fingerlings and least in the browns. Insofar as we know their reactions it appears that the brook fingerlings are least afraid while the brown are the most wary. It would seem reasonable, therefore, if mortality is largely from cannibalism that the relative survival should be as we find it.

It is widely recognized that mackinaw tend to be fish eaters but in Castle Lake they seem to be no more so than the brown. The fact that a considerable fraction of the lake population is adult brown trout is added indication that much of the fingerling mortality would be from cannibalism.

Predatory Birds

Mergansers, ospreys, kingfishers and cormorants are occasional visitors to the lake in the order of abundance named. The first two probably account for an appreciable fraction of the natural mortality and it may be inferred that the kingfisher on its infrequent visits catches a few small trout. Whether the cormorant which is very rarely seen, catches any Castle Lake trout is not known. Families of mergansers visit the lake, possibly two or three times each year, and a few which have been shot contained trout. Each year a lone osprey spends a few days at the lake and has been observed preying on the larger rainbow which swim in schools near the surface feeding on plankton and aerial insects.

With the exception of the mergansers the birds at Castle Lake are not serious factors in trout mortality.

Garter Snakes

Each year garter snakes can be found feeding along the shore on fingerling and rarely on yearling trout. They wait quietly among the rocks until a fingerling, in its search for food, comes close enough. The number of fish caught by snakes at Castle Lake can scarcely be guessed but it must be appreciable. Any serious attempt to improve survival in our trout waters would call for control of these snakes.

Diseases

Disease probably becomes a serious consideration at times but our observations have not brought this out clearly. Several medium-sized browns were observed on the lake bottom in 1941, and though they had been dead too long to tell, it did seem probable that they had been killed by disease. In 1943 nearly every brown trout examined had several cestode larvae[2] encysted on the surface of the viscera. However, we have no reason to believe these were lethal.

[2] These are the immature stage of a bird tape-worm but they are not harmful to man.

Although we always try to plant healthy fish still it may frequently be that the survival in the lake is influenced by undetected diseases or from weaknesses brought on by earlier diseases. We can not truthfully claim that hatchery raised trout are always as vigorous as wild fish but they are as nearly so as our present fish-cultural knowledge will permit. As methods of feeding and care are improved it seems reasonable to suppose that survival of the planted fish will increase.

Escape by Outlet Stream

In 1942 there was an appreciable outflow of water after the fingerlings were planted. A fyke net set for several days showed that some fish, mostly brook, were escaping. However, in subsequent years the outflow was more through seepage and fish could not easily escape. In 1944 and 1945 a wire screen trap was maintained in the outlet stream from the time the fish were planted until the fall snows began. No trout were caught during these periods. In the spring, particularly during May, there is up to 5 c.f.s. outflow and fish could easily escape at this time. Probably a few do leave but by this time the latest hatchery plant has become established and it would seem that they have little or no desire to escape the lake. We have not captured any marked trout in the small outlet stream below the lake, in fact few trout seem to occur there. Despite this evidence to the contrary it would be incorrect to say that escape plays no part in the return to the angler. In certain lakes the escapement is probably quite large but in Castle Lake it would seem to be a small factor. The time of planting in lakes is undoubtedly an important consideration and if possible it should be postponed until the spring overflow has subsided.

Fig. 33. Looking southwest across Castle Lake. February, 1938. Snow about eight feet deep.

Winter-kill

We have no evidence that fish are ever killed in Castle Lake by crushing under snow and ice or from oxygen depletion or by other strictly winter conditions. It is reasonable nevertheless to assume that fish hibernating among the rocks near shore occasionally become trapped and killed by the sinking of ice and snow.

Predatory Mammals

Mink probably occur in this area and may occasionally feed in Castle Lake. However, there is no evidence that they have frequented the lake since the experiments were begun.

Senescense

A certain number of trout undoubtedly die through natural ageing processes.

GROWTH AND CONDITION OF TROUT

Growth

Table 8 shows the relationship of length at planting time to average length in the first fishing season following the year in which the trout were planted. This table also gives the per cent caught in this first season. The following points should be observed:

a. The smallest rainbow at planting time had the greatest average length when recaptured during the first fishing season following the year in which they were planted. The explanation might be that they were planted earlier and benefited from the greater opportunity to feed on natural foods. Whatever the cause we may conclude that small rainbow fingerlings planted early in the season may have an advantage over larger fingerlings planted later.

b. The above conclusion seems to be true for the brown trout fingerlings as well, though not so clearly marked.

c. Large size at planting time does not insure a greater first year's growth in the brook trout fingerlings.

d. It will be noted that in all three species the size at planting time seems to have no special bearing upon the number caught during the first fishing season following the year in which they were planted.

TABLE 8

Growth of Trout to First Year

Date planted	*Length in inches* When planted	One year later	*Per cent caught in first season after planting*
RAINBOW			
September 9, 1940	3.0 in.	6.9 in.	1.8%
August 29, 1941	2.6 in.	6.4 in.	0.9%
June 11, 1942	1.5 in.	7.5 in.	3.1%
August 2, 1943	1.8 in.	7.1 in.	1.7%
July 29, 1944	2.4 in.	7.4 in.	5.8%
BROWN			
September 10, 1940	2.5 in.	6.0 in.	0.3%
September 18, 1941	2.2 in.	5.7 in.	0.07%
June 11, 1942	1.6 in.	5.8 in.	0.6%
August 2, 1943	1.5 in.	6.4 in.	0.4%
August 15, 1944	1.8 in.	6.6 in.	1.0%
BROOK			
August 20, 1940	2.7 in.	6.2 in.	2.2%
August 13, 1941	2.5 in.	6.0 in.	1.7%
June 11, 1942	1.6 in.	5.9 in.	0.1%
July 29, 1943	2.1 in.	7.1 in.	0.3%
July 29, 1944	2.2 in.	6.1 in.	2.6%

Table 9 is similar to the preceeding table except that the relationship is between size at planting time and average length in the second season following the year in which they were planted. It should be noted that:

a. The largest fingerlings at planting time are not the largest when captured in their second season. We may still conclude that from

the standpoint of size of caught fish there is no advantage in planting large fingerlings late in the season.

b. Survival to the angler does not seem to be greater in the rainbow and brown fingerlings which were largest at planting time but in the brook it appears that there is an advantage in planting large fingerlings. It should be pointed out that this might not necessarily be true if the lake contained fewer cannibalistic trout.

TABLE 9

Growth of Trout to Second Year

Date planted	*Length in inches* When planted	*Length in inches* Two years later	*Per cent caught in first two seasons after planting*
Rainbow			
September 9, 1940	3.0 in.	9.5 in.	2.9%
August 29, 1941	2.6 in.	9.7 in.	2.1%
June 11, 1942	1.5 in.	9.7 in.	4.0%
August 2, 1943	1.8 in.	9.2 in.	2.3%
Brown			
September 10, 1940	2.5 in.	8.1 in.	3.6%
September 18, 1941	2.2 in.	7.2 in.	1.6%
June 11, 1942	1.6 in.	8.2 in.	3.1%
August 2, 1943	1.5 in.	9.3 in.	2.1%
Brook			
August 20, 1940	2.7 in.	8.0 in.	3.0%
August 13, 1941	2.5 in.		1.9%
June 11, 1942	1.6 in.	7.8 in.	0.6%
July 29, 1943	2.1 in.	8.8 in.	0.4%

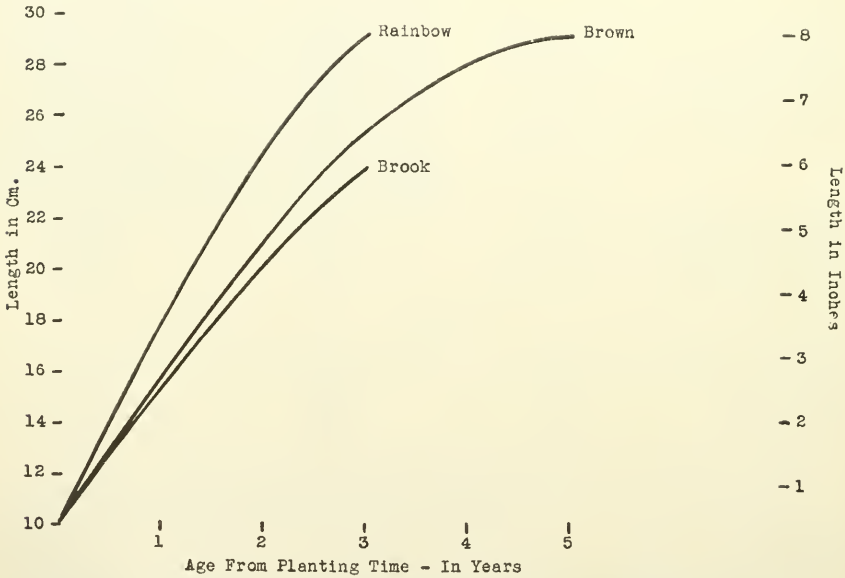

FIG. 34. Growth curves of trout in Castle Lake. Lengths are based on actual measurements of fish of known age at time of capture.

Condition Factors

TABLE 10

Condition Factors of Castle Lake Fish

	1941	1942	1943	1944	1945
Rainbow	1.02 (15)*	1.00 (44)*	1.05 (35)*	1.01 (22)*	1.08 (157)*
Brown	1.02 (49)	1.00 (46)	.91 (25)	.86 (51)	.90 (318)
Brook	1.03 (12)	.99 (36)	.88 (24)	.77 (7)	1.04 (44)

* Figures in parenthesis are the numbers of fish used in computing condition factors. In the five years, the fish under consideration ranged in length:
For rainbow, from 13-37 cm., average—22 cm.
For brown, from 15-35 cm., average—25 cm.
For brook, from 14-27 cm., average—20 cm.

For those not familiar with the condition factor (K) it may be explained that it is a ratio of length to weight, in other words it is an index to the "plumpness" of the fish. The factor is obtained through the following equation: $K = \frac{W \times 100}{L^3}$, where K is the condition factor in the metric system; W is the weight of the fish in grams and L is the length from snout to fork of tail in centimeters.

For the most part the factors given in the table above show a satisfactory condition in all groups. The factors for the brook in 1943 and 1944 and for the brown in 1944 were lower than might be desired. The cause is not evident, but it appears that the lake is not too crowded, in fact a few more fish might be accommodated to the benefit of the anglers. Roughly, though, we do know that the factors for the Castle Lake fish are not higher than those found in many other waters and for this reason alone we might well be careful about increasing the lake's population.

STOMACH CONTENTS OF CASTLE LAKE TROUT

Seven hundred and ninety stomachs were considered in this study (Tables 11 and 12). The numbers of stomachs of most of the classes of fish are statistically sufficient and it would seem probable that as a whole they give a fairly accurate picture of the foods eaten by trout in Castle Lake.

Table 11 shows the stomach contents classified according to the per cent of individual stomachs which contain the classes of food. This does not take recognition of the quantity of each class of food, it simply indicates the per cent of fish which had eaten *any* of that particular kind of food. This breakdown indicates "food preferences" of the Castle Lake trout and is not so indicative of the value of the food to the fish.

Table 12 shows the stomach contents classified according to the volume of a particular food present. Obviously this breakdown indicates both the food preferences and the "food value" but gives more weight to the quantity of food, in other words to its rank in growth promotion. This does not mean that all the foods are equally nutritious, volume for volume, but any measure which will show the relative volume of a food is probably of more practical importance than a measure which shows only the presence of a class of food. Thus it would seem that in this particular lake the data presented in Table 12 are more valuable to us than the data in Table 11. However, there are certain points brought out in Table 11 that are not shown in the other table and the opposite is

TABLE 11

STOMACH CONTENT ANALYSIS
1941-44, INCLUSIVE

Per Cent of Stomachs Containing Classes of Foods

Age	Specimens	Classes of Food: Surface	Bottom	Plankton	Fish
Rainbow					
1 year	76	39%	50%	45%	0
2 years	42	52%	40%	45%	0
3 years	13	85%	31%	16%	0
4 years	3	66%	0	0	33%
Brown					
1 year	36	36%	75%	11%	0
2 years	206	77%	70%	5%	1%
3 years	75	40%	83%	1%	4%
4 years	46	45%	37%	4%	9%
5 years	35	14%	66%	0	23%
Brook					
1 year	164	26%	55%	54%	1%
2 years	16	50%	75%	20%	0
Mackinaw					
All ages	78	5%	72%	22%	13%
Total	790				

TABLE 12

STOMACH CONTENT ANALYSIS
1941-44, INCLUSIVE

Per Cent of Foods by Volume

Age	Specimens	Classes of Food: Surface	Bottom	Plankton	Fish
Rainbow					
1 year	76	38%	36%	26%	0
2 years	42	48%	32%	20%	0
3 years	13	87%	9%	4%	0
4 years	3	73%	0	0	27%
Brown					
1 year	36	54%	42%	4%	0
2 years	206	50%	45%	1%	4%
3 years	75	23%	34%	trace	43%
4 years	46	38%	12%	trace	49%
5 years	35	8%	19%	0	73%
Brook					
1 year	164	31%	27%	37%	5%
2 years	16	65%	28%	7%	0
Mackinaw					
All ages	78	3%	44%	2%	51%
Total	790				

true. The best examples are to be found in the "plankton" and "fish" columns where one table alone might give the wrong impression. The mere presence of plankton in a class of stomachs is of little value unless we know the volume, but the presence of a fish will loom very large in Table 12 because of the size of each individual fish in any stomach. From the standpoint of nutrition the figure of the volume of fish eaten is important but from the standpoint of cannibalism and survival of planted fingerlings the presence of the smallest fragment of a fish is important evidence.

Both tables are necessary in such a study and though one table or the other if presented alone might simplify matters, still the whole story can not be told without both.

The "Classes of Food" need a few words of explanation. "Surface" food includes all the insects and arachnids which fall upon the surface of the water. This does not include immature forms of aerial insects such as caddis larvae, dragon fly nymphs, etc.

The "Bottom" foods include a great number of dissimilar organisms, in fact everything which spends most of the time on the lake bottom or on submerged plants. Thus in this group we have snails, annelids, insect nymphs and larvae, etc.

"Plankton" as the name implies are the plankton organisms. In this particular study we are concerned with copepoda, cladocera and rotifera. All are microscopic or nearly so and float about in the water with very little evident motion of their own.

"Fish" includes the young trout and probably the golden shiners and dace.

Food of the Rainbow

It is evident that the "surface" foods play a very important role in the rainbow diet, perhaps less so in the yearling group than in the older fish. The "bottom" foods are next most important but these seem to become less important as the fish grow older. Plankton is less important than the two preceeding but not greatly so. The younger the fish the more plankton it will eat and it appears that the oldest rainbow rarely eat this class of food. Of the 134 rainbow stomachs only one contained fish. From this it would appear that in Castle Lake the rainbow are not often cannibalistic. However, in many waters this species is very much given to cannibalism. One peculiarity of the rainbow is that it often eats algae and aquatic plants. We do not find this to be true of the other species. Whether they eat it for its own food value or for other foods contained in or on the plants is not known.

It can be said that the rainbow of Castle Lake are omnivorous but the "surface" and "bottom" foods and the plankton are far more commonly eaten than fish. With increasing age the rainbow seem to turn more to the "surface" foods and less to the "bottom" foods and plankton.

Food of the Brown Trout

For most of the brown trout in Castle Lake the "surface" and "bottom" foods are very important. With increasing age the "surface" foods are less frequently eaten. From the standpoint of volume the "bottom" foods are also eaten less as the fish become older. Plankton

is of rather minor importance except perhaps to the fingerlings. Cannibalism in the browns is quite common. With increasing age fish become more and more important in the diet.

The two really important differences between the browns and the rainbow are: 1. Rainbow eat much plankton while the browns eat little. 2. Browns eat considerable fish while the rainbow eat little.

FIG. 35. Eighteen-pound mackinaw trout caught in Castle Lake in 1941 by R. V. Miller, Jr. This fish is probably 17 years old.

Food of the Brook Trout

The diet of the brook trout in Castle Lake is more like that of the rainbow than that of the brown trout. "Surface" and "bottom" foods and plankton are all three used extensively while fish are not commonly eaten. So few of the brook trout in Castle Lake survive their second year that the number of large fish is too small to give information on their foods. Possibly older brook trout do eat other fish, but this point can not now be determined for Castle Lake. There is a 100% increase in the consumption of "surface" foods from the yearling to the two year old brook. On the other hand there is a very noticeable reduction in the frequency and volume of plankton consumption. This drop in plankton intake is much less in the rainbow of similar ages.

Food of the Mackinaw

The food picture in the mackinaw is quite unlike that of the other three species. This fish has rather definite likes and dislikes. It greatly prefers "bottom" foods to "surface" foods. In fact the "surface" foods play a negligible part in its diet in contrast to the other three species, where the "surface" types are, as a whole, the most important. In respect to plankton and fish the mackinaw resembles the brown trout. Both make little use of plankton and more use of fish. In fact the mackinaw can definitely be classed as a cannibal, at least this is true of the older individuals. The smaller mackinaw feed predominantly on "bottom" types, especially dipterous larvae.

If we must characterize the food habits of the mackinaw briefly we may say that the younger individuals feed very largely on "bottom" foods and the larger ones eat "bottom" foods and fish.

Comparison of the Four Species

It is clear that in Castle Lake the four species differ considerably in their food preferences and the foods of the age classes vary considerably too.

"Surface" foods play a very large part in the diets of the rainbow, brown and brook but not in the mackinaw. The "bottom" foods are very important to all four species. The plankton varies in volume and frequency of occurrence from species to species and age group to age group; it is of most importance to the rainbow, of least to the mackinaw. Fish are eaten by the larger mackinaw and brown trout.

The rainbow and brook, though displaying some differences, are fairly much alike. The browns are dissimilar, and the mackinaw are distinctly different.

MANAGEMENT

The following table is based on the costs of the numbers of trout which must be planted in order to yield one fish to the angler's creel:

TABLE 13

Cost of Each Fish Caught by Anglers in Castle Lake

Fish planted as:	Rainbow	Brown	Brook
Fingerlings	$0.30 each	$0.19 each	$0.69 each
Yearlings	0.13 each	0.15 each	0.13 each

Costs used in the above are based on the following overall production figures of the California State trout hatcheries:

Fingerlings—$2.67 per lb. or $0.011 each for average sized fingerlings weighing 15 per oz. (about 2 inches long).

Yearlings—$0.43 per lb. or about $0.05 each for fish weighing 8 per lb. (6 to 7 inches long).

It has been pointed out earlier in this paper that planting rainbow, browns and brook all together in Castle Lake is not the most efficient stocking policy. Therefore, it can be argued that the above production costs might be different if only one species were planted. Even though this is true the following comments seem justified:

1. Where predation is heavy it is more expensive to maintain fishing by planting fingerlings than by planting yearlings.
2. Where predation is heavy and where fingerlings must be planted it is best to use brown trout. This will probably hold true only in waters similar to Castle Lake.
3. Where predation is heavy the most expensive way to maintain fishing is by planting brook fingerlings, and the least expensive by planting rainbow or brook yearlings.
4. We can not be certain what we would find if predation were low but it seems quite possible that brook fingerlings would be as economical to plant as any other system. This aspect will be the subject of future investigations at Castle Lake.
5. The Castle Lake data show us that the hatcheries can not produce enough trout to yield to the angler much more than one limit [3] of trout for $2; and out of the $2 angling license fee a considerable part must go for patrol, administration, etc. This is not yet a critical matter because most of the trout caught by anglers in California are naturally spawned (wild) fish. However, as fishing increases the stock of wild fish will be further decreased to a point where catches will be unsatisfactory. This will happen despite the fact that with an increase in the number of anglers the revenue from license sales will rise, because the average angler catches from 60 to 70 trout per year,[4] and his license fee will produce only enough hatchery trout to yield one or at the most two limits. Thus if there is an increase of 100,000 trout anglers the following occurs:

   100,000 x $2.00=$200,000 increase in license money.
   One-half of this or $100,000 goes for trout production.
   $100,000 will produce 800,000 caught fish.
   100,000 anglers catching 60 fish a year=6,000,000 caught fish.

Thus with each increase of 100,000 anglers the number of all trout caught each year exceeds the number of hatchery fish caught by 5,200,000. Obviously there are two measures by which the otherwise inevitable exhaustion of our trout stock can be avoided. 1. Raise the license fee by several times what it now is and rear more hatchery trout. 2. Reduce the catch by any of several methods.

[3] The bag limit of trout is now fifteen per day.
[4] Based on catch statistics.

FERTILIZATION OF CASTLE LAKE

Although not included in the original program, a fertilization experiment became necessary in Castle Lake in 1944.

On July 1, two and one-half tons of soy-bean meal were spread over the shallower areas to determine the possibility of increasing the food organisms and thereby improving the growth and condition of the fish. The meal had a protein content of 44 per cent and cost $68 a ton. The quantity used amounted to 106 pounds per surface acre of the entire lake or $3.62 per acre. Actually the meal was distributed over only a small part of the lake bottom. Soy bean meal was chosen on the basis of experiments by Juday in Wisconsin in 1938.

The visible changes on the lake due to the meal were not great. Probably the most noticeable was the reduced visibility of the water. Whereas prior to the fertilization the Secchi disk visibility was 44-50 feet, soon after July 1st it was reduced to 20-25 feet. The water cleared somewhat by fall and the following spring the visibility was normal again. This turbidity was largely due to the great numbers of rotifers (Nothalca).

Aquatic plant growth increased slightly but this could have been due to factors other than the fertilization.

Plankton sampling showed no increase in abundance that could be indubitably ascribed to fertilization. The number of copepods per cubic foot did rise appreciably from 1944 to 1945 and this could have been due to the soy-bean meal, but the number of cladocerans showed some decrease at the same time. It does not seem probable that the increase in copepods caused any considerable improvement in growth rates or condition factors of the fish but this point can not be decided until the 1946 catch has been measured.

The standing crop of bottom food organisms in 1945 was not increased over the average for the preceeding years. It would seem likely that this food category as well as plankton should have been increased if the fertilization was effective.

There is no evidence at this time to show that one application of soy-bean meal improved the stock of fish nor the carrying capacity sufficiently to justify the expense.

Summary

1. Castle Lake lies about 11 miles southwest of the town of Mt. Shasta in Siskiyou County. It is in the Sacramento River drainage at an elevation of 5,200 feet. It is slightly larger (47 acres) and deeper (maximum 120 feet) than most lakes in the Klamath mountains, but otherwise typical of these small glacial cirque lakes.
2. Castle Lake was chosen for experimentation because of its typical character; because it has a road to it which makes for above average fishing intensity; because it is so located that all anglers can easily be checked; and because it is close to the District Fisheries Headquarters and State Fish Hatchery at Mt. Shasta.
3. The objectives of this investigation were to determine the most suitable species of trout to plant in mountain lakes of this type, the optimum size of fish at planting time, and the optimum num-

ber to plant. Three species were used in equal numbers, but the question of the most suitable was obscured by the fact that in a mixed population the success of the component species may be quite unlike their success if they inhabited the lake singly.

4. There is practically no natural propagation of the rainbow, brown and brook trout, and as the hatchery-planted fish were marked it was a simple matter to compute survival rates. All fish planted since 1938 have been recognizable either through marks or their lack, and all catches have been checked from 1941 through 1945.
5. Following are angling figures from 1941 through 1945:

Average number of angler days	580
Average angler days with zero catches	242
Average annual total catch	1,531
Average catch per hour	0.71
Average number of individual anglers	218

Fifty per cent of the annual catch is caught by an average of 13 anglers.

6. Per cent of catch (Average of 1941-45, inclusive):

Rainbow	*Brown*	*Brook*	*Mackinaw*
35%	47%	15%	3%

From 1938 to 1945 the numbers of rainbow, brown and brook planted have been approximately the same. The great differences in the percentages above indicate the dissimilar survival rates of these three species.

7. Pounds of trout caught annually (Average of 1943-45, inclusive):

Rainbow	*Brown*	*Brook*	*Mackinaw*	*Total*	*Average per acre*
153	268	32	36	489	10.4

Here we see an even greater difference between the three planted species despite nearly equal numbers stocked.

8. Per cent survival to the anglers:

Of Planted Fingerlings

Rainbow	*Brown*	*Brook*
0.5-7.8%	5 -9 %	0.4-3.2%
Av. 3.5%	Av. 5.5%	Av. 1.9%

Of Planted Yearlings

Rainbow	*Brown*	*Brook*
39%	35%	40%

The greatest loss, particularly in the fingerlings, is probably due to cannibalism during the first days in the lake. The differences in habits of these species may account for the survival differences. Brooks almost disappear from the catch by the third year after planting; browns play a significant part for five or six years after planting, and thus tend to build up a backlog of older fish; rainbows are intermediate between the other two.

9. From the standpoint of growth it appears that fingerling rainbow, brown and brook can be planted to advantage early in the season while they are still relatively small.
10. From the standpoint of survival it does not appear to make any difference what size the fingerling rainbow and browns are at

planting time. However, for the best survival in the brook trout the fingerlings should be as large as possible at planting time.

11. The growth rate of the rainbow in Castle Lake is most rapid, that of the brown is second and the brook third.
12. Approximate maximum ages of Castle Lake trout:

Mackinaw	*Brown*	*Rainbow*	*Brook*
20 years	7-8 years	6 years	3 years

13. The condition factors for the Castle Lake fish are satisfactory and it is possible that the lake could carry more trout.
14. The food preferences of the four species of trout in the lake differ considerably. Marked differences also occur in the various age classes. "Surface" foods play a very important part in the diets of the rainbow, brown and brook but not in the mackinaw. The "botton" foods are very important to all four species. The plankton and fish eaten vary in volume and frequency of occurance from species to species and age group to age group. The rainbow eat plankton but almost no fish whereas the brown and mackinaw eat fish but little or no plankton. The rainbow and brook, though displaying some differences, are fairly much alike. The browns are dissimilar and the mackinaw are unique.
15. A test fertilization with soy-bean meal in 1944 (106 lbs. per surface acre) has not appreciably improved the condition or growth rate of the trout.
16. The following costs are for caught fish, both when planted as fingerlings and when planted as yearlings:

Cost Per Fish Caught by Angler

Planted as:	Rainbow	Brown	Brook
Fingerlings	$0.30 each	$0.19 each	$0.69 each
Yearlings	0.13 each	0.15 each	0.13 each

With a mixed population and consequent heavy predation the brown fingerlings or the rainbow and brook yearlings are the most economical to plant.

17. It seems reasonable to assume that a mixed population such as that which has existed in Castle Lake is not as efficient from the standpoint of trout production as a population of one species. Beginning in 1946 this belief will be tested by stocking with brook trout alone.

APPENDIX

Physical and Chemical Data

Temperature

Temperature readings were obtained at two stations in Castle Lake at approximately two-week intervals throughout the May-October months of 1941-1945, inclusive. The "deep-water" station was located in the center of the south end of the lake while the "shallow-water" station was located in the center of the north end. In the deep end of the lake temperatures were taken at 25-foot intervals down to 100 feet (approximate bottom) except where more readings were necessary to characterize the thermocline. In the shallow end temperatures were taken at the surface and at the bottom (10-12 feet). Temperatures at top and bottom in this section were quite similar and approximately the same as the surface of the deep end which is shown in Fig. 36.

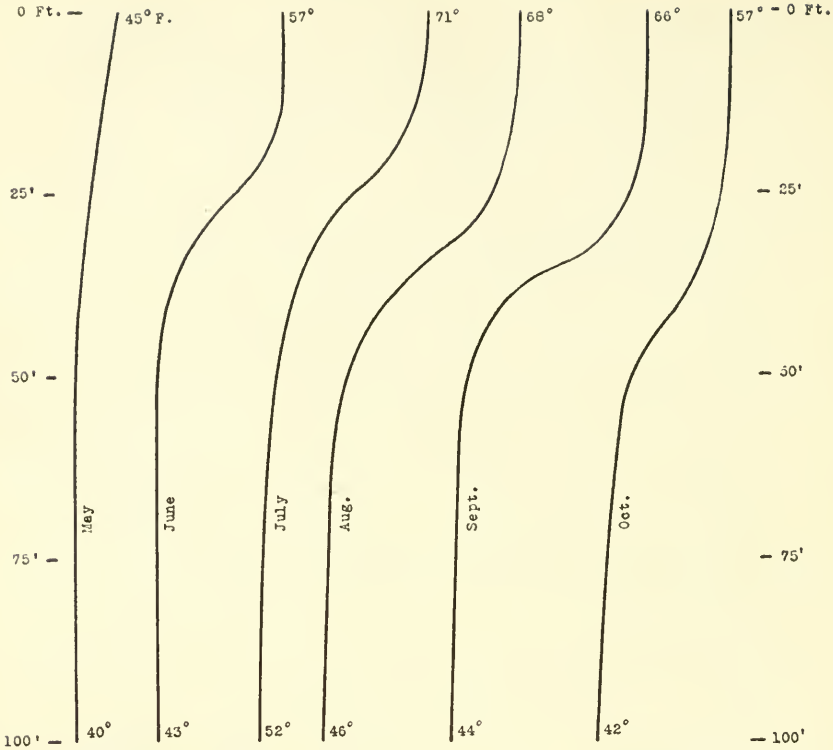

FIG. 36. Temperature curves for the deep water station. Curves smoothed by eye to show average conditions by the month.

There are a few points concerning water temperatures in Castle Lake which should be brought out.

1. At no time do temperatures in the lake reach the maximum tolerated by trout. In one year a surface temperature of 74° F. was recorded but this was above the average maximum. It is commonly believed that 70° F. is above the preferred range of most trout but still about 12° below the lethal point.
2. During the winter (December-April, inclusive) while the lake is frozen over the water temperatures are too cold for even moderate growth.
3. Fishing is affected, quite naturally, by the water temperatures. In early May the water is a little too cold for best results and in mid-summer the surface temperatures are too high. Best fishing occurs in late May, early June, late September and in October. Thus the temperatures produce good fishing for about two and one-half months. During the remaining parts of the open season the fishing is mediocre. It would be desirable if we could give definite critical temperatures for the optimum fishing range but at present we can not. In this lake the lower limit of the range seems to lie at about 45° F. or slightly under while the upper limit is somewhere between 60° and 65° F. The mid-summer lull in

fishing is very apparent in most mountain lakes in California and it is quite certain that temperature is at least the principal factor involved. The trout are far less easily observed during this warm period and it is apparent that they go into deeper, cooler water. However, the few attempts which have been made at trolling in the cooler water of Castle Lake have not been successful. Probably the feeding habits change sufficiently during mid-summer to make the common fishing methods less effective.

Oxygen

The oxygen picture in Castle Lake is quite variable from month to month and year to year. Samples have been taken from 0-100 feet at two-week intervals during the past five years and the lack of uniformity is remarkable. It would be necessary to take many more samples before the underlying causes of these changes could be cleared up. Nevertheless a few generalities can be made.

1. A few summer samples taken at 100 feet have shown oxygen tensions lower than 5 p.p.m. but at all depths ordinarily frequented by trout the oxygen is completely satisfactory.
2. The highest reading to date was 15.0 p.p.m. taken at 50 feet on July 29, 1943. The lowest was 1.0 p.p.m. taken at 100 feet on September 4, 1945.
3. Surface readings range from 9.0-13.0 p.p.m. In a general way the oxygen readings at 50 and 75 feet range lower than that at the surface. At 25 feet the oxygen ranges from a little above to a little below the surface readings.
4. No correlation has been observed between the habits of the trout in Castle Lake and the oxygen readings. This is probably the the same for most of our natural, mountain lakes but is quite unlike the situation found in many reservoirs where oxygen deficiencies become a serious consideration.

Hydrogen Ion Concentration

The pH of the Castle Lake water would seem to have little or no bearing on the habits of the trout. Readings usually lie between 7.5 and 6.5 with the water at 100 feet tending to be a little more acid in summer.

Visibility

The visibility of the Castle Lake water, as measured with a Secchi disk, ranges from 40-55 feet during the summer.

Plankton

TABLE 14

Average Numbers of Copepods and Cladocera per Cu. Ft.

	North end	E. shore	South end	South end
	10′-0′	15′-0′	50′-0′	100′-50′
Copepods				
1943	149	168	111	44
1944	301	257	125	68
1945	577	624	321	168
Cladocera				
1943	42	31	46	19
1944	139	110	42	17
1945	33	85	73	49

The figures above show an increase in the number of copepods in 1945. This rise is probably not due entirely to an increase in the net efficiency. However, it would seem to be unwise to say that this increase was due to the soy-bean meal put into the lake in 1944. There is too much natural variation from year to year to justify any such assertion. Of course, such a thing is entirely possible, in fact it would be strange if 106 pounds of soy-bean meal (44 per cent protein) per acre did not bring about some appreciable change. Probably the greatest benefit from this increase in the copepod crop would be to the fingerlings planted in 1945. This effect can not be measured until 1946. We have seen that there was a slight improvement in the condition factors of the combined age groups of all three species for 1945 but these figures are so variable that it seems unwise to claim that the increase is due to fertilization.

Phytoplankton, large enough to be caught in a #20 bolting cloth net, is so scarce in Castle Lake that it is not counted. Only three groups of zooplankton are worth considering. In addition to the Copepoda and Cladocera listed in the preceding table we have the rotifers. Most of these belong to the genus *Nothalca* and at times during the season they are very abundant. Soon after fertilization in 1944 they were sufficiently abundant to reduce the visibility from 45 feet to 20 feet. This bloom did not last long and by the following year they had returned to normal abundance.

Bottom Foods

TABLE 15

Number of Bottom Samples Taken

1941	17 samples
1942	20 samples
1943	24 samples
1944	29 samples
1945	24 samples
Total	114

Average Quantity of Food Per Sample

1941	.27 cc per 36 sq. in. sample	=1.16 gm. per sq. ft.
1942	.15 cc per 36 sq. in. sample	= .64 gm. per sq. ft.
1943	.22 cc per 36 sq. in. sample	=1.00 gm. per sq. ft.
1944	.12 cc per 36 sq. in. sample	= .52 gm. per sq. ft.
1945	.16 cc per 36 sq. in. sample	= .69 gm. per sq. ft.
Av.	.18 cc	Av. .80 gm.

Per Cent by Volume of Food Classes

	Annelids	*Diptera larvae*	*Snails & clams*	*Caddis larvae*	*Mayfly nymphs*	*Odonata nymphs*	*Neuroptera nymphs*
1941	13%	31%	3%	24%	3%	26%	
1942	24%	21%	5%	32%	2%	16%	
1943	23%	20%	6%	9%	1%	22%	19%
1944	12%	34%	9%	29%	2%	14%	
1945	22%	44%	7%	20%	3%	4%	
Av.	19%	30%	6%	23%	2%	16%	4%

Pounds of Trout Food Per Acre *

	North end	*South end*	*Entire lake*
1941	135 lbs.	50 lbs.	104 lbs.
1942	76 lbs.	54 lbs.	65 lbs.
1943	142 lbs.	46 lbs.	96 lbs.
1944	70 lbs.	37 lbs.	53 lbs.
1945	55 lbs.	84 lbs.	68 lbs.
Av.	96 lbs.	54 lbs.	77 lbs.

* In these computations 1 cc. of bottom organisms is estimated to weigh 1.1 gms.

The number of bottom samples taken in any one year was not sufficient to give a reliable picture of the bottom foods in Castle Lake. However, it seems probable that the data accumulated during the five-year period give a fairly satisfactory idea of the quantity and composition of this group of food organisms.

The variations in quantity of food organisms from year to year are to some extent due to variations in sampling technique and not due entirely to changes in the biological factors which influence bottom food production.

The breakdown of the bottom food as given in the five year average of "Per Cent by Volume of Food Classes" would seem to be a fairly reliable index to the situation existing in the lake. Certain of the variations from year to year are probably actual changes in the composition rather than changes in technique.

The average pounds of food per acre in the north end of the lake is probably a reliable one. The south end is more difficult to analyze because a large part of its area is much deeper than that at which the samples were taken. In fact the bottom lying deeper than 40 feet has little or no trout food. Therefore the average of 54 pounds indicates the standing crop near shore only. Adjustment for this fact is made in computing the pounds per acre for the entire lake.

The north end of the lake has an average depth of about 12 feet and, of course, is much more productive than the deeper water of the south end. In fact the bottom food production seems to drop off from a maximum in 12 feet of water to almost zero at 40 feet. However, trout food organisms, such as some annelids, do occur in Castle Lake at 95 feet.

Any value that the preceding figures on grams per square foot or pounds per acre may have will be from comparison with bottom food production in other waters. Once we know the approximate carrying capacity of this lake, and with knowledge of the standing food crops, the fish production of other waters may be judged from a study of their food crops.

The 1945 bottom food data clearly indicate that the soy-bean meal applied to the lake in 1944 did not increase the bottom food production.

OBSERVATIONS ON COOPER HAWK NESTING AND PREDATION[1]

By Henry S. Fitch, *United States Fish and Wildlife Service;* Ben Glading, *Bureau of Game Conservation, California Division of Fish and Game; and* Verl House, *United States Forest Service*

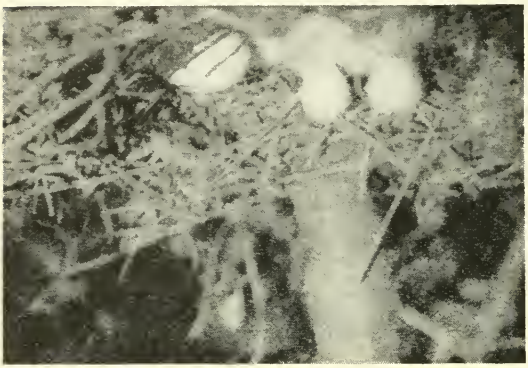

Fig. 37. Cooper hawk nest, eggs, and fledglings. May 29, 1939. Three of the young had already emerged and the fourth egg was pipped.

Studies were made on the activities and feeding habits of a pair of Cooper hawks and their young in the summer of 1939, during the course of a general wildlife program at the San Joaquin Experimental Range,[2] located in the Upper Sonoran foothills of the Sierra Nevada, about 25 miles east of Madera, California, in the blue oak and digger pine belt. Cooper hawks are permanent residents of the area, the population being augmented in fall and winter by migrants and winter residents.

Some data on the various prey species are available. The quail population at the time of observation (June) was estimated on the basis of censuses taken at other times of the year to be about one per acre, of which about one-half were young of the year. Towhees, mourning doves, kingbirds, and lark sparrows were also common in the summer. The mammal population included on the average about five ground squirrels, eight pocket gophers, and slightly more than one cottontail to the acre. Other kinds of mammals present were so largely nocturnal as to be seldom available as prey to the hawks. The lizard population could not be estimated accurately, but probably much exceeded the combined bird and mammal populations. The whiptail *(Cnemidophorus tesselatus),* fence lizard *(Sceloporus occidentalis),* brown-shouldered lizard *(Uta stansburiana),* and skink *(Eumeces gilberti)* were common.

Description and Brief History of the Nest

A nest was located about the middle of May, near the top of a dense live oak *(Quercus wislizenii),* about 30 feet above the ground. It consisted of a thick platform of dead twigs, apparently built originally by

[1] Submitted for publication March, 1946.

[2] Agencies cooperating in the general wildlife program are the U. S. Fish and Wildlife Service, U. S. Forest Service, California Forest and Range Experiment Station, University of California, and the California Division of Fish and Game. E. E. Horn and T. I. Storer form a special technical advisory committee.

Assistance rendered by the WPA is acknowledged.

wood rats. Other rat nests were present in the top of the tree and at its base. The nest was coarsely lined with a few dry oak leaves, pine needles, and strips of bark. There were four eggs.

During the two weeks interval from the date of discovery until the eggs hatched, the incubating female was observed on the nest on several occasions. On May 28, one egg had hatched and another had pipped. On the following morning the second egg had hatched and a third was partly broken open. Late in the afternoon of May 29, the third young had hatched and already was dry and fluffy; the fourth egg was beginning to hatch. On the afternoon of May 30, this last young had emerged and the four nestlings were of noticeably different sizes.

On June 3, one of the larger young was removed from the nest and brought into the laboratory where it was kept alive. The other three birds remaining in the nest were observed from a blind placed in the tree about 15 feet from the nest. On June 23, two of the young were observed to leave the nest for the first time. From this date, until the latter part of July, they were observed from time to time in the nest tree and the surrounding territory.

Supplementary information was gained from visits to another Cooper hawk nest located about one mile northwest of the one under intensive study.

FIG. 38. Nestling Cooper hawks, June 6, 1939, 8-10 days old. At this stage the birds were growing rapidly. One of the larger young had been removed and taken to the laboratory on June 3.

Behavior of Adult Birds

During the period of incubation, the female usually flew off the nest and left the immediate vicinity while observers were climbing the nest tree. She would sometimes move about in neighboring trees, calling occasionally. The male was not usually in evidence during incubation.

After hatching, the female was more reluctant to leave the nest and became increasingly aggressive on successive occasions. She no longer kept out of sight, but flew from one perch to another, cackling, and was sometimes joined by the male. His cackling was noticeably different from that of the female; the notes being less harsh and more rapidly uttered.

Because of the secretive habits of the adult hawks, little was learned regarding their method and range of foraging. After the nest was discovered, it was found that several blue oaks and digger pines on the same hillside, all within 150 yards, were favorite perches. Under each of these trees were accumulations of white excreta, showing that the birds spent much of their time there. Careful search beneath the perches failed to reveal any pellets. Apparently, these trees served mainly as loafing places and lookouts from which the area near the nest tree could be guarded at times when the birds were not actually forag-

ing. Scattered feathers beneath some of the perches indicated that occasionally prey was eaten there. On some occasions at least, the birds ranged far afield to forage. Several times they were seen to start out with rapid, direct flight to the east and slightly north, traversing an area that is more level and open than that where the nest was located. They continued in this direction until lost to view in the distance at least one-half mile from the nest. On other occasions one of the hawks was seen returning from this direction carrying prey. A male, presumably of this pair, was seen about three-eighths of a mile west-northwest of the nest and flying toward it. It seemed probable that the foraging territory was distinct from the nesting territory. The parent birds were not seen to make any kills near the nest during the time it was under observation.

Incubation of the eggs and brooding of the young was attended to entirely by the female in observed instances, during the time the nest was watched, but the male assisted in feeding the young. On June 13th, when the nest was kept under observation all day, seven food items were brought in by the parents, and the male brought four of these. The young were still small and downy on this date and the female spent much time brooding them while the male evidently was doing a large part of the hunting. Once, when the male brought in food while the female was on the nest, both parents fed the young. On other occasions items brought in by either parent were dismembered and fed to the young by the female. On June 23, 24, 27, 28, and 29, the parents were seen to bring in 18 items, 16 of which were brought in by the female and only two by the male. On these dates, the young were already partly feathered out and no longer required the protection of the female at the nest. After the young had left the nest the male was seen to bring food to the young on four occasions; the female was seen to feed them twice.

Behavior of the Young Hawks

Captive Bird

One of the nestlings was taken to the laboratory on June 3. Observed feeding, growth, and habits of the captive young hawk served to supplement the less complete observations on the three young left in the nest. From the start, this bird fed well and grew rapidly. It was fed small pieces of meat with the aid of forceps. At first, it was fed frequently, mainly on nestling sparrows. Later, its diet consisted of many kinds of food, among which were ground squirrels, cottontails, lizards, and snakes. No record of the food consumed was kept until June 7. Thereafter, except for the omission of a few days, all food taken by the bird up to the time it had attained adult size and could forage for itself was recorded and weighed. The weight curve of this bird (Fig. 39) shows that for the first 17 days after hatching, growth was extremely rapid, but then abruptly slowed down before the bird began to feather out and continued very slowly for the next three weeks, until the hawk had attained its full size. The amount of food taken varied greatly from day to day. The maximum daily intake was obtained by feeding at intervals of a few hours throughout the day until five meals had been given. However, the bird's appetite was variable and was noticeably decreased on a day following one of unusually heavy feeding. It is probable that the feeding of this bird differed from that

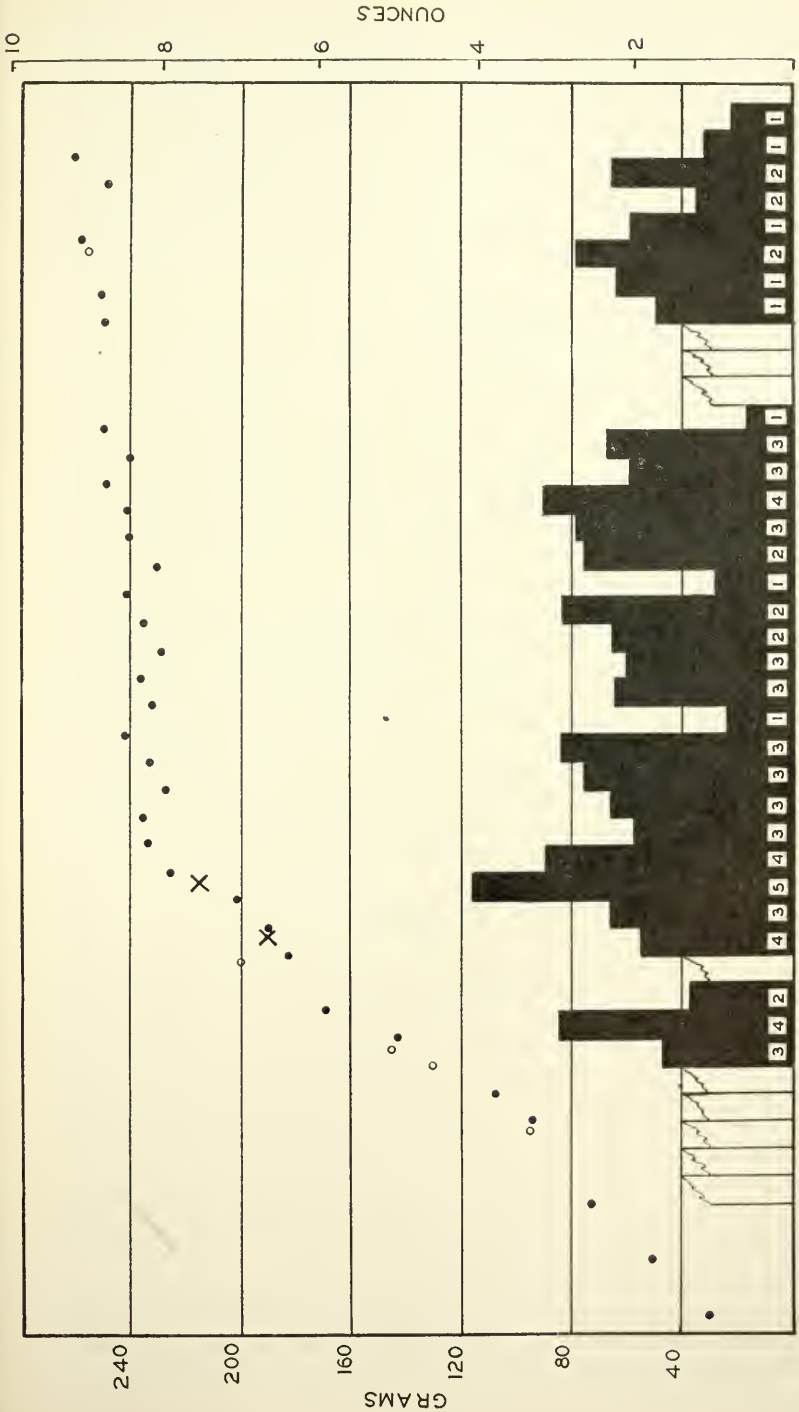

FIG. 39. Growth curve of young Copper hawks together with daily food intake of captive hawk. Solid dots represent weight of captive hawk before daily intake of food. Open dots are weights of same bird after some part of the daily food was fed. Crosses indicate weights of the largest wild bird in the same brood taken at the nest. Solid columns indicate weight of daily ration; open columns indicate some food was fed, but no record of amount was kept. Numbers at the bottom of the solid columns indicate the number of separate meals fed per day.

of those reared by the parents in that the meals were less frequent and were taken more rapidly and in larger pieces.

The food recorded as taken by the young bird during the six weeks of observation averaged 62.3 grams (more than two ounces) a day. Allowing this amount for the days when no record was kept, total consumed is estimated as 2,741 grams (roughly six pounds). For the whole brood this would amount to 10,964 grams or about 24 pounds. To furnish this amount, about 500 whiptail lizards would have been required if this preferred prey species had been used exclusively. At times the daily food intake approached 50 per cent of the weight of the young hawk (see Fig. 39).

The young hawk was removed from its nesting box and kept outdoors after it was nearly full size and had begun to feather out. At first, it spent much of its time perched about three feet above the ground in a lupine bush. At feeding time when it was called, if the bird was sufficiently hungry it would flutter down from this perch and run clumsily across the lawn to its meal. Even after it was able to fly, it seemed reluctant to do so, but still would run for 20 or 30 feet to its food. It was characteristically reluctant in coming to be fed even when hungry, but when called would answer with its own hunger "tseé-ear" call and, apparently waiting for its food to be brought to it, would leave its perch only after considerable urging.

On June 30, when it was slightly more than a month old, this hawk was able to fly out of the yard, and thenceforth, spent most of its time in nearby trees. On July 7, when it was called down to be fed, a small, live gopher snake was placed alongside the food. At first, the hawk not noticing, nearly stepped on the snake, but then seemed to recognize the reptile and flew off in a sudden fright and could not be called down again that day. On July 8, the hawk was offered a live, adult fence lizard and took this prey from the hand of the observer, then killed and ate it. On July 10, when the bird was unusually hungry, it was noticed attempting for the first time to catch its own prey, chasing grasshoppers on the lawn, but apparently without success.

To test the hawk's reaction to other prey, a live mouse *(Peromyscus maniculatus)* was released from a live trap and dropped in the middle of the lawn. The hawk, standing on the ground, watched intently for a moment as the mouse bounded away, then flew in pursuit, pounced upon it and stood screeching, holding down the prey with one foot. It pecked at the mouse, but twice relaxed its hold and allowed the mouse to escape, as yet seemingly uninjured. Each time, with remarkably quick and accurate dashes, the hawk recaptured the mouse before the latter was able to reach shelter. At first, it seemed unable to kill the prey, but merely pulled at the tail and fur. When disturbed, it flew to the roof, then to a nearby oak tree, carrying the prey. Twenty minutes later, it was again on the lawn with the remains of the mouse and had already eaten the head and forequarters. It continued to eat until the whole animal had been consumed.

From this experience the hawk learned to anticipate the release of prey whenever one of the small metal live traps was displayed. Upon sight of the trap carried by a person, or upon hearing the metallic sound produced by tapping the side, the hawk would fly to a vantage point on the roof or a tree and wait until the prey was dropped out. It would

then swoop down, snatch the mouse off the ground without stopping and would carry it away to a high perch and eat at leisure. It seldom failed, but on one occasion its attention was distracted as the mouse made for shelter so that its swoop was too late, and the mouse hid in a tangle of vines and other vegetation. The hawk searched briefly for it, then returned to the middle of the lawn and gave hunger calls. Two persons searched in the vines for the mouse and the hawk flew over and joined in the search, wading through the vines and peering intently for its prey when the foliage was parted by one of the searchers.

On successive occasions, the hawk showed increasing proficiency in killing prey. Once, when a three-quarters grown wood rat was released as an offering, the hawk swooped down without hesitation, seized the animal with both feet and sank its talons with jerky, contractile movements. The wood rat appeared to be dead after a few seconds and the hawk, burdened with its prey, flew off heavily to a perch where it commenced eating.

Repeatedly during the latter half of July, the hawk was seen to pursue cottontails and birds of various species. It was not seen to make any kills, but its varying appetite at feeding times suggested that it was successful occasionally. As it grew familiar with the surroundings it wandered farther afield, but continued to center activities about the buildings and lawn where it had been raised. At the end of July, its range of activity was more than a quarter of a mile in diameter.

On August 1, it was seen circling at an altitude of perhaps 100 feet maneuvering with a sparrow hawk. The latter was keeping above except when making occasional swoops. After each swoop of the sparrow hawk, the Cooper hawk pursued with rapid, direct flight until the other dodged and gained back its altitudinal advantage.

The Cooper hawk grew hostile in its demeanor towards humans as it became more independent. It would come to be fed if it was hungry, but would fly down, snatch the morsel and carry it away without stopping. If the food was too heavy to be carried away, or was held down by a person, the hawk would try desperately to drag it away, flapping and screeching. If approached, its protesting screeches would become even more pronounced and it would crouch over the food, "mantling" with wings and tail as it faced away from the observer. When coming in to feed, it would usually fly to the ground a few feet from the person who held the food and would stand off, eyeing him suspiciously and giving hunger calls. Then, with a sudden run forward, it would pounce on the food. If touched while feeding, it would prance about frantically, screeching and leaning back to strike with its feet. Several times when teased, the hawk became so enraged that it left its food to fly at the tormentor.

On August 4, this hawk was found in a quail trap about one-quarter of a mile from headquarters with two adult quail, of which one was already dead and the other dying from injuries. When approached, the hawk fluttered about the trap in an attempt to escape, giving the characteristic adult cackling notes (first heard on July 18, when it was alarmed by a dog). After a few seconds, it appeared to recognize the approaching persons, subsided, and gave the usual hunger calls. On the following day, August 5, it was again found in a quail trap with

a dead quail. At this time its activities were deemed not beneficial and its career was quietly terminated.

Wild Birds

Development of the young in the nest closely paralleled that of the captive bird. At all times during incubation of the eggs and growth of the young, the nest was kept scrupulously clean; usually no trace of prey could be found in it. On a few occasions stray feathers or the tail of a lizard remained after a feeding period. Excreta were voided over the edge of the nest. Though the nest was beneath the outer screen of foliage, it was not completely protected from the sunshine. Until the young had begun to feather out the female was brooding them almost constantly during the heat of the day. When she was flushed off the nest while it was partly exposed to the sunshine, the young began to show signs of distress almost immediately and moved about the nest in search of shade. When the young were old enough to notice their surroundings, they showed fear and hostility toward a human intruder. They would face him silently with mouths open, either standing erect or crouching. It was difficult to remove them because they would clutch the frame-work of the nest.

FIG. 40. Nestling Cooper hawks, June 15, 1939, 17-19 days old. At this stage the birds had just completed a period of rapid growth and were approaching full weight. They were feathering out rapidly.

Weights were taken of the young birds at several times during their development. These weights followed closely the development curve of the captive bird (see Fig. 39).

By June 23, the young were well feathered out and on that date they were seen flapping their wings and fluttering from one side of the nest to the other. In the afternoon, when the observer climbed to the nest to photograph it, two young left and fluttered and hopped from

twig to twig in the tree. Only the smallest hawk remained in the nest. On the following day all three were back in the nest, but the largest two left again when disturbed. On June 28, the smallest hawk still remained at the nest while the other two flushed. Thereafter, the young were not seen at the nest, but for several days they remained near the nest tree.

Throughout the period that they were in the nest, the young hawks were never heard to utter a sound, but on June 29, after they had scattered, loud and persistent hunger calls, "tsee-ar" were given by them. For several weeks after leaving the nest the young continued to depend on the parents for food. During this time their characteristic hunger calls served to inform the parents of their whereabouts.

Though perhaps guided to some extent by these calls, the parents seemed not to bring the food directly to the young. On July 11, one of the young was located sitting in a pine tree. After this young hawk had been watched for half an hour, the adult male suddenly appeared, flying low over the ground, carrying a whiptail lizard; he darted into the tree about ten feet below the young bird which gave persistent hunger calls but did not move from its perch. The adult gave short, cackling notes and began to eat the lizard. After five minutes, it stopped eating and sat holding the remains of the prey, giving short calls at intervals. The young bird in the tree kept calling persistently, but after an hour had made no move to secure the food held by the parent. Finally the male became alarmed by a movement of the observer and flew away with the lizard.

On the following day the female was seen carrying some object as she flew out of a tree where two of the young were calling. She perched in another tree about 100 yards distant. After a few minutes one of the young flew to the same tree and the female flew out without the prey, which she had evidently left on her perch. The young then secured the remains of the prey (a bird) from the limb where the female had been sitting. She had eaten most of it before leaving.

On the same day one of the young was seen to fly up from the ground beneath a tree and a freshly killed whiptail lizard was found at the spot from which it came. Probably this prey had been secured from one of the parents and dropped by the young. On the following day, July 13, one of the young which had its crop already distended with food was found in a pine, 30 feet above the ground, pecking at a partly eaten whiptail lizard which it was holding with one foot. It allowed the observer to approach directly under it but watched him intently, then flew to another perch 200 feet away, carrying the lizard dangling from its claws.

On July 15, the female, carrying a small bird, flew into a tree near the nest site, perched there and began to eat. Two of the young hawks gave hunger calls and flew to her from a tree about 200 feet away. When the observer approached, the female left, and still carrying the prey made a flight of about 100 yards to another tree, followed by both young. Immediately the female left without the prey and one of the young was seen carrying it.

On July 17, the young were ranging more widely than before and were covering an area roughly 300 yards in diameter. On August 1, two hawks, one giving the characteristic hunger calls of the young and

the other evidently an adult, were seen about two-fifths of a mile from the nest flying away from it toward an area where the parents often foraged. This was much farther than the young had been known to venture before. During the following weeks the entire family disappeared from the nesting territory, evidently having scattered as the young learned to secure their own food. There was no indication that the young were taught to hunt by the parents. Evidently the ability to find and catch prey came naturally as the birds developed.

Feeding Habits

While the young birds were in the nest, a total of 75 hours was spent watching from a blind placed in the tree about 20 feet from the nest. Observations were made to include every daylight hour, although certain daily periods received more attention than others. The adult hawks exhibited preference for mid-morning and mid-afternoon foraging periods. Activity in bringing prey to the nest tended to be greatest from 9 :00 a. m. to 11 :00 a. m. and from 3 :00 p. m. to 5 :00 p. m. These periods of activity are not synchronized with activity of birds, but perhaps correspond roughly with active periods of lizards which made up a large part of the total diet.

It is possible that the adult birds foraged during the early morning and late evening period and ate the food captured at these times themselves, choosing to feed the young during the mid-day periods on the prey most readily available at that time. However, many of the items that were brought to the nest were eaten on the spot by the adult hawks; others, such as whiptail lizards had been partly consumed before the remainder was turned over to the fledglings.

Several visits were made to Nest #2, located about one mile to the northwest; three food items were discovered at this nest.

A list of the food items that were brought to the two nests is given in Table 1. An average of .56 food items per hour was brought to nest #1 during 75 hours of observation on eleven different days.

The proportion of birds among the prey items was surprisingly small, only 26 per cent. Quail, generally a favorite prey of Cooper hawks, made up 13 per cent, while a rather unexpected item, lizards, comprised 68 per cent.

Bent, 1937, (Life histories of North American birds of prey, Part 1, U. S. Nat. Mus., Bull. 167, p. 118) and McAtee, 1935, (Food habits of common hawks, U.S.D.A. Circular 370, p. 10) mention lizards as a food source of minor importance to Cooper hawks. In the course of our observations on nest #1 all but three of the lizards recognized were whiptails. All of the lizards seen by us were large adult whiptails, fence lizards, and skinks. The brown-shouldered lizard, the commonest species on the area, is considerably smaller than the others and it is exceedingly quick in its movements. It was not recorded among the prey items, nor were the young of the larger species.

The small proportion of quail brought to nest #1 by these birds suggests two possibilities; (1) that under local habitat conditions this game species does not comprise an important part of the nestlings' food, or (2) that individual Cooper hawks vary in their choice of food. Three food items recorded from another Cooper hawk nest on the range, just

TABLE 1

Food Items Observed at Two Cooper Hawk Nests
San Joaquin Experimental Range, 1939

Food Species	Nest No. 1		Nest No. 2		Total	
	Number	Per cent of total	Number	Per cent of total	Number	Per cent of total
Whiptail lizard	19	50.0			19	46.3
Unidentified lizard	4	10.5			4	9.8
Fence lizard	2	5.3			2	4.9
Skink	1	2.6			1	2.4
All species of lizards	26	68.4			26	63.4
Valley quail	5	13.2	2	66.6	7	17.1
California woodpecker	2	5.3			2	4.9
Brown towhee	1	2.6			1	2.4
Lark sparrow	1	2.6			1	2.4
Unidentified small bird	1	2.6			1	2.4
All species of birds	10	26.3	2	66.6	12	29.3
Cottontail	2	5.3			2	4.9
Ground squirrel			1	33.3	1	2.4
All species of mammals	2	5.3	1	33.3	3	7.4
Totals	38		3		41	

before it was quitted by the young, included two young quail and one young ground squirrel, but no lizards. This sample is too small to afford a basis for comparison of food preferences in the two pairs, but it seems to suggest that there may be individual differences.

On several occasions the parents themselves were also seen to eat the remains of lizards and other prey items after the young had been fed.

Lizards are available as a food source for Cooper hawks during the summer months only. If summer food supply is an important factor in controlling distribution and abundance of these hawks, the high lizard population in this foothill belt must constitute a circumstance favorable to their prevalence in the area.

Summary

A Cooper hawk nest was observed during incubation and subsequent rearing of the young in late May, June, and early July, 1939. There were four eggs, all of which hatched. Hatching took place on three successive days, May 28, 29, and 30. For the next 20 days growth was extremely rapid and the daily food intake of one kept in the laboratory at times approached 50 per cent of the total weight. Weight increment slowed down greatly as the birds began to feather out. Young first left the nest on June 23, but remained in the vicinity and continued to be fed by the parents for about a month longer.

In observed instances brooding was done by the female only. Both adults joined in attempting to drive away human intruders from the vicinity of the nest. Feeding of the young was shared by both parents. Adults foraged at distances of one-half mile or more from the nest.

One of the young, taken from the nest on June 3 and reared in the laboratory, remained tame and stayed nearby after it learned to fly. It

learned to catch its own prey and covered an observed range of about one-quarter mile diameter.

Food items recorded as brought to the young by the parent hawks were 19 whiptail lizards, 5 valley quail, 4 unidentified lizards, 2 fence lizards, 2 California woodpeckers, 2 cottontails, 1 skink, 1 brown towhee, 1 lark sparrow, and 1 unidentified small bird. The large proportion of lizards is atypical of the feeding habits of Cooper hawks according to other studies.

EDITORIALS AND NOTES

NEW COMMISSIONERS: GENERAL H. H. ARNOLD AND WILLIAM J. SILVA

On March 20, 1946 Governor Earl Warren appointed two new Fish and Game Commissioners to fill the vacancies of Dom A. Civitello and the late H. L. Ricks.

General H. H. Arnold, retired chief of the Army Air Forces, was appointed to succeed the remainder of Ricks' term which expires January 15, 1949, but due to previous commitments with the U. S. Army was unable to continue until such time as his release.

William J. Silva, Modesto automobile dealer, was appointed to succeed Dom A. Civitello who retired because of extensive business duties. Silva's term will end January 15, 1950.

The appointment of these two new members to the commission brings to Fish and Game men who are sincerely interested in the conservation and preservation of our natural resources; with years of executive background coupled with a full and sympathetic understanding of the needs of our commercial fisheries.—*Emil J. N. Ott, Jr., Executive Secretary California Division of Fish and Game, April, 1946.*

RETIREMENT OF AUGUST BADE

August Bade, Chief of the Bureau of Game Farms since the bureau's inception in June of 1940 and Superintendent of State Game Farms for 15 years before that, retired from his position April 1, 1946. He will live henceforth in Napa.

Mr. Bade was induced to take over the California game program in 1925 after being in charge of game bird production in the State of Washington. It was in that year that the sportsmen of California petitioned the Fish and Game Commission to "do something about" the upland game bird situation. And it was at that time that the commission, responding to popular demand, allocated funds for the establishment of the State Game Farm near Yountville, Napa County.

Mr. Bade planned and developed the Yountville farm and a few years later, the State Game Farm near Chino, San Bernardino County. Thus was the State provided with game bird breeding facilities in both its northern and southern areas.

The retiring game chief was the "father" of California's nationally known game bird breeding system. Before his arrival, all game birds had been hatched with the old domestic hen as the foster mother. A little experimenting demonstrated that game birds could be hatched and reared by purely artificial methods.

That was the beginning of what has come to be known in other sections of the country as "the California system". The electric incubator

and brooder supplanted the domestic hen, and production was put on a basis comparable with that of other industries where mass production is the key to success.

Here's just an example of the differences in over a 20-year period. In 1926 the output of the Yountville Game Farm was 3,000 birds. Ten years later it had increased to 30,000. 1946, 20 years later, should show a number so large that the first year's output will seem like a mere drop in the bucket. In the 21 years that Mr. Bade has been head of the game farms, more than half a million upland game birds have been released in the State.

The Bureau of Game Farms will operate until June 30 under supervision of the Bureau of Game Conservation, with C. Van Ornum in charge of the Yountville Farm and E. D. Platt in charge of the Chino Farm. On July 1, 1946, the Bureau of Game Farms will become part of the Bureau of Game Conservation.—*LeRoy Johnson, Assistant to the Public Information Editor, California Division of Fish and Game, April, 1946.*

ALASKA CODFISH FROM CALIFORNIA WATERS

On August 18, 1945, a specimen of the Alaska codfish or Pacific cod *(Gadus macrocephalus)*, 25 inches total length and 7¾ pounds gross weight, was taken in 60 to 70 fathoms of water near Trinidad Head, 16 nautical miles north of Eureka, California, by the dragger "Rio Janeiro," Clarence Hubbard, master. On about October 19, 1945, another specimen, 20¾ inches total length and four pounds gross weight, was taken in 90 fathoms of water southwest of the entrance to Humboldt Bay, California, by the dragger "Genoa," John Massey, master. Ray Walker, superintendent of Hallmark Fisheries, Eureka, saved the specimens and turned them over to the Division of Fish and Game for positive identification.

Massey reported that he obtained six specimens of Pacific cod at the time but saved only the largest one as reported above. Hubbard also reported that he had taken several specimens at various times during dragging operations in the Eureka region in 1944 but had not saved these.

This species has not been reported previously so far south, but it is abundant in the Bering Sea, on both shores, and ranges southward as far as the off-shore banks of Oregon. It is usually found in 15 to 130 fathoms and within its range is an important food fish. An occasional specimen may attain a weight of 50 pounds and a length of 45 inches. From the foregoing reports, the range of this species can now be extended southward to the southern end of Humboldt Bay, California.

The fishery for the Pacific cod is carried on in Alaskan waters by vessels sailing from San Francisco and Puget Sound every spring and returning late in the summer. The catches are made by dory fishermen, the fish are cleaned and salted aboard ship, and the flesh is quite dry when landed. It is prepared ashore for human consumption in a variety of styles.

The Pacific cod is very similar to the Atlantic cod, differing mainly in having a smaller swim bladder. It may be recognized by the following characters: Body moderately elongate, compressed and tapering

behind; scales very small; color brownish, lighter below with numerous brownish spots; fins dusky, lateral line pale in color and arched anteriorly; chin with a distinct barbel; lower jaw included; back with three separate dorsal fins and the underside with two separate anal fins.

There is another, smaller member of the codfish family in California with which the young of the Pacific cod might be confused. This is the tomcod *(Microgadus proximus)*, found from Unalaska southward to Monterey. It rarely exceeds 12 inches in length, and the simplest distinguishing character between the two is that in the tomcod the vent or anus is placed ahead of the second dorsal fin, when a line is dropped vertically to the underside, whereas, in the Pacific cod the anus comes under the front portion of the second dorsal fin.

One remaining member of the codfish family reported in California waters is the wall-eyed pollack *(Theragra chalcogramma fucensis)*. Although this species also has three separate dorsal fins and two separate anal fins, as do the other two cods mentioned, the lower jaw is projecting rather than included and the barbel on the underside of the chin is minute. The pollack attains a length of 24 inches.—*J. B. Phillips, Bureau of Marine Fisheries, California Division of Fish and Game, December, 1945.*

RARE FISHES TAKEN NEAR LOS ANGELES

From time to time fishes that are rare off the coast of Southern California are reported to the California State Fisheries Laboratory on Terminal Island, and the specimens are usually brought to the Laboratory for identification. Records of such fishes are kept on file: the following are some of the more unusual ones that were reported from 1944 through February, 1946.

Notorynchus maculatus Ayres, seven-gilled shark. A specimen measuring about 30 inches in total length was taken off Portuguese Bend, Los Angeles County, in a gill-net operated by the boat "New Triumpho," and delivered to the Los Angeles Fish and Oyster Co. on August 30, 1944. This appears to be the first record of this northern species from the Los Angeles region, though it has been reported from San Diego, farther south.

Alosa sapidissima (Wilson), shad. Common about San Francisco and Monterey, the shad is caught only occasionally in the vicinity of Los Angeles. The latest one to be received at the laboratory was a 38-cm. fish that was brought into Fish Harbor, Terminal Island, in a seiner load of sardines on November 28, 1945.

Clupea pallasii Valenciennes, Pacific herring. Typically a northern species, the herring is only occasionally seen in the Los Angeles region, though it is sometimes rather common about San Diego. One specimen was found in a seiner load of sardines that were caught two to three miles off Newport on December 15, 1944. Another was collected from a load of sardines that was seined off Newport on November 29, 1945, and about a dozen more were reported from the same catch.

Oncorhynchus tschawytscha (Walbaum), king salmon. A specimen weighing about 18 pounds was taken in San Pedro Harbor by the small net boat "President" on September 6, 1944. The occurrences of this and other species of salmon in southern California were discussed by Hubbs in California Fish and Game for April, 1946.

Scomberomorus sierra Jordan and Starks, Spanish mackerel or Mexican sierra. Two or three fish identified as sierras by some of the fish market operators, who occasionally receive this fish from Mexico, were caught by a small ring-net boat in the immediate vicinity of San Pedro Harbor in the spring of 1944. The description of yellow spots on the sides tends to confirm the identification of these fish. This is a species abundant off Mexico and further south, and rarely straying northward to southern California. We have only one previous record for it in our files: a specimen gill-netted in Santa Monica Bay in 1929.

Caranx caballus Gunther, common green jack. Although it was reported from San Diego as early as 1858, this is a tropical species that very rarely comes as far north as southern California. A specimen 31 cm. in total length was taken in a local bait net and brought into Newport, whence it was sent to the State Fisheries Laboratory by Larry A. Fisher on September 11, 1945.

Naucrates ductor (Linnaeus), pilot fish. This is the northern limit of the range of this species, for which we have four earlier records at the Laboratory. The fifth record is that of a specimen caught by hook and line three miles off Newport and received by us on February 2, 1945.

Xantocles frenatus (Eigenmann). An example of this rather rare fish was brought into San Pedro with a load of sardines which had been caught in the vicinity by the seiner "Sea Ranger" on January 26, 1944. There are two earlier local records for this fish in the Laboratory files. Two specimens about 8½ inches in total length were found in the stomach of a rockfish (*Sebastodes* sp.) obtained at the San Pedro fish market in 1935; and another was taken with rockfish by a set-line boat in 1937.

Prionotus stephanophrys Lockington, California searobin. A specimen taken in Santa Monica Bay was reported in California Fish and Game for October, 1945. Now another has appeared, to provide the second known record of this species for southern California. It was caught by Orville Shelton on a mackerel set-line three miles off the Santa Monica Pier on February 26, 1946, and reached us through the courtesy of the Bay Fish Market. The specimen is 226 mm. in standard length and 282 mm. (approximately 11¼ inches) in total length. The color on the upper part of the body is greyish, with spots of a warm brown. The two dorsal fins and the caudal are pale grey with brown spots, the pectoral darker grey with brown spots. There is a large, very dark brown blotch between the fourth and fifth spines of the first dorsal fin. The ventral color, which contrasts sharply with the dorsal, is white anteriorly, changing to orange-pink below the first dorsal. The ventral and anal fins are the same pink, and the ventral third of the caudal is tinged with it. This color fades out in formaldehyde in two or three days.—*Anita E. Daugherty, Bureau of Marine Fisheries, California Division of Fish and Game, March, 1946.*

IN MEMORIAM

EDWARD JUDSON JOHNSON

Fish and Game Warden E. J. Johnson died at the Enloe Hospital in Chico on January 22, 1946, as the result of an injury received in an automobile accident on January 10, 1946. His condition was not considered serious at the time, but complications set in which made an operation necessary.

Warden Johnson was born in Humboldt County and served during World War No. 1 with the Motor Transport Corps. During his youth he was engaged in the lumbering industry, and worked for the Biological Survey as well as the State Division of Parks before he was appointed to the Bureau of Patrol on August 8, 1930. He served in Humboldt and Lake Counties and for the past seven years was stationed in Plumas County.

He is survived by a wife and children to whom we express our deepest sympathies.—*E. L. Macaulay, Chief, Bureau of Patrol, California Division of Fish and Game, March 27, 1946.*

REPORTS

FISH CASES

January, February, March, 1946

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalones: failure to show, drying, closed season, no license, undersize, overlimit	38	$1,040 00	
Angling: seining, shooting, illegally taking fish; using license of another; spearing; failure to show license; false statement to secure license; possessing spear within 300 feet of stream, near fish ladder; gaff hook within 300 feet of stream; operating set lines Mokelumne River; using set lines; fishing in closed stream, in closed season	67	1,385 00	
Bass: no license, more than one outfit, at night	54	800 00	
Catfish: undersize, selling undersize	7	195 00	
Clams: undersize, overlimit, in preserve	38	1,115 00	
Commercial: use of illegal drag net, failure to keep log, use of trammel net, no license, fishing crabs commercially on Sunday, District 10	41	4,460 00	90
Crabs: undersize, use of purse seine closed area, overlimit	15	920 00	
Lobsters: overlimit, undersize, use of fish and lobster traps District 20	5	280 00	
Pollution	5	400 00	
Salmon: overlimit, clubbing	2	125 00	
Sturgeon	1	25 00	
Trout: clubbing steelhead, gaffing steelhead, netting, overlimit, closed area, no license, closed season, rifle	30	1,130 00	
Totals	303	$11,875 00	90

GAME CASES

January, February, March, 1946

Offense	Number arrests	Fines imposed	Jail sentences (days)
Deer: female, doe, failure to tag deer, at night, closed season, spike, spotlighting	36	$3,650 00	
Deer meat: closed season, unstamped deer meat	27	1,880 00	
Doves: overlimit, closed season, shooting from auto, shooting from highway	13	555 00	
Ducks: shipping ducks improperly marked, shooting from power boat, no duck stamp, overlimit, unplugged gun, late shooting, no license, herding, refuge	114	4,181 00	
Geese: overlimit, unplugged gun, late shooting	12	870 00	
Grebe	2	75 00	
Hunting: refuge, shooting from vehicle, shooting from public road, no license, failure to show license, unplugged gun, at night	41	667 50	
Killdeer	1	25 00	
Meadowlarks	1	35 00	
Non-game birds	2	40 00	
Pheasant: closed season, no license, hen, shooting from vehicle	33	2,317 50	
Pigeons: unplugged gun, no license	3	60 00	
Quail: closed season	7	225 00	
Rabbits: no license, closed season, at night	27	1,005 00	
Robins	6	135 00	
Shorebirds	2	50 00	
Squirrel	1	10 00	
Swans	1	25 00	
Totals	329	$15,806 00	

SEIZURES OF FISH AND GAME

January, February, March, 1946

Fish:

Abalones	593
Abalones, pounds	20
Bass, black	18
Bass, black, pounds	6
Bass, white sea, pounds	61
Catfish, pounds	535
Clams	490
Crabs, dozen	11¼
Crabs	252
Devilfish, pounds	25
Elops affinis	1
Gaff hook	2
Lobster, pounds	150
Lobsters	32
Lobster traps	9
Mussels, pounds	75
Salmon, pounds	150
Spear	2
Trout	18

Game:

Deer	14
Deer meat, pounds	416
Doves	155
Ducks	152
Geese	10
Grebe	1
Meadowlarks	2
Pheasant, cock	12
Pheasant, hen	9
Quail	5
Rabbits	25
Robins	4
Shorebirds	2

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(Continued from inside front cover)

BUREAU OF LICENSES

H. R. DUNBAR, Chief—Sacramento
L. O'Leary, Assistant Chief—Sacramento
R. Nickerson, Supervising License Agent—Los Angeles
Emil Dorig, License Agent—San Francisco

ACCOUNTS AND DISBURSEMENTS

D. H. BLOOD, Departmental Accounting Officer—Sacramento

BUREAU OF PATROL

E. L. MACAULAY, Chief of Patrol—San Francisco
L. F. CHAPPELL, Assistant Chief of Patrol—San Francisco

CENTRAL DISTRICT (Headquarters, Sacramento)

C. S. Bauder, Inspector in Charge—Sacramento

Northern Division

Jos. H. Sanders, Captain—Sacramento
A. H. Willard, Captain—Rocklin
A. A. Jordan, Captain—Redding
E. O. Wraith, Captain—Chico
L. E. Mercer, Warden, Butte County—Chico
Rudolph Gerhardt, Warden, Butte County—Gridley
Taylor London, Warden, Colusa County—Colusa
Albert Sears, Warden, El Dorado County—Placerville
Harold Erwick, Warden, Tehama County—Corning
L. M. Booth, Warden, Lassen County—Susanville
Louis Olive, Warden, Siskiyou County—Tule Lake
Delmor Baxter, Warden, Modoc County—Nubieber
Don Davison, Warden, Modoc County—Alturas
Earl Hiscox, Warden, Nevada County—Nevada City
Nelson Poole, Warden, Placer County—Auburn
Wm. LaMarr, Warden, Placer County—Tahoe City
Charles Sibeck, Warden, Sacramento County—Sacramento
Eugene Durney, Warden, Sacramento County—Markleeville
Earl Caldwell, Warden, Shasta County—Burney
Walter Krukow, Warden, Shasta County—Redding
R. E. Tutt, Warden, Solano County—Dixon
Fred R. Starr, Warden, Siskiyou County—Dorris
R. W. Anderson, Warden, Tehama County—Red Bluff
C. L. Gourley, Warden, Trinity County—Weaverville
C. O. Fisher, Warden, Yolo County—Woodland
R. A. Tinnin, Warden, Yuba County—Marysville
Don Chipman, Siskiyou County—Dunsmuir
Paul Kehrer, Warden, Plumas County—Greenville
George Shockley, Warden, Plumas County—Portola
Ed. Hughes, Warden, Sacramento County—Sacramento

Southern Division

John O'Connell, Captain—Stockton
S. R. Gilloon, Captain—Fresno
R. J. Little, Warden, Amador County—Pine Grove
L. R. Garrett, Warden, Calaveras County—Murphys
F. A. Bullard, Warden, Fresno County—Reedley
C. L. Brown, Warden, Fresno County—Coalinga
Lester Arnold, Warden, Kern County—Bakersfield
Donald Hall, Warden, Kern County—Kernville
Ray Ellis, Warden, Kings County—Hanford
H. E. Black, Warden, Madera County—Madera
Gilbert T. Davis, Warden, Mariposa County—Mariposa
Hilton Bergstrom, Warden, Merced County—Los Banos
Wm. Hoppe, Warden, San Joaquin County—Lodi
Geo. Magladry, Warden, Stanislaus County—Modesto
W. I. Long, Warden, Tulare County—Visalia
Roswell Welch, Warden, Tulare County—Porterville
F. F. Johnston, Warden, Tuolumne County—Sonora
R. Switzer, Merced County—Merced

COAST DISTRICT (Headquarters, San Francisco)

Wm. J. Harp, Inspector in Charge—San Francisco

Northern Division

Scott Feland, Captain—Eureka
Lee C. Shea, Captain—Santa Rosa
Otis Wright, Warden, Del Norte County—Crescent City
Robert Perkins, Warden, Humboldt County—Garberville
W. F. Kaliher, Warden, Humboldt County—Fortuna
Larry Werder, Warden, Humboldt County—Eureka

Northern Division—Continued

Wm. H. Sholes, Jr., Warden, Humboldt County—Arcata
Jack Sawyer, Warden, Lake County—Lakeport
R. J. Yates, Warden, Marin County—San Rafael
Ovid Holmes, Warden, Mendocino County—Fort Bragg
Floyd Loots, Warden, Mendocino County—Willits
Garrie Heryford, Warden, Mendocino County—Ukiah
M. F. Joy, Warden, Napa County—Napa
Karl Lund, Warden, Napa County—Napa
Bert Laws, Warden, Sonoma County—Petaluma
Ray Bruer, Warden, Sonoma County—Santa Rosa
Harley Groves, Warden, Sonoma County—Cloverdale

Southern Division

O. P. Brownlow, Captain—Oakland
J. W. Harbuck, Warden, Contra Costa County—Antioch
J. G. McKerlie, Warden, Alameda County—Alameda
Warren Smith, Warden, Monterey County—King City
F. H. Post, Warden, Monterey County—Salinas
J. P. Vissiere, Warden, San Benito County—Hollister
C. R. Peek, Warden, San Mateo County—San Mateo
C. E. Holladay, Warden, Santa Clara County—San Jose
F. J. McDermott, Warden, Santa Cruz County—Santa Cruz
Owen Mello, Warden, Monterey County—Carmel Highlands

SOUTHERN DISTRICT (Headquarters, Los Angeles)

Earl Macklin, Inspector in Charge—Los Angeles
H. C. Jackson, Captain—Los Angeles

Western Division

L. T. Ward, Captain—Escondido
F. W. Hecker, Captain—San Luis Obispo
Fred Albrecht, Warden, Los Angeles County—Los Angeles
Walter Emerick, Warden, Los Angeles County—Los Angeles
L. R. Metzgar, Warden, Los Angeles County—Los Angeles
C. L. Towers, Warden, Los Angeles County—Los Angeles
A. L. Stager, Warden, Los Angeles County—Pomona
Frank Bartol, Warden, Los Angeles County—Los Angeles
Theodore Jolley, Warden, Orange County—Norwalk
E. H. Glidden, Warden, San Diego County—San Diego
Henry Ocker, Warden, San Diego County—Julian
Orben Philbrick, Warden, San Luis Obispo County—Paso Robles
R. E. Bedwell, Warden, Santa Barbara County—Santa Barbara
H. L. Lantis, Warden, Santa Barbara County—Santa Maria
A. F. Crocker, Warden, Ventura County—Ventura
L. A. Golden, Warden, San Luis Obispo County—Arroyo Grande
John Spicer, Warden, Ventura County—Ojai
Henry Shebley, Warden, Ventura County—Fillmore

Eastern Division

R. J. O'Brien, Warden, Imperial County—El Centro
C. J. Walters, Warden, Inyo County—Independence
James Loundagin, Warden, Inyo County—Bishop
Robert Stedman, Warden, Mono County—Leevining
W. C. Blewett, Warden, Riverside County—Indio
Cliff Donham, Warden, Riverside County—Idyllwild
W. C. Malone, Warden, San Bernardino County—San Bernardino
Erol Greenleaf, Warden, San Bernardino County—Big Bear Lake
Otto Rowland, Warden, San Bernardino County—Victorville
Walter Shannon, Warden, San Bernardino County—Redlands
Geo. D. Werden, Jr., Warden, Riverside County—Blythe

MARINE PATROL

Tate Miller, Captain—Terminal Island
Lars J. Weseth, Captain—Terminal Island
Ralph Classic, Captain—Monterey
T. W. Schilling, Captain—San Francisco
Walter Engelke, Captain and Warden, Cruiser *Bonito*—Newport
Robert Mills—Newport
Kenneth Hooker, Warden, Launch *Minnow*—Novato
Bolton Hall, Warden—Tiburon
N. C. Kunkel, Warden—Newport Beach
Leslie E. Lahr, Warden—Wilmington
Ralph Miller, Warden—San Francisco
G. R. Smalley, Warden—Richmond
T. J. Smith, Warden—San Diego
Carmi Savage, Warden—Santa Monica
R. C. Schoen, Warden—Terminal Island
John Barry, Warden—Terminal Island
N. J. Mullen, Warden—Terminal Island
Howard Shebley, Warden—Terminal Island
E. R. Hyde, Warden—Monterey
Ellis Berry, Warden—Monterey
Walter Gray, Warden—Eureka
J. Ross Cox, Warden—Watsonville

MARINE PATROL AND RESEARCH BOATS

Cruiser *Bonito*, Catalina
Cruiser *Shasta*, Redding
Cruiser *Yellowtail*, Santa Monica
Cruiser *Tuna*, Monterey
Cruiser *Broadbill*, Newport
Launch *Minnow*, San Rafael
Cruiser *Rainbow III*, Antioch
Launch *Shrapnel*, Suisun