CALIFORNIA FISH AND GAME

"CONSERVATION OF WILD LIFE THROUGH EDUCATION"

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DEPARTMENT OF NATURAL RESOURCES

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REPORT ON FISHERIES RESOURCES IN CONNECTION WITH THE PROPOSED YOLO-SOLANO DEVELOPMENT OF THE UNITED STATES BUREAU OF RECLAMATION[1]

By Leo Shapovalov

Bureau of Fish Conservation
California Division of Fish and Game

Introduction

The U. S. Bureau of Reclamation has been investigating the possibilities of development of certain lands and waters in Yolo, Solano, Napa, and Lake Counties as part of the Central Valley Project of California. In a preliminary mimeographed leaflet, not dated but probably issued early in 1945 (U. S. Bureau of Reclamation, No Date a) the project is described as follows:

> "The proposed Yolo-Solano development is a multiple-purpose feature of the Central Valley Project, providing for irrigation, domestic water supply, power, salinity control, navigation, and recreation benefits for the rich areas of Yolo and Solano Counties, along the west side of the Sacramento Valley, the gently sloping valley floor to the east of the Coast Range, and the marshlands on the north shore of Suisun Bay. The project could suppy water to Benicia Arsenal and Vallejo and in its later phases could make available water for the irrigation of 21,000 acres of land in the Napa Valley, which could be delivered via a 3½-mile tunnel[2] extending from Suisun Valley to Napa Valley through the foothill ridge that separates the two.
>
> "The Yolo-Solano project in general involves (1) the storage of runoff waters from Cache and Putah Creeks in Lake and Napa Counties, by means of three dams and reservoirs, and (2) diversions from the Sacramento River at Knights Landing and Lindsey Slough.
>
> "The Cache and Putah Creeks storage works would irrigate the western part of the proposed service area in both Yolo and Solano Counties; and water from the Sacramento River would irrigate the eastern portion.
>
> "Preliminary studies conducted by the Bureau of Reclamation show that this project is practicable for early postwar construction and presents an unusually favorable ratio of benefit to cost. Plans are tentative and subject to modification as additional information, now being obtained, is made available. In the meantime, interested landowners and existing irrigation interests will be consulted for their suggestions and approval before the project is finally submitted for authorization."

Since the issuance of the above material the Bureau of Reclamation stated in a press release (U. S. Bureau of Reclamation, 1945) that it had received a request from the Lake County Board of Supervisors for a survey of Lake County water and land problems. A preliminary investigation of possible reservoir sites on streams tributary to Clear Lake was subsequently made by engineers of the bureau. The construction of reservoirs on tributaries of Clear Lake, for purposes of irrigation and flood control, would tie in directly with the Yolo-Solano development.

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[1] Submitted for publication October 24, 1946.

[2] Under present plans this water would be carried by a conduit instead of a tunnel. Photographs are by the author.

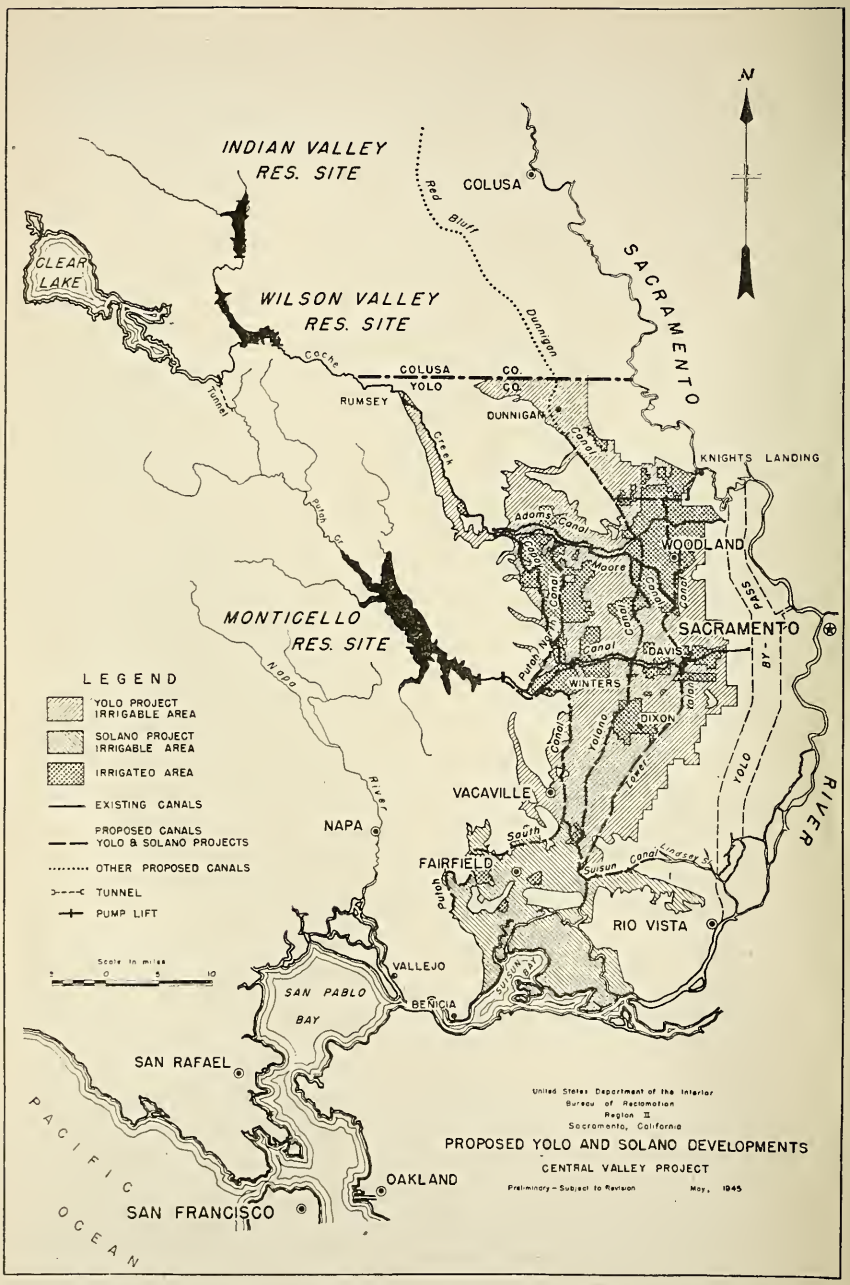

FIGURE 9. The proposed Yolo-Solano development of the United States Bureau of Reclamation

The U. S. Bureau of Reclamation also issued (probably in May, 1945) another undated pamphlet (U. S. Bureau of Reclamation, No Date b) consisting of tables of statistical data (including estimated construction and operational costs, irrigable land areas, hydrology, and physical features of the storage works) for the Yolo-Solano development. A map of the project dated May, 1945, is attached to the above pamphlet and is included in the present report as Figure 9.

The material relating to various features of the Yolo-Solano development contained in the present report is based upon the previously cited material issued by the U. S. Bureau of Reclamation, upon information gathered by the writer at a conference with Messrs. E. A. Pesonen and H. M. Posz of the Bureau of Reclamation and Dr. James W. Moffett of the U. S. Fish and Wildlife Service, held at Sacramento on June 11, 1945, upon the Bureau of Reclamation's application (No. 11279, February 6, 1946) to the California State Division of Water Resources to appropriate the necessary water for the project, and upon unpublished material received from the Bureau of Reclamation.

The purpose of the present report is to describe briefly the proposed development and existing conditions, to prognosticate the changes in the fish populations and fisheries which are likely to result through the construction of the project, and to make such recommendations in regard to the construction and operation of the contemplated physical works and to the waters involved as will insure their maximum development and utilization as sport fishing areas.

Description of the Proposed Development

The Yolo-Solano development would include the following physical works:

MONTICELLO DAM AND RESERVOIR

This dam and reservoir would be located on Putah Creek at the junction of Yolo, Solano, and Napa Counties, about eight miles directly west of Winters, in T. 8 N., R. 2 W., Sec. 29. The dam would be a concrete, gravity-overflow type of structure, 300 feet high, with a crest length of 860 feet. This dam would create a lake with a storage capacity of about 2,200,000 acre-feet and a maximum water surface of 21,700 acres. The lake would be 18 miles long with an average width of three miles, and would be one of the largest in California, approximately one-half the size of Shasta Reservoir. The elevation of the maximum normal pool would be 471 feet.

In addition to controlling the floods of Putah Creek, this lake would become the storage reservoir for run-off of the Clear Lake basin on Cache Creek by the construction of a three-mile tunnel from the outlet of Clear Lake to the headwaters of Soda Creek, an upstream tributary of Putah Creek. Irrigation water now delivered by Cache Creek to a considerable portion of the service area of the Clear Lake Water Company could be delivered by this tunnel, Monticello Reservoir, and the Putah North Canal, if the company so desires. Additional water could also be delivered from Monticello Reservoir. Monticello Reservoir would also provide 140,000 acre-feet of flood control storage.

A power plant at Monticello Dam, with a capacity of 18,000 kilowatts, would generate 46,000,000 kilowatt-hours annually. Of this,

approximately one-half would be used for pumping plants on the proposed Yolo-Solano development canals, and the balance would be exported to other canal pumping plants of the Central Valley Project. It is likely that this power would not be available for commercial use.

INDIAN VALLEY DAM AND RESERVOIR

This dam and reservoir would be located 18 miles west of Williams on the North Fork of Cache Creek, in T. 14 N., R. 6 W., Sec. 9, Lake County. The dam would be an earth-fill structure, 208 feet high, with a crest length of 710 feet, and would create a lake six miles long with a storage capacity of about 250,000 acre-feet and a maximum normal water surface of 3,550 acres. The elevation of the maximum normal pool would be 1,468 feet. The water from this reservoir would irrigate principally lands in the lower Cache Creek drainage basin. No power would be generated.

WILSON VALLEY DAM AND RESERVOIR

These works would be constructed at a later date. They would be located about 30 miles southwest of Williams on the main stem of Cache Creek, in T. 13 N., R. 5 W., Sec. 19, Lake County. The dam site is located about 10 miles below the outlet of Clear Lake.

Wilson Valley Dam would be an earth-fill structure about 230 feet high and 830 feet long on the crest. It would create a lake seven miles long with a storage capacity of 210,000 acre-feet, of which 66,000 acre-feet would be reserved for flood control. The area of the maximum normal water surface would be 2,900 acres. The elevation of the maximum normal pool would be 1,085 feet. No power would be generated.

Storage in Indian Valley and Wilson Valley reservoirs would provide flood control along Cache Creek and would regulate the releases of irrigation water to provide a firm supply in the northern portion of the service area throughout the irrigation season.

CANALS AND DIVERSION STRUCTURES

The project embraces six principal canals, totaling about 168 miles in length. These are Putah Main Canal, Putah North Canal, Putah South Canal, Suisun Canal, Yolano Canal, and Lower Yolano Canal. An additional canal, Rumsey Canal, would irrigate the lands of Capay Valley.

Putah Main Canal. This canal would originate at the Putah Creek Diversion Dam, a 38-foot-high dam which would be constructed on Putah Creek about two miles below Monticello Dam. Water in the canal would flow in an easterly direction along the south bank of Putah Creek until it reached a division point, located about three miles downstream from Putah Creek Diversion Dam. The capacity of the canal would be 1,580 second-feet.

Putah North Canal. This canal would originate at the division structure located about three miles downstream from Putah Creek Diversion Dam and would extend 13 miles northward to the vicinity of Madison, and could supplement the supply to lands now being served by the Capay Canal of the Clear Lake Water Company.

Putah South Canal. This canal would originate at the division structure located about three miles downstream from Putah Creek Diversion Dam and would transport water southward along the base of the foothills on the west side of Sacramento Valley, passing within 1½ miles to the eastward of Vacaville, skirting the foothills to the north of the Fairfield-Suisun area, and terminating at a point 1½ miles southwest of Cordelia, near the mouth of American Canyon. The canal would have a total length of 42 miles and would serve the western portion of Solano County, together with a portion of the uplands in the Suisun-Fairfield area.

Suisun Canal. This canal would originate with a diversion at the head of Lindsey Slough, which joins Sacramento River about two miles above Rio Vista. The canal would extend westward four miles through a cut in Denverton Ridge to Denverton Slough, from which the diverted water would flow into Montezuma Slough to form a fresh-water pool for salinity repulsion and irrigation of the Suisun marshlands. The supply for the Suisun Canal would be augmented by connection with the Putah South Canal and the lower ends of Yolano and Lower Yolano canals.

Yolano and Lower Yolano Canals. These canals would originate at Knights Landing, extend southward through the lowlands of the eastern portion of Yolo and Solano Counties, and terminate at the Suisun Canal. The Yolano Canal would have a total length of 37 miles; the Lower Yolano, 42 miles.

Rumsey Canal. This canal would originate at a diversion point on Cache Creek in T. 12 N., R. 4 W., Sec. 12, Yolo County. It would irrigate the lands of Capay Valley. The capacity of the canal would be 200 second-feet.

Existing Conditions

GENERAL DESCRIPTION OF THE WATERSHEDS

Cache and Putah Creeks nominally are tributaries of the Sacramento River on its west side, but in recent years no water from these streams has reached the Sacramento River because of the complex system of water use and flood control in their lower reaches, which will be discussed later in this report. In physical characteristics, Cache and Putah Creeks are much alike. In order to present a better understanding of the topography and location of these streams, the following general description is quoted from McGlashan (1929).

Cache Creek. "The Cache Creek drainage basin lies on the eastern slope of the Coast Range in Lake, Colusa, and Yolo Counties, immediately south and west of the south end of the Stony Creek Basin and north of the Putah Creek Basin. The upper part of the area, comprising about 824 square miles, lies in the central part of Lake County, south of the divide separating the Eel River and Cache Creek Basins. It is roughly rectangular in shape, and contains Clear Lake in its center. From Lake County the basin extends southeastward to the Sacramento Valley as a strip about 50 miles long and 10 miles wide. The total area of the basin is 1,290 square miles.

"Cache Creek is the only known outlet of Clear Lake. The lake is very irregular in shape and has an area of 65 square miles and an altitude of 1,325 feet at mean level. Its length is 20 miles and its greatest width seven miles. The upper part, or main lake, has a maximum depth of 35 feet, but the lower neck has a few small areas as much as 50 feet in depth. The drainage area tributary to the lake is about 417 square miles, chiefly toward the south and west. The principal creeks flowing into the lake are Scotts, Middle, and Clover from the west, and Doba, Kelsey, and Cole [8] from the south. They are torrential during the rainy season, but are practically dry in the summer.

"From the lake Cache Creek flows southeastward to the Yolo Basin and ultimately into Sacramento River through sloughs. Its total length is about 80 miles.

"The largest and most important tributary of Cache Creek is the North Fork, which drains 250 square miles in the eastern part of Lake County. The only other important tributary is Bear Creek, which drains the western part of Colusa County. These creeks are very small in the summer, but rarely become dry. All the tributaries are torrential during the rainy season.

"The upper part of the Cache Creek drainage basin in Lake County is mountainous and very rugged. Some of the peaks reach an altitude of 6,000 feet above sea level, and their slopes, as well as those of the lower ranges, are very steep. About five miles below the outlet the creek enters Cache Creek Canyon, in which it flows for 25 miles on an average grade of 35 feet to the mile. In some places the canyon walls are vertical cliffs 300 feet high. Below the canyon the creek enters Capay Valley, from one to three miles wide and 20 miles long, through which it winds for a distance of nearly 30 miles before entering the Sacramento Valley.

"On the northern slope of the ranges around Clear Lake are fine belts of fir, oak, and pine. Elsewhere on the high ranges the vegetation consists of a dense growth of greasewood and chaparral. A strip along the northern edge of the basin is included in a national forest.

"The mean annual precipitation ranges from 17 inches in the Sacramento Valley to 40 inches or more on the mountainous summits in Lake County, where much of it occurs as snowfall in the winter.

"The upper part of this basin contains springs, a number of which, especially in the North Fork Basin, have medicinal properties that attract many visitors."

Putah Creek. "The Putah Creek Basin lies on the eastern slope of the Coast Range south of the Cache Creek Basin and north of Napa Valley. It includes the southern part of Lake County, the northern half of Napa County, and small parts of Yolo and Solano Counties. The basin is rather long from northwest to southeast and comparatively narrow, being about 20 miles wide at the north and less than 10 miles at the east. It has a total area of about 810 square miles.

"Putah Creek rises in the northwestern corner of the basin in the St. Helena Range and flows southeastward into the Yolo Basin near Davis, and thence into Sacramento River through Cache Slough. The total length of the creek is about 80 miles. It has numerous tributaries

[8] Cole Creek is not named on Punnett's map of Lake County or on the sketch map accompanying Water-Supply Paper 45 (Pl. I).

which have a heavy flood discharge in the winter but are practically dry during the summer. The chief tributaries are Soda Creek from the north and Pope Creek from the west.

"The topography of the Putah Creek Basin is very rugged. Much of the upper basin is rough and precipitous. The underlying rock is an impervious slate and serpentine with only a thin soil covering. There is very little tilled land in the basin except below the foothills. Altitudes range from about 100 feet in the valley to about 5,000 feet on the mountain summits.

"The lower parts of the basin are comparatively barren of timber, though they support a considerable growth of grass and brush which extends down as far as the foothills. At moderate altitudes timber grows scatteringly, and the mountain summits are covered by a fairly heavy timber growth.

"The mean annual precipitation varies widely in different parts of the basin. Along the foothills it averages about 28 inches, in the central

FIGURE 10. St. Helena Creek one-half mile by road above Middletown, Lake County, June 26, 1940. A trout stream above, it was already dry below this point

part about 40 inches, and along the crest of the divide, where some of it occurs as snowfall in the winter, about 65 inches. Helen Mine, on the northern slope of Mount St. Helena, receives almost 100 inches annually.

"Below the foothills is a large area of rich irrigable land, which could be supplied with water from Putah Creek. Some of this land is already irrigated and has proved to be susceptible of the highest state of cultivation.

"At least two good reservoir sites exist on the main stream, one near Winters and the other near Guenoc."

To the foregoing description it may be added that in the upper reaches of both the Cache and Putah Creek systems, small, permanent tributaries enter the main streams through narrow, wooded and brushy

canyons. In a number of these trout may be found and the temperatures normally are below 70 degrees F. Some of these small tributaries start in springs. But as these streams reach or approach the main streams they usually dry up in the summer months (Fig. 10) and the trout are replaced by the assemblage of fishes typical of the lowland areas of the Sacramento River system: Carp, various native cyprinids, suckers, black bass, and sunfishes. Summer water temperatures that often exceed 80 degrees F. prevail. The surrounding terrain becomes less rugged and the sparsely wooded foothills are replaced by the fields and orchards of the Sacramento Valley. Those sections of both Cache and Putah Creeks that flow through the valley become intermittent during the summer months, even in years of abundant rainfall (Fig. 11). In part this is a natural condition, in part it is caused by the use of water for agricultural purposes, either by direct diversion or by pumping, and in part by flood control measures, road construction, grazing, and other man-created activities that have caused erosion and consequent silting up of the stream beds. As a result, during the summer these streams are dry in portions and the water in the intervening stretches is of high enough temperature to render them unsuitable for trout and salmon except in the winter and spring months.

FIGURE 11. Putah Creek on Phillips Ranch, below Winters, Yolo County, June 18, 1940. View downstream from Stevens Bridge. Later in the summer the stream is dry both above and below this stretch of water.

FLOOD CONTROL AND WATER USE

A description of the principal changes that have taken place in the lower courses of Cache and Putah Creeks as a result of man-made projects will now be described.

As previously stated, no water from either of the streams reaches the Sacramento River by way of the original channels, even at high water, but flows into the Yolo By-pass and thence down the by-pass to the latter's entrance into the sloughs entering the Sacramento River between Rio Vista and Walnut Grove. The Yolo By-pass is a large, artificial, cut and diked channel that extends from Verona (a little below Knights

Landing) to the above-mentioned point. It was constructed to care for the excess water of the main Sacramento River at flood stage. Throughout most of each year the Yolo By-pass is dry and is planted to beans and other crops or used as grazing land. When the Sacramento River is at flood stage and reaches a certain level it spills over the Fremont Weir (Fig. 12), located at the head of the Yolo By-pass, and flows down the by-pass. In years of little rainfall no water runs down it, even in the winter months. On the east side of the Yolo By-pass there is a main cut and this cut carries water through most of the year, even when other portions of the by-pass are dry. The tide extends up this main cut to a little above the point of entry of the sewage from Woodland, i.e., above the present entrance of Cache and Putah creeks.

FIGURE 12. Fremont Weir. Top of weir is about eight inches lower at this point than elsewhere

The old main channel of Putah Creek ran through the grounds of the University of California College of Agriculture at Davis. Now there is only a small, local flow in this channel, which is also known as the North Fork of Putah Creek. This old channel is cut off from the main flow of Putah Creek, which goes down what is known as the South Fork of Putah Creek.

Near the old bridge crossing near the Mt. Diablo Gun Club, on the Cowle Property in the Yolo By-pass, Putah Creek breaks into several channels or sloughs. When there is sufficient flow the water of Putah Creek flows into the Long Ponds, which are lakes in the Yolo By-pass.

During the winter of 1939-40 the water was five feet deep at the Mt. Diablo Gun Club. At that time the overflow of Putah Creek united with the water coming down the Yolo By-pass and flowed in a big channel during the winter and early spring, flowing into the main cut of the Yolo By-pass between the Sacramento Northern Railroad and Long Ponds.

There are several lakes or ponds in the Yolo By-pass in the vicinity of Sacramento. Gradually these are drying up and becoming smaller. Mr. Abe Woodard of the California Division of Fish and Game has told the writer that in former years there were sturgeon, striped bass, salmon, and other fishes in Long Ponds, Todhunter Lake, Green Lake, and the other lakes of this region.

Some years ago a break-through occurred in the west levee of the Yolo By-pass, and it is through this break that the Woodland sewage and Cache Creek now enter the by-pass. The sewage runs in a pipe to this break, then in a pipe through a solid concrete dam crossing Cache Creek cut or slough, then through an open ditch across the Yolo By-pass to the east side of the by-pass, where it empties into the cut or channel extending down the length of the by-pass on the east side.

The old channel of Cache Creek now comes to a dead end against the north levee of the Yolo By-pass.

DAMS ON CACHE CREEK

There are three dams on Cache Creek, all owned by the Clear Lake Water Company of Woodland. The uppermost dam is known as the Clear Lake Impoundment Dam, the middle dam as the Capay Dam, and the lowermost one as the Moore Dam. None of them has a fishway, but the Moore Dam is removed in winter and is then not an obstacle to fish. The others are impassable to fish, except under unusual circumstances.

1. *Clear Lake Impoundment Dam.* As its name implies, this dam was built for the purpose of increasing the storage capacity of Clear Lake over the normal amount and to regulate the flow out of the lake. No water is diverted at this point.

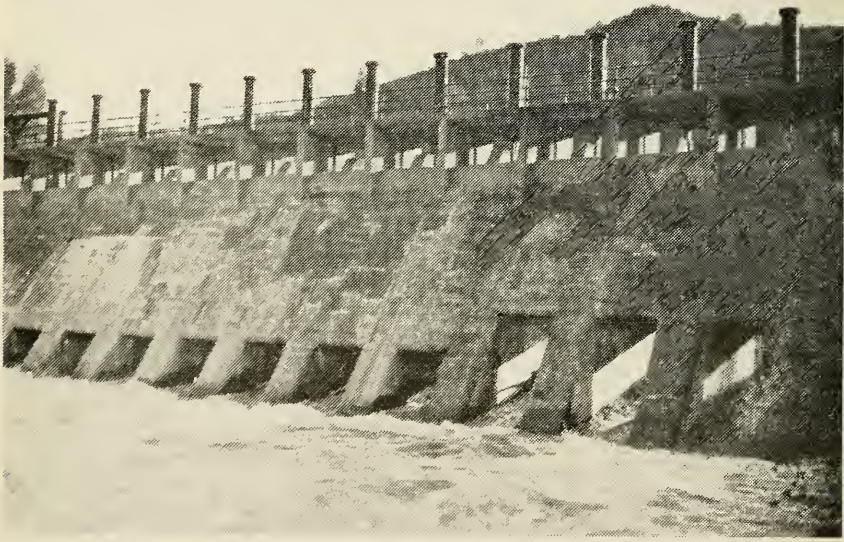

FIGURE 13. Clear Lake Impoundment Dam on Cache Creek. Outlet gates at bottom of dam are open. March 7, 1940

This dam (Fig. 13), located in T. 12 N., R. 6 W., Sec. 6, at an elevation of 1,250 feet, was constructed in 1914. It is of the gravity-straight type. The distance from crest to stream bed is 33 feet and the length of the crest is 260 feet. There is no spillway. The storage capacity is 420,000 acre-feet.

At high water some fish can get past the dam with some difficulty, since at such times the outlet gates, which are located at the bottom of the dam, are opened. One of the local residents told the writer that in 1937-38 some steelhead ascended Cache Creek past all three dams and were taken in Clear Lake. The caretaker at the dam reported that he had seen large Sacramento squawfish, known locally as "chapaul", *Ptychocheilus grandis* (Ayres), pass upstream through these gates, but that he has never seen adult salmon or steelhead at the dam. It is possible that the fish reported from Clear Lake were large resident trout or large trout that had come down into the lake from some of its tributaries.

2. *Capay Dam.* This dam (Fig. 14) is located in T. 10 N., R. 2 W., Sec. 16, near the small town of Capay, Yolo County, at an elevation of about 215 feet. It was built about 1912. It is 10 feet high and 600 feet wide at the crest. In the spring a three-foot extension of flash boards inserted in H-beams is placed across the entire dam. The only water normally going past the dam during the summer is seepage. A wooden apron is present. There are two outlet gates near the bottom of the dam but these are never used.

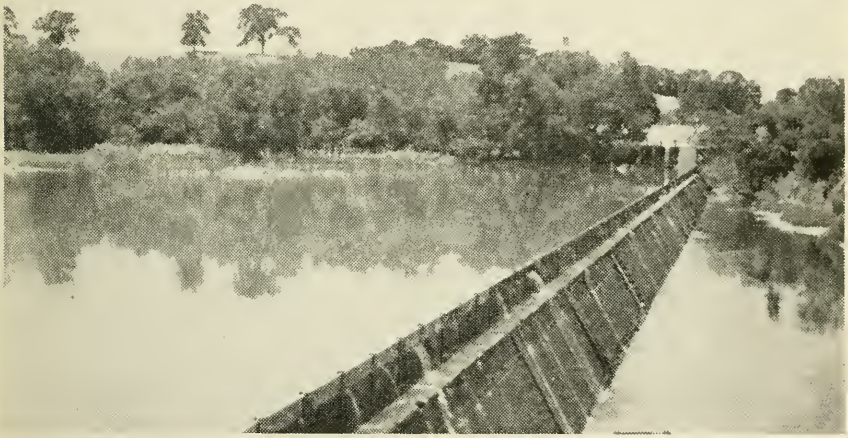

FIGURE 14. Capay Dam on Cache Creek. Three-foot flash board extension in place. June 18, 1940

A large diversion takes off from each side of the dam. The south diversion, known as the Capay Canal, is shown in Figure 15.

Capay "Reservoir" is now silted in to the top of the dam, so that there is practically no storage of water.

3. *Moore Dam.* This dam (Fig. 16) is located on Cache Creek in T. 10 N., R. 1 E., Sec. 30, about 12 miles below Capay Dam, in Yolo County, at an elevation of about 105 feet. It is about four feet high. One branch of the diversion from the north side of the Capay Dam (Adams Canal) is brought down to the Moore Dam, where it crosses over to the south side of the stream immediately above the dam. In other words, the diversion from the north side of Capay Dam empties into the reservoir formed by

FIGURE 15. Diversion from south side of Capay Dam (Capay Canal), near take-off. June 18, 1940. Flow at time 303 second-feet

Moore Dam and is taken out again from the south side of Moore Dam, whereupon it is known as the Moore Canal. Moore Dam is put in early each summer.

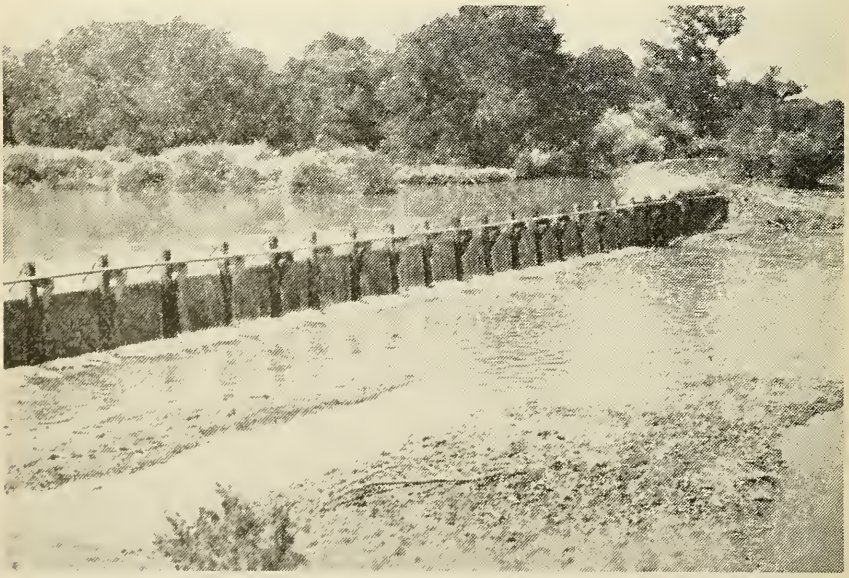

FIGURE 16. Moore Dam on Cache Creek. View from downstream side, showing Adams Canal coming *into* Cache Creek from north side. The water then crosses over and is taken out from the south side as the Moore Canal. June 18, 1940.

DAMS ON PUTAH CREEK

The only dams on Putah Creek are the one known as the Putah Creek Dam at Winters and a temporary one on the Bar X Ranch. Neither of these dams has a fishway, but each is removed in the winter and is then no obstacle to fish.

1. *Putah Creek Dam.* This dam is located in T. 8 N., R. 1 W., Sec. 22, Yolo County, at an elevation of 107 feet (Fig. 17). It is owned by the City of Winters. This dam is of the gravity type; flashboards are used. The distance from crest to stream bed is 11 feet and the crest length is 170 feet. It has a concrete base and concrete buttresses at the sides. There are three outlet gates in the center of the dam. The storage capacity is 177 acre-feet.

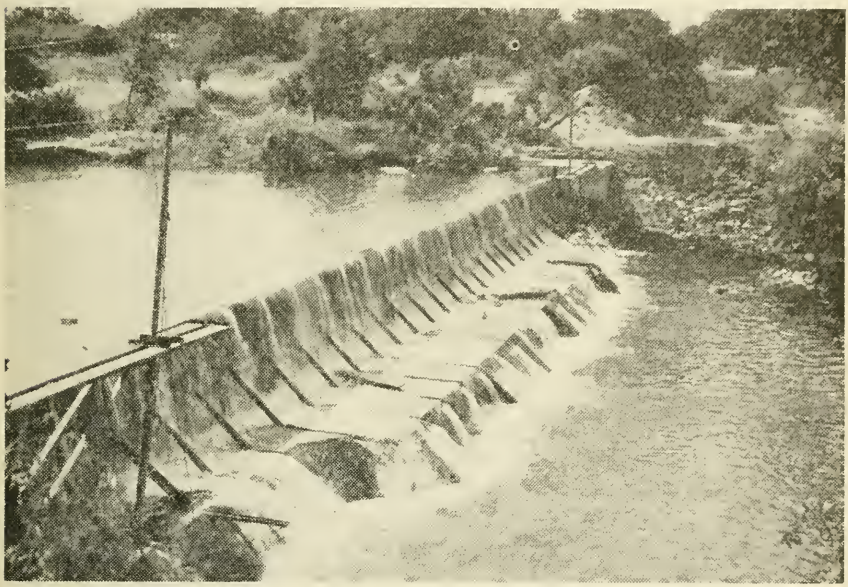

FIGURE 17. Putah Creek Dam, on Putah Creek at Winters. Note the three outlet gates in the center of the dam. June 18, 1940

There are no diversions leading from this dam and the reservoir serves essentially for percolation. Water is also pumped for irrigation from the impounded water behind the dam.

2. *Dam on Bar X Ranch.* This dam is located on the Bar X Ranch, between Middletown and the "Steel Bridge," in Lake County. Water is diverted for irrigation. This dam is not a barrier to fish in winter.

WATER FLOWS

Cache Creek. During most years in the summer the size of the flow in Cache Creek is almost entirely dependent upon the amount of water let out of Clear Lake. In the summer practically all of the water is diverted at Capay Dam, so that the stream is nearly always dry below that point.

In 1912 Warden R. L. Sinkey (1912) reported that Cache Creek was usually "practically dry" at the Moore Dam from July until the onset of the winter rains. He also wrote as follows:

"Main Cache Creek is quite a creek from the lake out. I would judge on the riffles it would run a stream two feet deep, 15 or 20 feet wide of an average season. The last two years it hasn't been half that size.

"North Cache Creek runs just a small stream. Just enough to keep fairly well cleaned. All the tributaries to North Cache Creek are just small streams, such as any small mountain stream."

Putah Creek. In the summer Putah Creek normally goes dry in the vicinity of the Putah Creek Dam at Winters and reappears as a stretch of running water several miles below the dam. This stretch is below Stevens Bridge, on the Phillips Ranch (Fig. 11). The stream also goes dry above the dam for about three miles (to Cody's). It dries up from about two miles above John Storlan's Bridge to about a mile above North Camp (Boy Scout camp). It dries up at the Pope Valley road crossing. The flow in sections between is permanent, even in dry years.

Underground gravel strata are supposed to take considerable water from the stream.

There are a number of pumps in the vicinity of Winters. Some of them do not pump directly from the stream, but in effect use stream water.

In 1912 Warden R. L. Sinkey (*op. cit.*) wrote of Putah Creek: "Becomes dry anywhere below Winters during the summer months." Also: "Putah Creek is just a small stream in the summertime. St. Helena Creek, Anderson Creek, Dry Creek run just small streams. Big Canyon Creek runs more water, I think, than all the rest."

DISTRIBUTION OF FISHES IN CACHE AND PUTAH CREEKS

As might be expected from an examination of the previous description of the drainage basins of Cache and Putah Creeks, practically the entire courses of the main streams and the lower courses of most of their tributaries are unsuitable for the maintenance of year-round populations of trout, due to high summer temperatures or the lack of water (Fig. 18). In the headwater tributary streams, however, some trout of the rainbow-steelhead complex are to be found (Fig. 19). To a large extent these form independent, self-sustaining populations in the different streams.

It is difficult to define the exact limits of the trout populations, and in fact these limits probably vary with the time of year. As in many other California streams that start in wooded, mountainous areas and flow into lowland valleys, trout are not infrequently caught at the start of the fishing season in the spring in the stretches of stream that flow into the valley floor and which later go dry or attain unsuitable temperatures.

In Cache Creek, trout are reported not to be caught in the vicinity of Capay Dam. However, local residents report that the upper portions of the North Fork of Cache Creek and its tributaries are fine trout fishing streams.

During the wet winter of 1937-38 considerable numbers of king salmon reached Capay Dam and the caretaker at the Clear Lake Impoundment Dam stated that some of them got past Capay Dam at the time.

FIGURE 18. Falls on Bear Creek, tributary to Cache Creek in Yolo County, approximately 400 yards above the mouth. Carp, Green Sunfish, Large-mouthed Black Bass, Sacramento Squawfish, suckers, and roaches were found in the pool below the falls, but no trout. The water temperature was 84 degrees F. and 85.5 degrees F. above the falls. June 19, 1940.

FIGURE 19. Bartlett Creek, tributary to North Fork of Cache Creek in Lake County. View from bridge approximately one-half mile above mouth. Here Bartlett Creek undergoes a transition from a trout stream to a cyprinid and sucker stream. June 28, 1940.

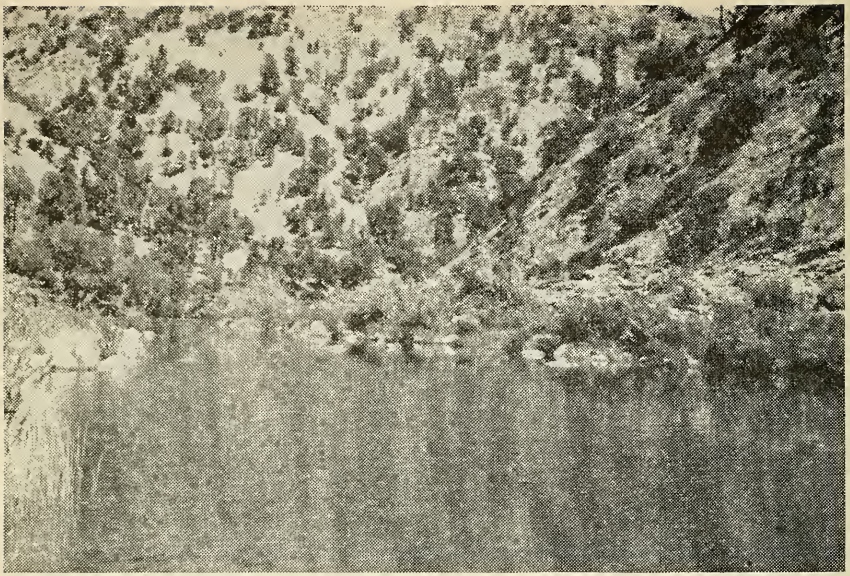

FIGURE 20. Putah Creek at Recreation Beach, Yolo County. It is a fine Smallmouth Black Bass stream in this region. June 20, 1940

FIGURE 21. Hell's Half Acre, the gorge of Putah Creek, in Lake County. Smallmouth Black Bass are abundant in this portion of the stream. June 27, 1940

In the Putah Creek system, early in the season some trout are caught in the vicinity of Middletown. They are reported to be caught in Coyote Valley. Trout two to three inches long were present about 150 yards above the mouth of a small, unnamed tributary of Soda Creek, in turn

a tributary of Putah Creek, on June 25, 1940. This stream is on the Rutherford-Monticello road, in T. 8 N., R. 4 W. In past years some trout have been taken in Putah Creek in the vicinity of Monticello by state fish rescue crews. It is not certain whether these were offspring of sea-run steelhead or stream trout. Some king salmon have also been taken in the vicinity of Monticello by fish rescue crews.

Unlike trout and salmon, the various members of the sunfish family, such as the black basses, green sunfish, and bluegill, and the various introduced and native "rough fish" (non-game fishes), such as the carp and the various native cyprinids, are able to withstand high water temperatures and, in most cases, poorer oxygen conditions. As a result of this, the smallmouth black bass is widely distributed in Putah Creek and spawns extensively throughout almost its entire course (Figs. 20 and 21).

The smallmouth black bass is usually found in clear water. Whereas the water of Putah Creek is quite clear in the spring and summer, the water of Cache Creek remains quite murky. The roiliness of the water in the latter stream is due to the fact that the water originates in

FIGURE 22. Cache Creek, with Clear Lake Impoundment Dam in background. The water is being released through outlet gates at the bottom of the dam, roiling the stream below. March 7, 1940.

Clear Lake and probably also to the fact that at Clear Lake Impoundment Dam it is let out through the outlet gates at the bottom, stirring up the bottom materials (Fig. 22). During his 1940 survey the writer found no young or adult smallmouth black bass in Cache Creek, and in his unpublished report stated that the lack of natural propagation of this species was probably associated with the roily water.

On July 26, 1946, Mr. Garth Murphy of the California Division of Fish and Game examined Cache Creek from the Colusa-Yolo County line downstream to Guinda (Fig. 23). The only young fish that he found were suckers. A microscopic examination made by him of the sediments that roil Cache Creek downstream from Clear Lake Impoundment Dam revealed that they consist of about one-third organic material and two-thirds materials of an abrasive nature (mostly broken diatoms). This abundance of abrasive material probably accounts for the dearth of young fish other than suckers in the stream. It appears that whereas the suckers are tolerant of the abrasive action of the sediments, the smallmouth black bass and other species are unable to withstand their effects. The sediments probably cause considerable damage to the eggs of black bass by smothering them and also probably adversely affect the young and possibly the adults, particularly in the gill region.

FIGURE 23. Cache Creek from bridge at Rumsey, Yolo County. Black bass are now reported to be much less abundant in this region than in former years. June 19, 1940

Shad are reported to run up Putah Creek, and also to come up Cache Creek as far as Capay Dam. Striped bass may also run up to Capay Dam; a few are reported to have been caught below it.

Extensive water use, flood control measures, and erosion and consequent silting up of the streams and filling in of the holes caused by overgrazing, deforestation, and road construction have increased the temperatures and lowered the summer flows of many of the streams. Principally because of increased summer temperatures, the trout have been pushed higher and higher up many of the streams, and as they have been pushed back the various rough fish, especially the cyprinids, have proceeded farther and farther upstream, into what was formerly the realm of the trout alone. For example, there was once fine trout fishing in stretches of Putah Creek that are practically devoid of trout at the present time.

Table 1 records the fishes which have been observed in Clear Lake and tributaries, Cache Creek and tributaries, and Putah Creek and tributaries in recent years.

TABLE 1

Distribution of Fishes in Clear Lake, Cache Creek, and Putah Creek

Species of fish	Clear Lake	Cache Creek	Putah Creek
Family Petromyzonidae. The Lamprey Family.			
Entosphenus tridentatus (Gairdner). Pacific Lamprey		X	X
Family Clupeidae. The Herring Family.			
Alosa sapidissima (Wilson). Atlantic Shad		X	X
Family Salmonidae. The Salmon and Trout Family.			
Oncorhynchus tshawytscha (Walbaum). King Salmon		X	X
Salmo qairdnerii Richardson. Rainbow Trout	X	X	X
Family Catostomidae. The Sucker Family.			
Catostomus occidentalis Ayres. Western Sucker	X	X	X
Family Cyprinidae. The Carp or Minnow Family.			
Orthodon microlepidotus (Ayres). Greaser Blackfish	X	X	X
Mylopharodon conocephalus (Baird and Girard). Hardhead		X	X
Lavinia exilicauda Baird and Girard. Hitch	X	X	X
Ptychocheilus grandis (Ayres). Sacramento Squawfish	X	X	X
Gila crassicauda (Baird and Girard). Sacramento Chub	X		X
Pogonichthys macrolepidotus (Ayres). Split-tail	X		
Hesperoleucus symmetricus (Baird and Girard). Roach	X	X	X
Rhinichthys osculus (Girard). Black Dace		X	X
Cyprinus carpio Linné. Carp	X	X	X
Family Ameiuridae. The Catfish Family.			
Ictalurus catus (Linné). White Catfish	X	X	X
Ameiurus nebulosus (Le Sueur). Brown Bullhead	X		X
Family Poeciliidae. The Top-minnow Family.			
Gambusia affinis (Baird and Girard). Mosquitofish	X	X	X
Family Gasterosteidae. The Stickleback Family.			
Gasterosteus aculeatus Linné. Three-spined Stickleback	X		X
Family Centrarchidae. The Sunfish Family.			
Archoplites interruptus (Girard). Sacramento Perch	X		
Pomoxis nigro-maculatus (Le Sueur). Black Crappie	X		
Lepomis cyanellus Rafinesque. Green Sunfish	X	X	X
Lepomis macrochirus Rafinesque. Bluegill	X	X	X
Huro salmoides (Lacépède). Largemouth Black Bass	X	X	
Micropterus dolomieu Lacépède. Smallmouth Black Bass	X?	X	X
Family Serranidae. The Sea Bass Family.			
Roccus lineatus (Bloch). Striped Bass		X	
Family Cottidae. The Sculpin Family.			
Cottus gulosus (Girard). Riffle Sculpin	X		
Cottus sp. Sculpin		X	X
Family Embiotocidae. The Viviparous Perch Family.			
Hysterocarpus traski Gibbons. Fresh-water Viviparous Perch	X		

Changes in the Fish Fauna and Fisheries Which Are Likely to Result Through the Construction of the Development

Changes which are likely to result in the fish fauna and fisheries through the construction of the development will depend in part upon the order in which the various units are completed.

1. If Monticello Dam is constructed first and independently of the other dams, the waters which will be affected directly will be the portions of Putah Creek and its tributaries flooded out by the reservoir (approximately 18 miles of the main stream) and that portion of the stream below the reservoir. Putah Creek above the reservoir and Cache Creek and its tributaries will not be affected physically.

As seen from the previous list, Putah Creek is now inhabited by an assemblage of fishes typical of the Sacramento River fauna. Upon completion, Monticello Reservoir may be expected to become rapidly populated by those elements of the fauna which are adaptable to lowland

warm-water reservoir conditions. Of the game fishes, the white catfish (known locally as fork-tail catfish), brown bullhead (known locally as square-tail catfish), green sunfish, and bluegill may be expected to become dominant forms. Of the rough fish, the western sucker, Sacramento squawfish, and carp may be expected to become dominant forms.

The general statement may be made that trout will not assume a place of importance in the reservoir, although a small number may be present in it. Principal adverse factors which will limit the trout population are (1) unsuitable reservoir water conditions (principally temperatures and oxygen regime) and (2) competition and interference from other fishes.

The Pacific lamprey, Atlantic shad, and king salmon, being anadromous forms, will be limited to the portion of the stream below the reservoir, even if they are able to enter Putah Creek from Yolo By-pass.

The position of the smallmouth black bass, which is now present in Putah Creek both below and above the site of the reservoir, is problematical. Generally, it is not considered to be especially well suited to warm-water reservoirs, but it has maintained itself in Milliken Reservoir, Napa County, and some other impoundments which have not been considered to fit the ideal requirements of the species, and so may become an important element in the reservoir fauna.

The position of the other rough fish known to be present in Putah Creek, the greaser blackfish, hardhead, hitch roach, black dace, mosquitofish, and sculpin, is also problematical. On the basis of experience elsewhere, the roach may be expected to be relatively unsuccessful. The others may become quite numerous, but none of them may be expected to be of as much importance in the economy of the reservoir as the western sucker, Sacramento squawfish, and carp.

Several species present in Clear Lake, in the main Sacramento River, and in tributaries of the Sacramento River near Putah Creek are absent from the list of fishes observed in Putah Creek in recent years. Among these are the split-tail, Sacramento perch, black crappie, largemouth black bass, and fresh-water viviparous perch. Whether these forms are actually absent from the stream or simply have escaped notice is not known. If they are present in the stream above the reservoir site, any of them may be expected to persist in numbers in Monticello Reservoir, since they all occur in numbers in Clear Lake. The Sacramento chub, whose presence in Putah Creek is not certain, for some reason appears to be a rare form in Clear Lake.

The reason for the apparent absence or rarity of the largemouth black bass in Putah Creek is not clear. The physical and chemical conditions of the stream may be responsible, or it may be simply that the smallmouth black bass has attained and maintained a dominant position.

Whatever the reason, if the largemouth black bass is actually absent from or rare in Putah Creek in the vicinity of the reservoir site, and the smallmouth black bass fails to adapt itself to lake conditions in this instance, Monticello Reservoir will be left without an outstanding game fish (the white catfish, brown bullhead, green sunfish, and bluegill are much less highly prized in this area than are the black basses and trout, especially since they are readily available in Clear Lake and other waters of the region). In such an eventuality the reservoir will also be

left without a predatory species capable of making serious inroads into the rough fish populations.

In view of the above considerations, it appears desirable to make a heavy plant of largemouth black bass in Monticello Reservoir as soon as it contains sufficient water, in order to build up a strong population of the species and to keep not only the rough fish but also the green sunfish and bluegill under some semblance of control.

Along with Monticello Dam, the 38-foot high Putah Creek Diversion Dam would be constructed about two miles downstream from it and would create a lake approximately two miles long. The initial fish population of this body of water would be about the same as that of Monticello Reservoir. For the same reasons advanced for the latter, it would probably be desirable to make a heavy plant of largemouth black bass in the reservoir formed by Putah Creek Diversion Dam.

The fish fauna and angling in Putah Creek above Monticello Reservoir will probably remain pretty much as they are now. That is, the smallmouth black bass may be expected to remain as the dominant species and to furnish excellent angling, despite the possibility of invasion of this section of the stream by cyprinids from the reservoir. Some trout will continue to be caught, especially early in the season, in the stream in the vicinity of Middletown and in Coyote Valley and at upstream points, as well as in some of the tributary streams.

It is still not clear as to what flows would exist in Putah Creek below Putah Creek Diversion Dam, nor what temperatures would exist in the stream.

If sufficient flows to maintain fish life in good condition are released downstream from the diversion dam, the probabilities are that the smallmouth black bass and green sunfish will furnish the bulk of the angling, although the possibility exists that under certain conditions the largemouth black bass and one or both of the catfishes will become important.

Under present plans the canals of the Yolo-Solano development would have flows only during the irrigation season, and so cannot be relied upon as fishing waters.

Insofar as fish protection is concerned, screening should be required at the head of the Putah Main Canal, which would originate in the body of water formed by the Putah Creek Diversion Dam. The question of screening Suisun, Yolano, and Lower Yolano Canals for protection of salmon migrants should be further investigated after operating schedules of this project, and certain factors in the Central Valley Project, have been more definitely determined.

2. Indian Valley Dam is planned as the second of the three large dams. Under present plans, the construction of the Clear Lake-Putah Creek Tunnel is contingent upon the building of Indian Valley Dam.

If this dam and tunnel are built, the new waters which will be affected directly will be the portions of North Fork of Cache Creek and its tributaries flooded out by the reservoir (approximately six miles of the main stream), that portion of North Fork of Cache Creek below the reservoir, all of Cache Creek below the present Clear Lake Impoundment Dam, Soda Creek from the entrance of the tunnel to its entrance into Putah Creek, and Putah Creek from the entrance of Soda Creek to Monticello Reservoir. In addition, Monticello Reservoir and the waters

below it will be affected in that any fish species not already present in them but present in Clear Lake will probably be introduced by way of the tunnel. This introduction would not be desirable, but it is believed that no possible form of screening would be effective in preventing the passage of all fish downstream through the tunnel.

As seen from the previous list, Cache Creek, like Putah Creek, is now inhabited by an assemblage of fishes typical of the Sacramento River fauna. However, it is possible that some of the species are not found as far upstream as the site of Indian Valley Dam. These include the Atlantic shad, king salmon, carp, white catfish, black crappie, green sunfish, bluegill, largemouth black bass, smallmouth black bass, and striped bass. In fact, the only species definitely known to be present above the Indian Valley Dam site are rainbow trout, western sucker, and some of the native cyprinids, including the Sacramento squawfish.

In view of the above, it appears that even if no control or stocking is carried out, Indian Valley Reservoir may have a fish fauna different from that of Monticello Reservoir.

What sort of control program would be justified prior to construction of the dam is not yet certain. The most feasible program would probably consist simply of the construction of a small temporary dam impassable to upstream fish at some point below the Indian Valley Dam site.

Although it is not certain that this program would be successful in entirely eliminating all undesirable species, it is known that the adults of the western sucker and Sacramento squawfish migrate upstream to spawn in the spring and then return downstream. Therefore, it is quite possible that under such a program some of the undesirable species would be eliminated entirely within the course of a few years and that others would be reduced to such a point that they would not assume a dominant role in the reservoir when Indian Valley Dam is constructed. Since the cost of such a project would be relatively low and since no valuable runs of anadromous fishes are involved, it is recommended that such a dam be constructed.

Whether or not poisoning of those upstream waters which are inhabited by fish species not desired in the reservoir should be attempted in addition could be decided after the temporary dam had been constructed and its effects observed. Such waters would include North Fork of Cache Creek from the temporary dam to its source (approximately 24 miles), Bartlett Creek to a point about one-half mile above its entrance into North Fork of Cache Creek, Stanton Creek to a point at least five miles above its entrance into North Fork of Cache Creek, and portions of several minor tributaries.

If the undesirable species are eliminated or strongly controlled by the time that Indian Valley Dam is constructed, it is recommended that the reservoir be stocked with trout of the rainbow-steelhead complex, the exact strain to depend upon results of current stocking experiments in lowland reservoirs. If the control program is not successful, it will probably be desirable to stock the reservoir heavily with black bass (the species to be stocked will depend in part upon the success of the smallmouth black bass in the Monticella Reservoir and may be determined later) and probably with some bluegill.

The operation of Indian Valley Reservoir will affect radically the character of North Fork of Cache Creek from the dam to its entrance into Cache Creek during the irrigation season. If releases of water sufficient to maintain fish life in good condition can also be made from the dam during the rest of the year, North Fork of Cache Creek and Cache Creek from the entrance of North Fork of Cache Creek at least to the point of diversion of Rumsey Canal should furnish fair to good angling, probably for one or both species of black bass and for green sunfish, and possibly for trout, if the temperature of the water is sufficiently low (Fig. 24). Such releases of water during the nonirrigation season should be provided if possible.

FIGURE 24. North Fork of Cache Creek at State Highway 20 bridge crossing, Lake County, March 7, 1940. This stream is now usually dry at this point in the late summer.

A relatively small year-round flow should also be maintained in Cache Creek from the present Clear Lake Impoundment Dam to the entrance of North Fork of Cache Creek, in order to maintain fish life in good condition. Angling for largemouth black bass might be possible in this section.

If a year-round flow could be maintained through the Cache Creek-Putah Creek Tunnel, angling, probably for smallmouth black bass, might be possible in this section.

In connection with the matter of the maintenance of flows in Cache Creek below the present Clear Lake Impoundment Dam and through the Cache Creek-Putah Creek Tunnel, one point should be mentioned. The absence of the young of black bass and of other fishes except suckers in Cache Creek below Clear Lake Impoundment Dam and the probable relationship between this phenomenon and the abrasive sediments originating at the dam and in Clear Lake have already been noted. Consequently, it would be desirable to release the water from Clear Lake Impoundment Dam in some manner that would eliminate as much silt as possible from it.

3. Wilson Valley Dam would be the last of the major works to be constructed. Its ultimate construction will depend upon the outcome of additional foundation exploration and future water requirements. In view of this, this dam and the resulting reservoir need be given only brief consideration in the present report.

If Wilson Valley Dam is built, the reservoir formed by it may be expected to contain the full complement of fishes present in Clear Lake, since most of these are now present in Cache Creek at the dam site and since those not now present will necessarily be introduced through the release of water down Cache Creek from Clear Lake Impoundment Dam.

Recommendations in regard to stocking of Wilson Valley Reservoir should be deferred until the results of fish management practices in Monticello Reservoir and Indian Valley Reservoir have been analyzed. The probability is that heavy initial stocking with largemouth black bass and some initial stocking with bluegill will be in order.

The construction of Wilson Valley Reservoir would affect directly for a second time the major portion of the waters changed by the building of Indian Valley Dam and the Clear Lake-Putah Creek Tunnel. The waters which would thus be affected directly would be the portions of Cache Creek and North Fork of Cache Creek and their tributaries flooded out by the reservoir (approximately 7½ miles of the former and eight miles of the latter) and all of Cache Creek below the reservoir.

If releases of water sufficient to maintain fish life in good condition can be made from the dam throughout the year, Cache Creek from the dam at least to the point of diversion of Rumsey Canal should furnish fair to good angling, probably for one or both species of black bass and for green sunfish. Such releases of water during the nonirrigation season should be provided.

4. The amounts of water which should be requested for release downstream into Putah Creek from Putah Creek Diversion Dam and into Cache Creek from Capay Dam and the times of release of such water will depend upon the construction and operation of certain downstream works of the Yolo-Solano development and of certain other works of the Central Valley Project. The physical works which would affect the desired releases into Putah and Cache Creeks include (1) Knights Landing Canal and Pumping Plants, (2) Zamora Canal, (3) Suisun Canal, Pumping Plant, and Marshland Reclamation Features, (4) Lateral System and Drainage, and (5) Suisun Bay to Sacramento Navigation Canal. The requested releases will also depend upon the operation of the Yolo by-pass and, less directly, the proposed Delta Cross Channel.

It is probably somewhat outside the province of the present report to discuss in detail these features and their effects on fish life, since they are being studied in varying detail by other fisheries workers of the U. S. Fish and Wildlife Service and the California Division of Fish and Game. However, to complete the picture of the Yolo-Solano development, a brief general discussion of these works and their possible effects on fish life will be given.

In a previous report (Shapovalov, 1940) the writer pointed out that salmon and steelhead could enter Cache and Putah Creeks only at such times as excess water of the Sacramento River at flood stage flowed down Yolo By-pass. He further pointed out that under existing conditions there was normally no flow in Cache and Putah Creeks at the time

that the main king salmon fall run was ascending the Sacramento River and that at the time no plan that would assure a flow of water in the lower portions of Cache and Putah Creeks in all years in the autumn months, when the main run of king salmon is taking place, appeared feasible. However, even under the adverse conditions existing at the time that the above-cited report was written, considerable numbers of king salmon (as well as striped bass and Atlantic shad) ascended Yolo By-pass as far as the entrance of Putah and Cache Creeks and in years of favorable run-off entered the latter streams. Specific examples were cited earlier in this article.

Since the above-cited report was written, Shasta Dam has been completed and the several dams on Cache and Putah Creeks and the other physical works cited earlier in this section have been projected. Control and leveling out of the fluctuations in flow of the Sacramento River through the construction of Shasta Dam has decreased the amount of water let down Yolo By-pass and the length of time over which it is let down.

Balanced against this situation, which is, of course, unfavorable to the ascent of Yolo By-pass by king salmon, is the possibility of maintaining flows in the lower portions of Cache and Putah Creeks during the autumn months through the release of water from the proposed dams on these streams, and thus making available some of the fine spawning gravels contained in them.

The general matter of making potential spawning areas in Cache and Putah Creeks available to anadromous salmonids is complicated by the proposed downstream physical works which have been listed in this report. Their probable relationship to the runs of salmon and steelhead will have to be studied and treated in separate reports. If it is found possible to maintain even small runs through the Yolo By-pass, every effort should be made to release sufficient water downstream into Putah Creek from Putah Creek Diversion Dam and into Cache Creek from Capay Dam to insure successful spawning of salmon and steelhead, especially in view of the acute depletion of the Sacramento River king salmon.

5. The final portion of the Yolo-Solano development and allied works which remains to be considered concerns the effects of possible construction on fish life in Clear Lake.

If Indian Valley Dam and the Cache Creek-Putah Creek Tunnel are constructed, Clear Lake will be used for regulatory storage and then only for short periods during floods. The general physical effect of these works will be to level out fluctuations in Clear Lake. The effects on fish life in Clear Lake probably will not be of great magnitude and are not expected to be unfavorable.

Several dam sites on tributaries of Clear Lake have been investigated, but data in regard to them are not yet available. If such dams are constructed, they will further regulate the level of Clear Lake and may alter its temperature and oxygen regimes. The effects on fish life in Clear Lake and downstream waters can not be prognosticated until engineering and operating data for these dams are known. The construction of dams on tributaries of Clear Lake does not appear to be imminent.

Summary of Recommendations

It is recommended that:

1. A heavy initial plant of largemouth black bass be made in Monticello Reservoir as soon as it contains sufficient water.
2. A heavy initial plant of largemouth black bass be made in Putah Creek Diversion Dam Reservoir as soon as it contains sufficient water.
3. Sufficient flows be released downstream from Putah Creek Diversion Dam to maintain a black bass and sunfish fishery.
4. The intake to Putah Main Canal be screened to prevent entrance of fish into it.
5. A small temporary dam impassable to upstream fish be constructed on North Fork of Cache Creek a short distance below Indian Valley Dam site at the earliest possible time, prior to the construction of Indian Valley Dam. If undesirable fishes present above the dam are not eliminated by this means alone, poisoning of the waters above the dam containing these fishes be carried out in addition.
6. If the undesirable species are eliminated or strongly controlled in the waters above the dam site by the time that Indian Valley Dam is constructed, the reservoir be stocked with trout of the rainbow-steelhead complex, but if the control program is not successful, the reservoir be stocked heavily with black bass (the species to be stocked to depend in part upon the success of the smallmouth black bass in Monticello Reservoir and to be determined later) and probably with some bluegill.
7. Sufficient water be released downstream from Indian Valley Dam during the nonirrigation season to maintain fish life in good condition at least as far downstream as the point of diversion of Rumsey Canal, on Cache Creek.
8. The intake to Rumsey Canal be screened to prevent entrance of fish into it.
9. A relatively small year-round flow be maintained in Cache Creek from the present Clear Lake Impoundment Dam to the entrance of North Fork of Cache Creek, in order to maintain fish life in good condition.
10. A year-round flow be maintained through the Cache Creek-Putah Creek Tunnel and downstream to Putah Creek, in order to maintain fish life in good condition and provide angling.
11. Water from Clear Lake Impoundment Dam be released in some manner that would eliminate as much silt as possible from it.
12. Formulation of a stocking program for Wilson Valley Reservoir be deferred until the results of fish management practices in Monticello Reservoir and Indian Valley Reservoir have been analyzed. (The probability is that heavy initial stocking with largemouth black bass and some initial stocking with bluegill will be recommended.)

13. Sufficient flow be released downstream from Wilson Valley Dam during the nonirrigation season to maintain a black bass and sunfish fishery at least to the point of diversion of Rumsey Canal.

14. The amounts of water for downstream release from the various dams of the Yolo-Solano development and the times of release of such water be determined after the order of construction of certain downstream works of the Yolo-Solano development and of certain other works of the Central Valley Project has been decided and engineering data and operating schedules for same have been made available. The physical works which would affect the desired releases into Putah and Cache Creeks include (1) Knights Landing Canal and Pumping Plants, (2) Zamora Canal, (3) Suisun Canal, Pumping Plant, and Marshland Reclamation Features, (4) Lateral System and Drainage, and (5) Suisun Bay to Sacramento Navigation Canal. The requested releases will also depend upon the operation of the Yolo By-pass and, less directly, the proposed Delta Cross Channel.

15. If even small runs of salmon and steelhead can be maintained through the Yolo By-pass, sufficient water be released downstream in Putah Creek from Putah Creek Diversion Dam and in Cache Creek from Capay Dam to insure successful spawning of these runs.

16. The intakes to Suisun Canal and Yolano and Lower Yolano Canals be screened to prevent entrance of fish into them.

Summary

The proposed Yolo-Solano development of the U. S. Bureau of Reclamation is a multiple-purpose feature of the Central Valley Project of California, providing for the development of certain lands and waters in Yolo, Solano, Napa, and Lake Counties for purposes of irrigation, domestic water supply, power, salinity control, navigation, and recreation.

In general, the project involves (1) the storage of runoff waters from Cache and Putah Creeks in Lake and Napa Counties, by means of three large dams and reservoirs, and (2) diversions from the Sacramento River at Knights Landing and Lindsey Slough. The three proposed dams and reservoirs are the following: Monticello Dam and Reservoir on Putah Creek, Indian Valley Dam and Reservoir on North Fork of Cache Creek, and Wilson Valley Dam and Reservoir on Cache Creek. These works would be constructed in the order listed. Construction of reservoirs on tributaries of Clear Lake is also being considered.

The lower portions of both Cache and Putah Creeks now become dry or very low and warm in the summer months and are inhabited by an assemblage of fishes typical of the Sacramento River fauna, including many "rough fish" (nongame species). Aside from Clear Lake and its tributaries, the only sport fishing of consequence which exists in these stream systems is a limited amount of trout angling in the headwater regions and good angling for smallmouth black bass in Putah Creek for a major portion of its course.

Monticello Reservoir would flood out approximately 18 miles of Putah Creek, including some of the fine smallmouth black bass areas,

but with proper management could be expected to provide a considerable warm-water sport fishery.

Indian Valley Reservoir would not destroy any important sport fishing areas, and might support a trout fishery, especially if the rough fish now present above the dam site could be eliminated prior to construction.

Wilson Valley Reservoir also would not eliminate any important sport fishing grounds. Plans for its development should be deferred until the results of fish management practices in Monticello Reservoir and Indian Valley Reservoir have been analyzed.

Adequate year-round releases of water from the various dams would probably create fair to good stream angling, probably for one or both species of black bass and for green sunfish.

Maintenance of flows in the lower portions of Cache and Putah Creeks during the autumn months through the release of water from the proposed dams might make available to king salmon some of the fine spawning gravels contained in these streams, provided that runs of the species can be maintained through the Yolo By-pass after construction of the proposed downstream works.

If Indian Valley Dam and the Cache Creek-Putah Creek Tunnel are constructed, fluctuations in Clear Lake will be leveled out. The effects on fish life in Clear Lake probably would not be of great magnitude and would not be expected to be unfavorable.

Specific recommendations for management, including stocking, rough fish control, screening, and maintenance of flows, are listed.

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A NEW TRANSPLANT OF THE PIUTE TROUT *(SALMO CLARKII SELENIRIS)* FROM SILVER KING CREEK, ALPINE COUNTY, CALIFORNIA[1]

By Elden H. Vestal

Bureau of Fish Conservation
California Division of Fish and Game

Introduction

The Piute trout was described by the late Dr. John O. Snyder in 1934 [2] as a variant of the black-spotted or cut-throat trout of the Lahontan Basin which had differentiated from the parent stock and attained its unusual coloring due to its isolation in remote headwaters of the East Carson River drainage. Because the very limited area which this small but beautiful trout inhabits makes it susceptible of extinction by man or by a geologic catastrophe, its native habitat (Silver King Creek and tributaries above Llewellyn Falls, Alpine County) has for years been closed to all fishing. In a further effort to insure the survival of this form several hundred were transplanted, with the cooperation of the Mt. Ralston Fish Planting Club, into the Leland Lakes in El Dorado County in 1937, but apparently failed to establish themselves there.

Recently, especially since May, 1945, the once abundant population of this trout in Upper Fish Valley of Upper Silver King Creek basin has declined. This decline is due largely to poaching by anglers, local and visiting alike, who have openly considered the sequestered population of Piute trout above Llewellyn Falls a tempting pleasure. To what extent blame also can be placed on stockmen and packers operating in the general area is uncertain; but the writer is of the opinion that our failure to engender the full cooperation of these groups in protecting the Piute is a major factor for consideration.

Consequently, for some time the writer has sought to locate a new and more remote basin in which to transplant and establish a small population of Piute trout supplementary to the parent group in Upper Fish Valley. At the April, 1946, meeting of the Eastern Sierra Packers Association in Independence, California, District Ranger Al Noren, of the Inyo National Forest, suggested survey of the upper Cottonwood Creek basin of the White Mountains in eastern Mono County, possibly with such a purpose in mind. This was done and is here reported, together with details of the new transplant of Piute trout to that locality.

Acknowledgments

A note of appreciation is due Messrs. Mervyn and Frank McKay, of Coleville, California, who helped to procure the trout. Still another is due Messrs. Elliot Earl, and District Ranger E. M. Stone of the U. S. Forest Service, Robert L. Franklin, operator of the Eva Belle Mine, and Murray Cutter, of Beverly Hills, California, for help in distributing

[1] Submitted September, 1946.
[2] Snyder, John O. 1934. A new California Trout. California Fish and Game, Vol. 20, No. 2, pp. 105-112, and one color plate.

the fish. I am particularly grateful to District Ranger Al Noren, of the Inyo National Forest, for help and transportation during the survey of the upper Cottonwood Creek basin and in transportation and distribution of the transplant. Mr. Jack C. Fraser, student biologist with the biological staff of the Bureau of Fish Conservation, gave invaluable assistance to the writer throughout the project.

Survey of Upper Cottonwood Creek Basin

On July 3, 1946, Mr. J. C. Fraser and the writer joined District Ranger Al Noren in Bishop for a survey trip into the upper Cottonwood Creek Basin. The party was augmented by Warden A. Crocker, of Big Pine, California.

The upper basin is located due east of Piute Mountain and southeast of White Mountain Peak, in southeastern Mono County, California (Fig. 25). It is comprised of more than 15,000 acres and is characterized by enormous weathered and rounded outcrops of granite on the slopes and by low granite ridges separating the tributaries of the North and South Forks of Cottonwood Creek. Predominant cover, up to timber line, on the upper and chiefly north-facing slopes is made up of foxtail pine *(Pinus balfouriana)* with some limber pine *(Pinus flexilis)* interspersed. On the south-facing slopes and extending well down into the North and South Fork canyons are dense growths of desert mountain mahogany *(Cercocarpus ledifolius)*; this gives way to sage brush *(Artemisia tridentata)* and bitter brush *(Purshia tridentata)* in more open areas in the floor of the basin. Along the streams, aspen *(Populus tremuloides)* groves and dense willow *(Salix* sp.) thickets are common. Small meadows mark the vicinity of springs and moist places along the stream margins.

Elevations in the basin range from 9,450 feet at the junction of the two forks of the creek to over 12,000 feet on Piute Mountain; but the principal range of the streams proper is from the former named elevation to about 10,900 feet.

Since the North Fork was barren of fish life above a natural barrier about one-half mile above the junction with the South Fork (Fig. 25), this tributary received most attention. On July 3, 1946, at 12.45 p.m., the crystal clear stream was flowing an estimated 2½ c.f.s. at a temperature of 58.5 degrees F. The stream averaged about four feet in width and varied from three inches in depth on riffles to over two feet in pools. Excellent pools, and riffles characterized by gravels practically ideal for spawning, were observed. Aside from aspens and dense willow thickets, rubble and boulders, the undercutting of banks, and accumulations of dead limbs and twigs offered ample stream shade and shelter. Mayfly nymphs and pupae were so abundant that a small bobbinet dip net easily caught a teaspoonful of the insects at a stroke; and whole areas of the bottom were blackened by them. Midges in various stages were also abundant. There was every indication, therefore, of ample foods available for trout.

Extreme fluctuations in flow of the stream, which is largely spring fed, are infrequent. On August 22, 1946, only moderate scouring of the stream resulted when a cloudburst during a thunderstorm occurred on the northeastern side of the North Fork Basin. There is indication that water from melting snow in the spring swells the volume of the stream to as much as 7 c.f.s.

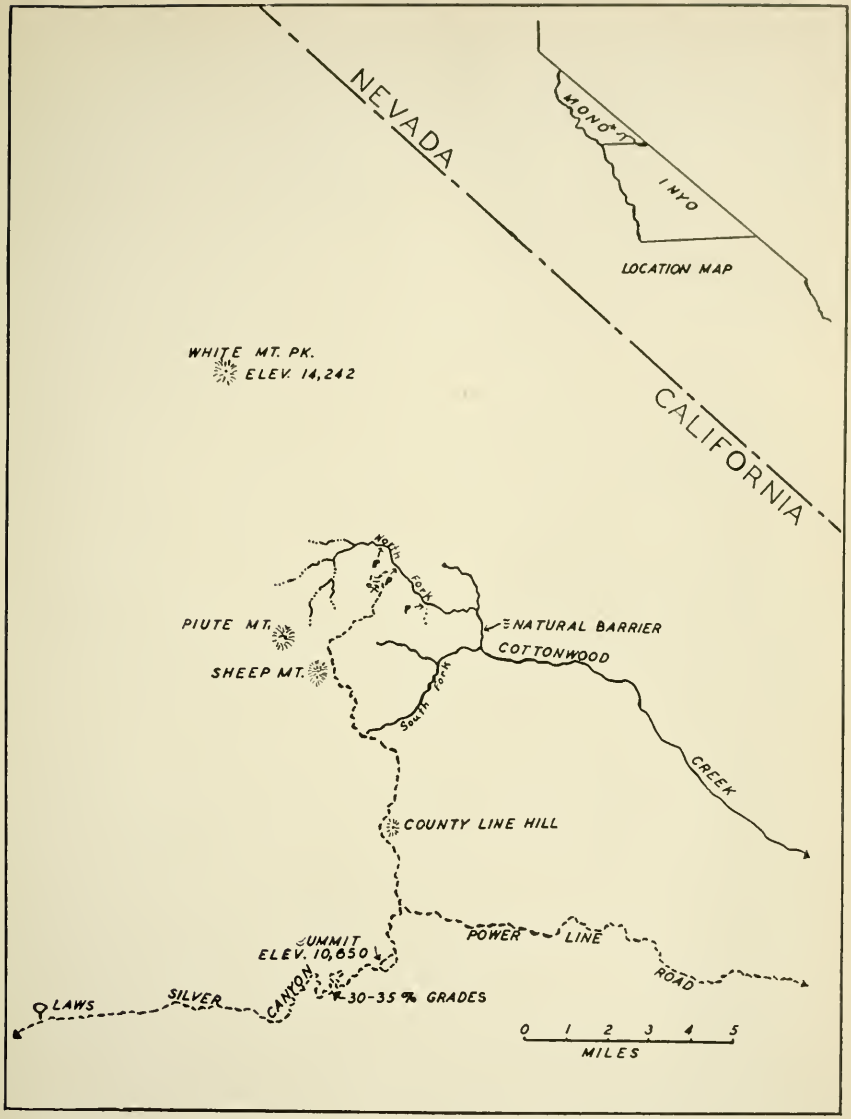

FIGURE 25. Sketch map showing location of newly established sanctuary for Piute Trout and of transplants (P) on North Fork of Cottonwood Creek

Below the small barrier mentioned in the lower North Fork, eastern brook trout, 5 to 12 inches long and in excellent condition, were observed in numbers such as the writer has not seen in any stream in several years. The South Fork also contained many fine-appearing eastern brook.

Some Shasta Beaver were introduced into the North Fork Basin on August 8, 1946. It is yet too early to state what effect these might have on development of the stream as a trout sanctuary.

A small herd of cattle from the Deep Springs Valley Ranch, Nevada, are seasonally ranged in the basin, but nothing was observed to indicate any deleterious effects on the streams from the ranging stock.

From all observations it was inferred that the North Fork of Cottonwood Creek would provide and could be developed as a fine sanctuary for the Piute trout. A major factor in formulating the inference was the geographical position of the stream, remotely situated, and accessible from the Owens Valley only by a steep and narrow, unimproved mountain road which requires a four-speed vehicle and has grades of 30 to 35 percent for hundreds of yards. The trip from Bishop, California, to the stream, a distance of some 40 miles, required about four hours in a Forest Service heavy duty pickup truck. According to Mr. Noren, the road is maintained largely by the Nevada-California Electric Corporation and to a lesser extent by the Inyo National Forest. It is probable (and desirable) that the road could be used in control of access to the Cottonwood Basin.

The upper Cottonwood Basin is accessible from the Nevada side only by foot or horseback for a distance of about 29 miles.

Procurement and Transfer of Trout

This phase of the project was divided into three principal steps, namely, (1) reconnaissance trip to Upper Fish Valley for the purpose of locating a suitable number of Piute trout, (2) capture of the fish and transportation to Hot Creek Hatchery for a brief rest period, and (3) transportation of the trout to and planting in the North Fork of Cottonwood Creek.

Reconnaissance Trip. The reconnaissance trip was completed August 6 and 7, 1946, by the writer, accompanied by Mr. J. C. Fraser. The trip was made on horseback from Little Antelope Valley Pack Station, three miles from Coleville, California, and required some three and one-half hours since it was decided to ride into Fish Valley via the vicinity of the middle section of Silver King Creek near "The Forks." At this point the combined streams of Corral and Coyote Valleys (larger of the two) enter from the east. Upon arriving in Lower Fish Valley, below Llewellyn Falls, 12 trout, all rainbow, were taken from the stream and examined; one exhibited faint orange-crimson marks extending forward on the throat toward the tongue. Several Piute trout, about five to eight inches long, were seen in this section of the stream among the rainbow and the contrast in coloration and markings between the two was most striking.

Above Llewellyn Falls, in Upper Fish Valley, only Piute trout were found; and 18 caught with hook and line, after brief examination, were released. The trout occurred along Silver King Creek in Upper Fish Valley proper, and as far up its main tributaries, Four-mile Canyon, Ball Canyon, Fly Valley, and Bull Canyon, as natural barriers permitted. In the Fly Valley and Bull Canyon tributaries the distribution amounted in total to less than one-half mile of stream; above the barriers are magnificent trout streams which, though now barren, could be utilized and stocked with the Piutes and would aid considerably in increasing the diminished numbers of the fish. At any rate, if formerly the Piute trout occurred in

abundance they were now astonishingly decimated; the writer had to search yards of stream in some sections before more than a few fingerlings were observed. More fish were seen proportionately in the rocky pools and cascading portions of Four-mile and Ball Canyons than were seen in the main stream.

August 7th, the party returned to Little Antelope Valley via Coyote and Corral Valleys, formerly barren of fishlife and in streams of which sheepmen had reportedly planted Piute trout a few at a time in buckets from Upper Fish Valley. Particularly in Coyote Valley the trout were found to be as common, if not more so in some sections, as in the stream above Llewellyn Falls. It was decided to attempt capture of fish here in the event a sufficient number could not be obtained in Upper Fish Valley. Both Coyote and Corral Valley Creeks were found to contain barriers in their lower sections.

Capture of Fish and Transportation to Hot Creek Hatchery. On August 21st and 22d, the trip into Upper Fish Valley was made in order to capture a number of the Piute trout for the transplant to the White Mountains. On both days thunderstorms and general cloudiness occurred; and a better condition for this part of the project could hardly be desired.

During the afternoon of August 21st, 21 adult Piute trout, 6 to 10 inches long, were caught and placed in live-cars in the mouth of Bull Canyon Creek. Thirty-five more, three to six inches long, were similarly taken and cared for by nightfall. Since no more than 73 fish-of-the-year and fingerlings were caught in hand nets in Upper Fish Valley, it was decided to rely upon Coyote Valley Creek for the majority of fish of this size.

Next morning the party moved to Coyote Valley where 42 more trout, three to six inches long, and some 209 fish-of-the-year were taken with hand nets and a small seine. With a thunderstorm rapidly moving in from the east, the party moved to Corral Valley where another group of 27 trout was captured and segregated in pack cans. At this point the capture of fish was concluded and upon reloading the pack cans, temporarily "ditched" in Corral Valley Creek, the party continued its return to Little Antelope Valley.

Summary of the captures is given below:

Large fish (6 to 10 inches long)	21
Middle-size fish (3 to 6 inches long)	77
Fingerlings (1¼ to 3 inches long)	309
Total	407

En route to Hot Creek Hatchery two large fish and one of the middle-size group were lost when they jumped out of the pack cans. Other than this, the trip was uneventful. Upon arrival at the hatchery, the trout were released in a divided raceway to "rest" for the remainder of the night.

Transplanting of the Trout in Cottonwood Basin. Early next morning the fish were reloaded in six pack cans on a regular planting pickup truck and were taken to Bishop where the party was joined by Messrs. Noren, Stone, and Earl for the trip into the White Mountains.

Mr. Noren and the Inyo National Forest provided extra fuel, water, tires, and a 2½-ton, four-wheel drive truck, to ensure safe movement of the trout to their destination.

Although the party left Bishop at 7.25 a.m., making only three short stops en route (the last to take on Mr. Robert Franklin who drove the 4 x 4 truck down into the North Fork Canyon), arrival at the creek and planting of the first group of fish occurred at 11.40 a.m.

The trout arrived in excellent condition, with the temperature in the pack cans from the time of departure to the time of planting varying downward only one degree Fahrenheit. The large fish (totaling 17, two having been held out for color photos) were placed farthest downstream in the section selected for the transplant. The middlesize group (76) were planted farther upstream; and the small fish (308, one having been killed in loading) were planted in the uppermost part of the transplant section. All fish, totaling 401, were well distributed over about one mile of stream. The fish immediately sought cover and within two to five minutes individual fingerlings began to feed.

Since bird and reptile predators were not seen at this elevation during the survey on July 3d nor during the time the fish were planted, it is believed mortality from this cause will be very low.

Closure of the North Fork of Cottonwood Creek by official order from the State Department of Natural Resources and signed by the Governor occurred on August 8, 1946.

Summary and Recommendations for Management

Following a survey July 3, 1946, of the North Fork of Cottonwood Creek in the White Mountains of eastern Mono County, a stream barren of fishlife, it was inferred that this tributary would provide a new and remote sanctuary for the Piute trout *(Salmo clarkii seleniris)* whose numbers have recently been decimated by poachers in its native Upper Fish Valley, Alpine County, California.

Accordingly, on August 6 and 7, 1946, Piute trout for the transplant were located; and on August 21st and 22d, 407 fish of all sizes were captured. Next day 401 were planted in the North Fork of Cottonwood Creek.

Official closure of the stream has been published.

If the sanctuary is to be successfully developed careful management must be effected; toward this end the following recommendations are made:

1. That minor barriers above the principal barrier in the stream be removed or improved to permit free movement of the Piute trout along the stream.

2. That at least annual observational visits by a fisheries biologist be made to the sanctuary in order to take stock of the situation from year to year.

3. That, if necessary, one or more additional plants be made in order to establish the trout population firmly in the stream.

Appendix

The following recommendations are made for the future management of Upper Fish Valley, Alpine County, and tributaries:

1. Planting of all barren tributaries of Upper Fish Valley with Piute trout should be accomplished as soon as possible in order to utilize fully the basin set aside for this species. Care should be taken to place fish above all major barriers as a safeguard in the event that major geologic change of detrimental nature occurs to Llewellyn Falls.

2. The valley should be visited by a fisheries biologist periodically in order to keep in touch with the general situation and changes occurring over a period of time. Entry into the area is most easily made from Little Antelope Valley, near Coleville.

SPAWNING HABITS OF THE STRIPED BASS *(ROCCUS SAXATILIS)* IN CALIFORNIA WATERS[1]

By Chester Woodhull
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California Division of Fish and Game

Introduction

As a part of the striped bass investigation recently inaugurated by the Bureau of Fish Conservation, serious attempts have been made to locate spawning grounds of these fish.

Early California reports had indicated still waters of bayous behind flooded islands of the Sacramento-San Joaquin River delta as spawning areas. These findings are in strong contrast to the reports from the Atlantic seaboard—the Roanoke River—that spawning occurs in fast-flowing water. In the last 15 years facts have come to light bearing on striped bass in California which controvert the earlier indications of spawning in still bayous, and point to their use of river reaches with considerable current for this purpose.

Shifts in the migrations or habitats of fishes are not uncommon, especially in this day when the works of man change the waterways or introduce pollution factors. During recent years innumerable changes have been made in the channels frequented by the striped bass—notable is the deep water project from San Francisco to Stockton. New canneries and oil refineries may have a yet undetermined effect.

It can be seen that up-to-date information on the spawning habits and areas of the striped bass in California is needed should it become necessary to protect them during the spawning season, or while they are on the spawning grounds.

Review of the Data on Spawning of Striped Bass in California Waters

Some of the earliest work on the spawning of striped bass in California was done by G. A. Coleman and N. B. Scofield (1910). Their work included experiments on the artificial spawning of these fish. Their findings indicated that the bass spawn during the months of May and June. Unfortunately, these able workers did not locate the spawning areas.

In 1931 the California Division of Fish and Game published Fish Bulletin Number 28, "*The Striped Bass of California*," by E. C. Scofield. This publication includes data on the commercial fishery[2] and a very good section on the life history of the bass. Scofield indicated that the fish spawned in the lower delta region, in the vicinity of Suisun Bay, during the spring months.

Hatton (1940) during his work on the Central Valleys Fisheries Investigations, located larval and juvenile striped bass at various points

[1] Submitted for publication, November, 1946.
[2] In 1935, legislation was passed that removed the striped bass from the commercial catch.

in the delta region in June of 1939; and in May of 1940 (Hatton, 1942) collected eggs estimated to be 12 hours old in plankton nets set at night in Piper Slough, Three-mile Slough, and in San Joaquin River between Three-mile Slough and Big Break. He suggested that, since the eggs were at no time abundant in his nets, possibly the major spawning areas were elsewhere.

On May 5, 1944, Assistant Chief of Patrol Harp and State Fish and Game Wardens Hooker and Mills, while on regular river patrol, noticed striped bass spawning in Fisherman's Cut, located in the lower delta region.

During a field trip on May 11, 1943, Messers Alan C. Taft and Brian Curtis, of the Bureau of Fish Conservation, saw striped bass spawning in the late afternoon at the mouth of Middle River. During this trip ova of the bass were collected in plankton net hauls at the scene of spawning.

Verbal reports to Mr. Curtis on May 11, 1943, indicated that bass were spawning in the lower five miles of the Mokelumne River. The fish were observed by anglers to be engaged in spawning activities during the late afternoon.

On May 12, 1946, Calhoun, of the Bureau of Fish Conservation, while sampling the striped bass fishery, found ripe fish (flowing milt and eggs) in the vicinity of Marysville, on the Sacramento River.

Late in April, 1946, the writer found ripe striped bass in the San Joaquin River near the town of San Joaquin City.

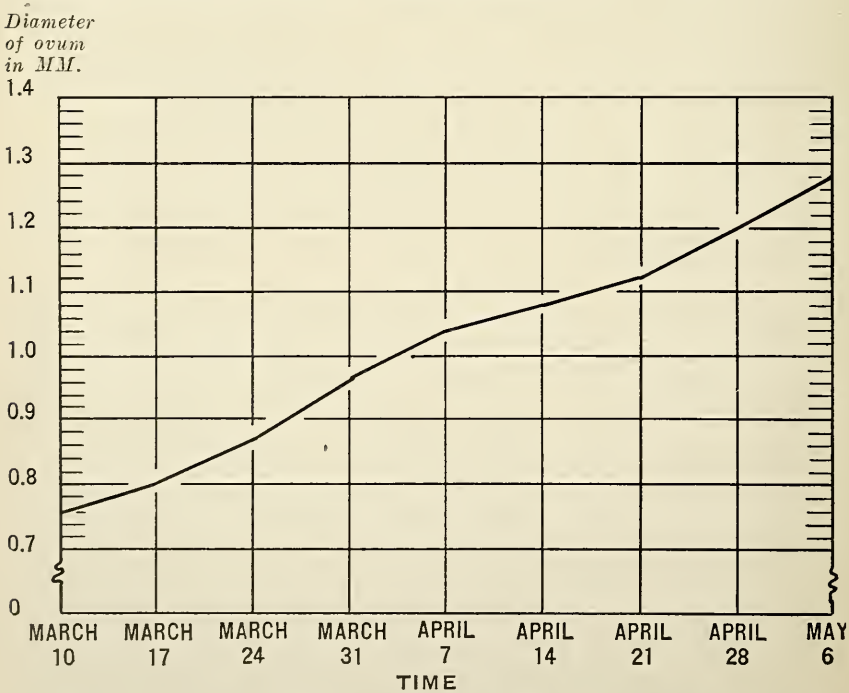

FIGURE 26. Average ovum diameters. Data based on approximately 10 ovaries per week. Each sample was taken from the mid-section of an ovary, and held in normal saline solution for about four hours. The sample was then gently shaken to free eggs. Measurements of 30 individual eggs, selected at random, were made with a stage micrometer at a magnification of 60X.

Prespawning Data

From various sources, indications were that as the striped bass approach the spawning season they appear at the surface of the water and splash about, giving rise to the term "rock fight."[3] Another criterion of the approach of the season is the egg diameter; when the eggs are in a condition to be extruded into the water they range in size from 1.0 to 1.35 mm. (about 1/20 inch). As the fish become ripe the eggs and ovaries change from a creamy color to a pale green.

Numerous striped bass anglers were interviewed during the early spring months to gather information on the appearance of the fish at the surface of the water. From this source, information pointed to the fish surfacing in various areas between Antioch and points up to about 100 miles upstream on both the San Joaquin and Sacramento Rivers. Indications were that the fish venture up to Marysville, and beyond, on their spawning migrations up the Sacramento River. In the San Joaquin River striped bass in a spawning condition have been found near the town of Patterson. Most of the anglers were of the opinion that they had seen rock fights during the month of May.

Ovary samples were collected and ovum diameters measured after they were held in a normal saline solution. Figure 26 illustrates the diameter increments from March 10, 1946, when the ovaries were starting to turn a greenish color, until the fish started their annual season's spawning.

Striped Bass Spawning Observations

From the correlation of the data it was expected that the fish would start to spawn early in May; therefore, all during field work, from the middle of April on, a very close watch was kept on areas in the open rivers that were frequented by the bass. On the afternoon of May 6, 1946, the first rock fights were seen by the writer in the vicinity of Venice Island, in the San Joaquin River. The river at this point, about 60 miles from the Golden Gate, varies in salinity from 1 to 7 parts of chlorine per 100,000 of water; at this time, because of the high water stage of the San Joaquin River, salinity was at the minimum figure. The river here is greatly affected by tides, with a mean range of 3.1 feet. Because of the great volume of water coming down the river, and strong tides up to four miles per hour, the duration of outward flow is about an hour longer than that of the incoming tide.

At the time the observations of May 6th were started, the tide had just turned and started flowing inward. At 4 p.m. the temperatures were: air 86 degrees F.; water 67 degrees F. The water was rather turbid, and visibility was limited to about 15 inches.

At about 3 p.m., on May 6, 1946, the striped bass first appeared at the surface slowly swimming about with parts of their backs and dorsal fins out of water. The fish seemed to be isolated females aimlessly wandering about, occasionally joined by another large fish, then sounding. At about 4 p.m., innumerable groups of from 5 to 30 large bass started to appear on the surface. These groups would mill around for a few moments, then all head up or down stream and roll over on their sides at about a 45 degree angle, at the same time throwing water in all directions

[3] Striped bass (*Roccus saxatilis*) are sometimes known on the Atlantic Coast as *rock fish*. In this area the term "rock fight" was coined.

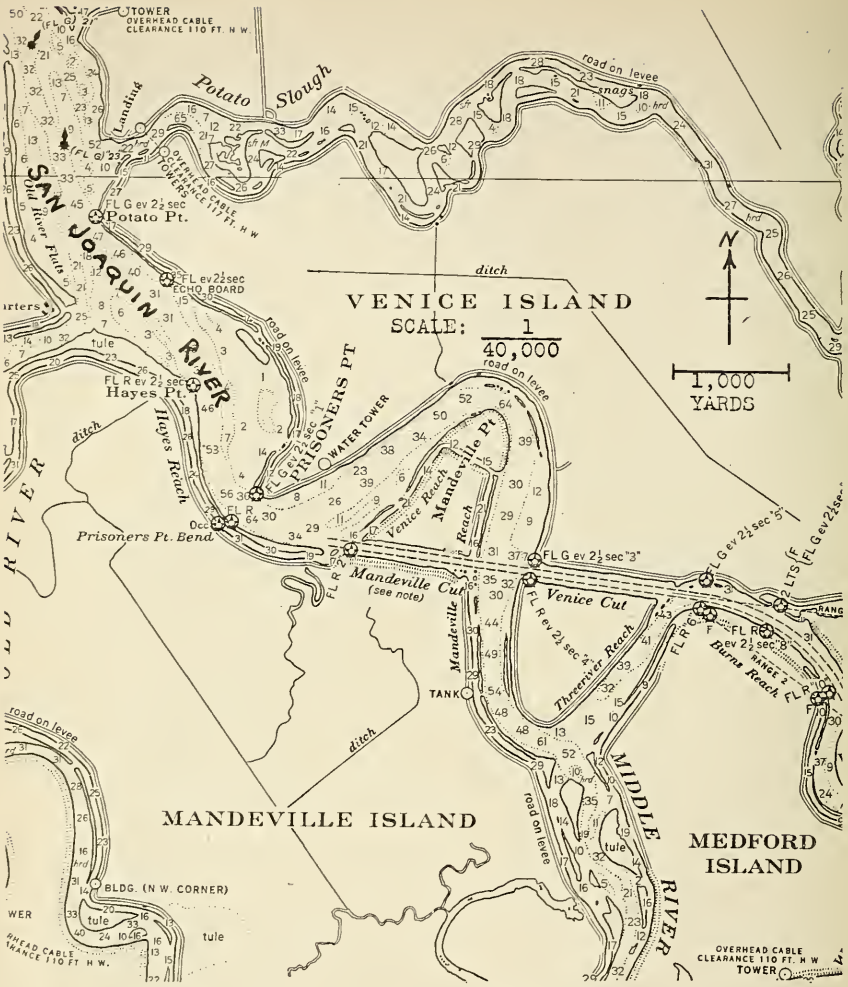

FIGURE 27. Venice Island, San Joaquin County, California. From U. S. C. and G. S. Map Number 5527. Spawning observations on striped bass were made along Mandeville Reach in the natural river channel.

with their tails. The groups of splashing fish would remain at the surface for as long as several minutes. From their actions and the position of their bodies the bass were spawning, if similarity to the actions of spawning trout can be used as a criterion. The groups of bass were scattered along some three miles of the river, mainly in the shallower portions, although a few groups were out in deep water. It is of interest to note that when the bass are splashing about it is possible to approach within a very few feet of the groups.

A No. 6 plankton net was hauled through a group of splashing fish, and eggs were picked up. The eggs of this haul were not water hardened[4]

[4] During their first hour after extrusion the eggs absorb water (water harden), creating a large perivitelline space. This acts as a shock absorbing medium to protect the embryo.

and their mean diameter was 1.78 mm. (about one-sixteenth inch). A portion of this sample was kept in fresh water for one hour, then preserved; the eggs then had a mean diameter of 3.30 mm. (about one-eighth inch). This plankton haul demonstrated that the bass seen splashing about were actually spawning.

Spawning was still in progress at 7 p.m. when the author left the area, and a farmer living nearby stated that fish were splashing about all night. The next morning, May 7th, it was noted that a few small groups of bass were still spawning up until noon. High winds and rough water made further observations impossible.

Numerous plankton hauls were made in the area where bass were observed spawning the day before, and developing eggs were found in depths of 15 to 35 feet, generally within five feet of the river bottom.

During the afternoon of May 6th, the author had been sampling the sportsmen's catch of striped bass. It is of interest to note that 17 anglers

FIGURE 28. The San Joaquin River. View is from Venice Island, opposite Mandeville Point, to the south. The water in the foreground is where heavy spawning of striped bass occurred on May 6, 1946. Photograph by the author.

caught 42 fish that were of an average of 18 inches total length, and all were mature male fish (milt flowing). The large fish were present in the area, but were not striking. During the actual spawning time no fish were caught, even though the anglers, excited by the sight of so many large fish, attempted to take them in every possible manner.

It would be well to mention the part played by small male fish. They would accompany the larger ones, but would dart through the water, in and through the groups, sometimes leaping into the air in low, graceful jumps. The small fish were not deliberate in their actions as were their elders.

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A FIELD STUDY OF A RATTLESNAKE POPULATION

By Henry S. Fitch [1] and Ben Glading [2]

Introduction

Unusually favorable opportunity to study the habits of the Pacific rattlesnake, *Crotalus viridis oreganus*, in the field was afforded the writers as resident biologists at the San Joaquin Experimental Range in the Sierra Nevada foothills of Madera County, California.[3] This section of the foothill belt is sparsely settled and is used primarily for cattle range. Along with intensive studies of the vegetation and various rodent, game and predator species in progress at the experimental range, investigation was made of the growth, movements, seasonal habits and feeding of rattlesnakes.

This report is concerned mainly with data obtained from April, 1938, to June, 1940, during which period a total of 749 rattlesnakes were recorded; 515 were marked and released and 234 were brought in dead by various cooperators. One hundred and sixteen recaptures were made of the 515 marked snakes. Fragmentary data prior to 1938 are included.

We are indebted to many field men at the San Joaquin Experimental Range for their aid in contributing live rattlesnakes and for help and suggestions in securing data used in preparing this report. Among these are: Harold Biswell, Erwin Decker, Robert Gardner, Charles Graham, Frank Hagarty, Veryl House, Charles Kaley, Albert Leavitt, Stanley Litchfield, Ronald Loughery, Marvin McDonald, James McPheeters, Bernard Mitchell, Jesse Nelson, Fenimore Ramley, Louis Sharp, Raymond Sharp, William Sholes, Edward Stoddard, Elmer Sundell, Freeman Swenson, Kenneth Wagnon and Robert Wilson. In particular, thanks are due to Freeman Swenson, who collected many of the snakes on which our data are based and whose sustained interest and cooperation did much to further the study.

Description of the Study Area

The San Joaquin Experimental Range, a tract of approximately 4,600 acres, lies in the Upper Sonoran Life Zone. The climate is characterized by hot dry summers and wet moderately warm winters. From early June to the middle of September daily maximum temperatures commonly exceed 100 degrees Fahrenheit, and precipitation is rare. The rainy season is from October to April; during this period daily minimum temperatures of slightly below 32 degrees Fahrenheit are frequently recorded, particularly in December, January and February. During the years 1934 to 1945 precipitation records at the range average 22 inches annually.

Low rolling hills and occasional deep ravines are features of the topography. Outcrops of granite boulders are common and furnish hiding

[1] U. S. Fish and Wildlife Service.
[2] Bureau of Game Conservation; California Division of Fish and Game.
[3] This cooperative study was undertaken as part of research on rodent ecology under the direction of Everett E. Horn of the U. S. Fish and Wildlife Service. Assistance rendered by WPA project No. 165-2-08-225 is acknowledged.

places for rattlesnakes and their prey. The vegetative type may best be described as grass-woodland with scattered patches of brush (Figure 1). Principal trees are digger pine *(Pinus sabiniana)*, blue oak *(Quercus douglasii)* and interior live oak *(Q. wislizenii)*. The brush is of the chapparal type, mainly buckbrush *(Ceanothus cuneatus* and *C. divaricatus)*, and manzanita *(Arctostaphylos mariposa)*. The herbaceous vegetation, mainly annual grasses and forbs, furnishes an abundant food supply for the rodent population.

FIGURE 29. Typical habitat of rattlesnakes on the San Joaquin Experimental Range, showing granite rocks, trees, and brush. (Photo by E. E. Horn.)

Small mammals providing food for rattlesnakes include ground squirrels, wood rats, cottontail rabbits, kangaroo rats, pocket gophers, meadow mice, white-footed mice, and pocket mice. The larger of these, squirrels, kangaroo rats, wood rats, and pocket gophers are often found in populations of several to the acre, whereas the mouse populations are generally more sparse.

Methods Employed in the Study

The majority of the rattlesnakes recorded were live ones collected by the rodent investigating staff in the course of routine field work. Others were contributed or pointed out in the field by the various collaborators enumerated above. Many of these live snakes were observed accidentally; however, through attentiveness to the actions and behavior of ground squirrels many more were discovered. A squirrel in the presence of a rattlesnake would move around with exceedingly slow and cautious steps, straining forward, watching, and twitching its tail spasmodically, sometimes giving chirps of a peculiar vibrating quality, staring intently with such concentration that an observer could often approach unnoticed to within a few yards. Such squirrels, in observed instances, always kept out of striking distance, and were usually ignored by the snake. By learning to distinguish this peculiar "snake call" of the

ground squirrel, and the accompanying nervous tail-waving, observers often located a snake from distances of 100 yards or more.

Most of the dead snakes recovered were contributed by WPA and CCC personnel who happened on them in the course of routine work. In 1939 and 1940 a small cash reward was posted for the return of dead marked snakes; since the identifying marks were not generally known, this resulted in the donation of more dead snakes for measurement and recording than would have been brought in otherwise.

Captured live snakes were marked individually by clipping out scutes (scales) on the ventral surface of the tail with fine sharp scissors. In clipping out a scute, the epidermal layers were completely removed, laying bare the connective tissue surrounding the tail muscles (Blanchard and Finster, 1933). Two half-scute excisions were made on each snake, one on each side, located by counting posteriorly from the anus, beginning with the first complete subcaudal scute as number one. The snake was then catalogued under a formula based on the positions of these markings, for example: 8 left—4 right, or 2 left—16 right, etc. These marks leave permanent scars that lead to easy identification of the individual. Injuries resulting from the excisions healed rapidly, and apparently, caused little discomfort to the snakes.

During the first half of the study, measurements were taken by holding the snake's body extended, but not unduly stretched, in a horizontal position for a length of time sufficient to insure some degree of muscular relaxation, then marking the positions of the tip of the snout and the posterior edge of the anal plate with pegs and measuring the distance between them to the nearest millimeter with a steel tape. Later, a measuring board, having heavy leather straps to hold the snake's head in position, was used. Lengths recorded pertain to head-and-body measurement described above. Total over-all length was not used since considerable difference exists in relative lengths of tails in males and females, and further variations would be introduced by broken strings of rattles. The number of rattles, and the presence or absence of a "button" (the original terminal rattle) were noted for each snake. A fine copper wire (about 30 gauge B.S.) was wound between the proximal and the second rattles, in order to show the number of rattles added or lost between sucessive captures. Small snakes (less than 100 grams) were weighed on laboratory balances reading accurately in tenths of a gram. Larger individuals were weighed to within a few grams on a larger beam balance.

Sex was determined by probing through the anus into the tail with a blunt wire, which, in the case of males, could be easily inserted into the invaginated hemipenis for about one-third of the tail length; whereas in the case of females, it could not be inserted to any appreciable extent. Each snake was tested for food items at the time it was measured and marked. Undigested remains in the stomach were forced up and identified by holding the snake's body extended and palpating the ventral surface, with steady pressure of the thumb upward and forward, exercising care not to injure the snake. The findings regarding the feeding habits have been set forth elsewhere (Fitch and Twining, 1946).

All dead snakes which could be obtained were measured by the same method recorded above, and were examined for possible marks, food items, and breeding condition.

Ordinarily, each snake was liberated at the exact point where it was captured, but those released in the heat of the day were placed where shade and shelter were available. Several caught in the immediate vicinity of buildings at the range headquarters, where they might have constituted a hazard, were released at distant points on the range, in each instance replacing one of the same sex and approximate size, known to have been killed.

Seasonal Occurrence

HIBERNATION AND WINTER OCCURRENCE

Rattlesnakes of the population studied apparently pass the period of winter dormancy singly or in small groups. They are not known to congregate in large numbers at hibernation "dens" such as have been described for regions farther north or at high altitudes, where the winter climate is severe, and there is a long hibernation involving complete dormancy. Several individuals were found during the winter. In late December, 1938, and early January, 1939, five adults and one young were found hibernating singly in holes and crevices beneath large boulders. They were slow in their movements, but were not fully dormant. On December 14 and 16, 1938, the two warmest days of that winter (maximums 64 and 66 degrees Fahrenheit), juvenile rattlesnakes were found active on the ground surface. On February 16th, another unusually mild winter day (maximum 60 degrees Fahrenheit) a rattlesnake was found in semiactive condition beneath the fallen wall of an old barn; it was able to rattle feebly. On February 24, 1939, one found beneath a boulder was cold and sluggish, but was able to move and rattle.

SPRING EMERGENCE

The first spring temperatures above 70 degrees Fahrenheit will usually signal general emergence of these snakes from hibernation. On March 16, 1939, the temperature rose to a maximum of 77 degrees Fahrenheit, initiating this general emergence; on this day the first fully active snake of the year was found sunning itself at the edge of a rock and two more were discovered in nearby crevices. This spot was inspected frequently for the next few days, but no more snakes were found. Five days later (March 21) two were discovered, followed by one on the sixth day after emergence, and two on the seventh.

In the week following the first appearance in 1940, groups of seven, four, four, three, two, two, and two snakes were found. Such associations are found only in this emergence period, and are assumed to represent small hibernating groups. The associations do not necessarily result from attraction between the sexes; they may consist of small or half-grown young with adults, or of adults of the same sex. Snakes found at other seasons with but one exception were discovered singly, or, during the breeding season, in mating pairs.

SPRING AND SUMMER OCCURRENCE

During the spring months, April, May, and June, rattlesnakes are found in greatest abundance at the San Joaquin Experimental Range and perhaps in most representative numbers for each age and sex group. In the summer, however, a marked difference in the relative abundance of adult males and adult females was noticed. The activity of large females

(those in excess of 700 mm.) is very much reduced in the period July to October. Thus, in 1938, of 21 such large females found, 18 were taken before July 1st, and in 1939 of 34 found, *all* were recorded before July. In adult males this tendency is less marked: of 52 recorded in 1938, 28 were taken before July 1st and 24 afterward; and of 108 recorded in 1939, 96 were taken before July 1st and 12 afterward. Midsummer inactivity of adult females is possibly correlated with the physical difficulties of locomotion while in a gravid condition.

Medium sized or adolescent snakes (501 to 700 mm. in length) of both sexes showed a peak in numbers comparable to that of the adult males during spring, with a similar reduction during the summer and early fall. Small young (under 500 mm.) showed a similar abundance in spring, but did not decline as abruptly in numbers during the summer.

EFFECT OF WEATHER ON OCCURRENCE

Temperatures were recorded for the exact times of many encounters with snakes (Fitch MS). In general, these notes show that the optimum temperatures for rattlesnake activity and occurrence where they could be readily seen was between 80 and 90 degrees Fahrenheit. Above 90 degrees their occurrence dropped off sharply; they were rarely seen at midday during the hot months. As the weather becomes warmer through the summer, snakes move about mostly between dusk and dawn; the larger ones become almost entirely nocturnal. This probably accounts for the scarcity of records throughout the months of July, August, and September. During this season of nocturnal activity the young snakes characteristically emerge from shelter earlier than the adults, and sometimes are in evidence before sunset.

Calendar dates signalling seasonal changes in development or activity vary considerably from year to year in response to different weather conditions.

TABLE 1

Yearly Variation in Activity and Development of Rattlesnakes at the San Joaquin Experimental Range

	1938	1939	1940
General emergence from hibernation	April 11	Mar. 16	Mar. 19
First breeding record	April 19	Mar. 23	Mar. 21
Last breeding record	June 4	April 27	May 5
First record of young with one rattle and a button	May 26	May 8	Mar. 13
Last spring record of young with only a button	June 7	June 1	June 11
Last record of young with one rattle and a button	Aug. 5	Aug. 1	Aug. 2
First appearance of newborn young in fall	Oct. 7	Sept. 11	Sept. 19
Average length in mm. of young of the year[1]			
March	None recorded	293.0 (3)	326.6 (5)
April	308.0 (1)	315.4 (14)	320.8 (22)
May	340.7 (6)	351.9 (37)	343.3 (22)
June	353.1 (15)	409.7 (21)	364.3 (21)
July	394.1 (8)	428.1 (14)	422.6 (19)

[1] Figures in parentheses indicate number of snakes measured for the sample.

In 1938 there was a cold, late spring, with retarded plant growth and an unusual amount of rain during March and April; young ground squirrels, the rattlesnakes' chief prey, were not recorded above ground before May 3d. In 1939, however, March and April were warm with scarcely any rainfall and the first recorded young ground squirrel was on March 23d, about six weeks earlier. In general the 1940 season resembled that of 1939 and contrasted with that of 1938. The large average size recorded for March young in 1940 is due to the inclusion of two remarkably accelerated individuals in this small sample. In early spring of 1940, the young were more advanced than in early spring of 1939 because they had been born one month earlier in the fall; hence the occurrence of a snake with one rattle and a button as early as March 13th. The young in 1940 failed to maintain their early advantage, and this may indicate that feeding conditions were less favorable than in 1939.

Movement

Considerable data were accumulated on movements as a result of the release and recapture of marked snakes; among the 515 marked, 116 recaptures were recorded. In general, marked snakes captured at different points on different occasions moved progressively farther from the original starting point. Frequently after periods of weeks or months, even years, a snake was found at about the same spot where it had been captured before; indicating a possibility that it had never left the spot at which it was first discovered. Marked individuals released at points distant from the places where they were captured, were found long afterward near the points of release, indicating they had traveled but little and that homing instinct is lacking. Some marked snakes which were encountered on several successive days at the same spot, disappeared from the vicinity, and later were found at a new location. The most extensive movement was one of slightly more than a mile and a half, made by an adult female snake in 13 months. All other movements were less than a mile; one was between three-fourths and one mile; three others were between one-half and three-fourths mile; nine others were between one-fourth and one-half mile. Of the remainder, all were less than a quarter-mile, but 17 of these moved more than a hundred yards. Greatest rate of movement was shown by an adult male, caught late one afternoon, marked, and released immediately. On the following morning, soon after sunrise, it was recaptured about a quarter of a mile away. The most sedentary individual recorded in the 1938-40 studies was a half-grown female, which, after 22 months, was found 30 feet from the point where it had been released.

Figure 30 illustrates the rate of movement in rattlesnakes in feet per day from the point of release. In calculating this rate of movement it was assumed that snakes were free to move only during the spring and

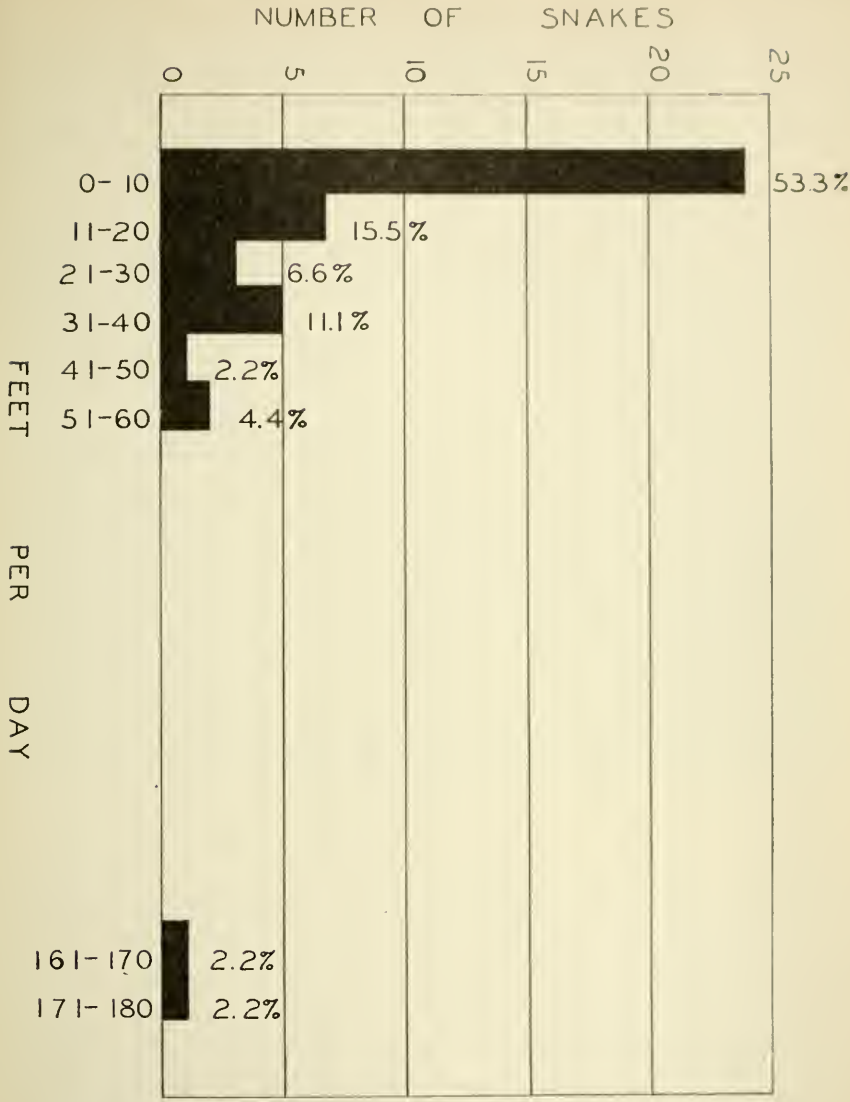

FIGURE 30. Rates of movement in a rattlesnake population based on recapture of marked snakes. In calculating days elapsed between release and recapture, hibernation periods were subtracted.

summer months and that no movement occurred during the hibernation period. The number of days that a snake was free to move was calculated as the interval from the time of the first recorded snake in the spring to the last one noted in the fall. It will be noted that the largest group (53.3 percent of all recorded) is the one that moved less than 10 feet per day. Our observations indicate that practically no movement from the point of release was made in most instances among this group.

Breeding Habits

The breeding season is limited to a few weeks in spring beginning almost immediately following emergence from hibernation. In 1938 emergence from hibernation took place about April 11; on April 19 the first mating pair was found. During the 54-day period following emergence, 10 mating pairs were found, comprising 35 percent of the total number of adults taken, and 27 percent of all rattlesnakes taken in

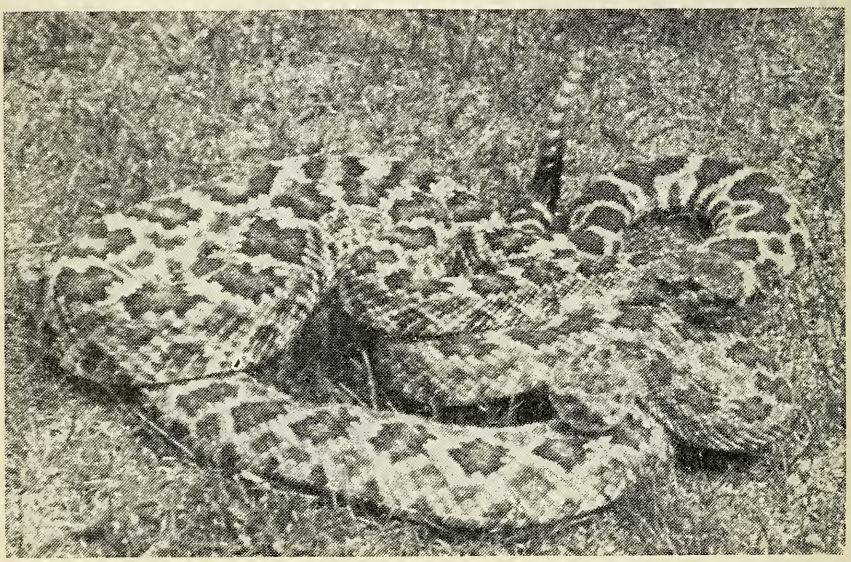

FIGURE 31. Mated pair of rattlesnakes. The male (above) is larger and of darker coloration

this interval. In 1939, emergence from hibernation took place about March 16, and all nine of the mating pairs were found within a period of 36 days, the first on March 23, and the last on April 27. Within this period the mating snakes comprised 20 percent of all the adults found and 15 percent of the total number found. In 1939 the breeding season was several weeks earlier than that of 1938, with scarcely any overlapping of calendar dates. The earliest appearance of young differed correspondingly in these two years. In 1938, young first were observed on October 7, 171 days after the earliest record of mating; while in 1939 the first young were found on September 11, after a period of 172 days had elapsed. It seems probable that this time approximates the normal gestation period.

Mating snakes found in the field were sensitive to disturbance. In one exceptional instance, a female was first observed on April 27, and was subsequently found near the same spot on April 29, May 4, 5, 7, 8, and 13. On the night of May 4 she ate a pocket gopher and thereafter was too lethargic to move when disturbed as the observer lifted her tail to look for the identifying mark. On May 13, at 8.15 a.m., another slightly larger snake was found with this one, and apparently copulation was in progress. At 8.45 and 9.20 a.m. the snakes had not

moved perceptibly, but at 11.20 a.m. the male had disappeared. The female had moved a few inches and coiled, but was still sluggish and merely clicked her rattles when disturbed. At 6.30 p.m., a snake, almost certainly the male of this pair, was captured about 50 feet from where the mating had occurred. This mating is especially noteworthy because of the small size of both snakes. The female had a head and body length of only 543 mm. and had three rattles and a button; the male had a head and body length of 615 mm. and had four rattles and a button.

In each of several mating pairs observed the female lay quiescent while the male moved over her with quick, gliding movements. The female of one pair suddenly escaped into high grass after several minutes of courtship on a squirrel burrow mound; the male searching the vicinity, twice returned to the place where she had been, nosing slowly over the ground there. Another pair was seen emerging from a squirrel burrow together, the male rearing his head about a foot above the ground. Most of the pairs found were in well-concealed situations.

In some instances, it appeared that the snakes of a pair were merely near each other, but no courtship activity was in progress at the time of discovery. Most of the pairs discovered were encountered during the morning hours. Our observations suggest that the process of mating extends over a period of only a few hours, and that associations between members of a pair are temporary even within the breeding season.

Thirteen dead, gravid females were examined and the number of developing embryo snakes found in each was recorded (Table 2).

TABLE 2

Number of Developing Embryos in 13 Dead Gravid Female Rattlesnakes Recorded in Late April, May and early June, 1938, 1939, and 1940

Length of female	*No. of developing embryos*	*Length of female*	*No. of developing embryos*
885 mm.	8	814 mm.	3
873 mm.	9	770 mm.	11
855 mm.	9	754 mm.	7
835 mm.	11	752 mm.	11
832 mm.	9	720 mm.	2
830 mm.	7		
820 mm.	5	812.3 mm. (Average)	7.6
820 mm.	7		

Composition of the Population

Among 489 snakes measured in 1938 and 1939 there were 294 males and 195 females, ranging from less than 300 mm. to more than 1,300 mm. in head and body length, as shown in Table 3.

TABLE 3

Percentages in Size Groups of Male and Female Snakes Measured in 1938 and 1939

Length of snakes	*Percentage of total males*	*Percentage of total females*
200-300 mm.	2	4
300-400 mm.	21	20
400-500 mm.	14	15
500-600 mm.	4	10
600-700 mm.	4	5
700-800 mm.	9	23
800-900 mm.	9	21
900-1,000 mm.	22	2
1,000-1,100 mm.	10	-
1,100-1,200 mm.	4	-
1,200-1,300 mm.	1	-

These figures illustrate that males attain much larger average and maximum size than do females. Adult snakes are more commonly encountered than small young, and medium sized snakes are much scarcer than either.

During the 10 weeks' period following emergence in different years, young born the preceding fall were found in the following ratios, to the total numbers of rattlesnakes recorded: 1937, 23 percent (of 113); 1938, 16.2 percent (of 99); 1939, 23.9 percent (of 207); 1940, 21.5 percent (of 233). Later in the season each year the young comprised a higher percentage of those recorded, probably because of the more retiring and nocturnal habits of the adults during the dry season.

Snakes which have passed their second hibernation, and are in their second growing season, cannot always be distinguished from older or younger year classes, but it is certain that they comprise only a small percentage of the total population and thus have undergone severe reduction in numbers before reaching this age. The small snakes are much more subject to predation than the mature ones, and may be less successful in obtaining food. They lack the reserve of fat usually found in adults, and perhaps often die from starvation. Individuals which have attained the size of large adults probably have a relatively long life expectancy, as the population turnover mainly involves the young of the smaller size groups.

Growth

Records were kept of the growth of all snakes recaptured a month or more after the release date. These data are shown for males in Figure 32 and for females in Figure 33. Growth tends to be much slower in snakes more than 700 mm. in length, but is so variable that any general

statement of the growth rate is difficult. One snake attained mature size (over 700 mm.) in two growing seasons (at the age of 2½ years). The rate shown by most others suggests that they usually require about four years to attain adult size. The relatively few records for repeat females suggest that they grow somewhat more slowly than males.

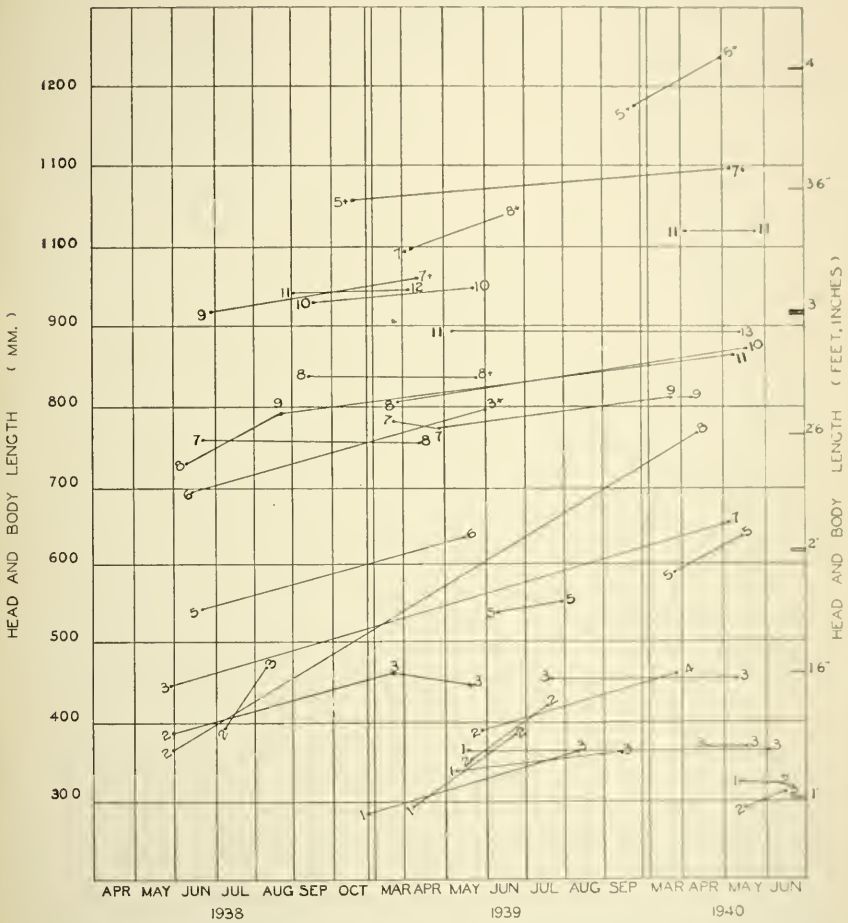

FIGURE 32. Repeat records of recaptured *male* snakes showing increment in length and rattle number. The lines indicate individual snakes showing dates of release and recapture. The figures (2, 3, etc.) indicate the total number of rattles. Figures followed by a + indicate that the rattle string was broken but rattle increment is indicated by use of the fine wire technique.

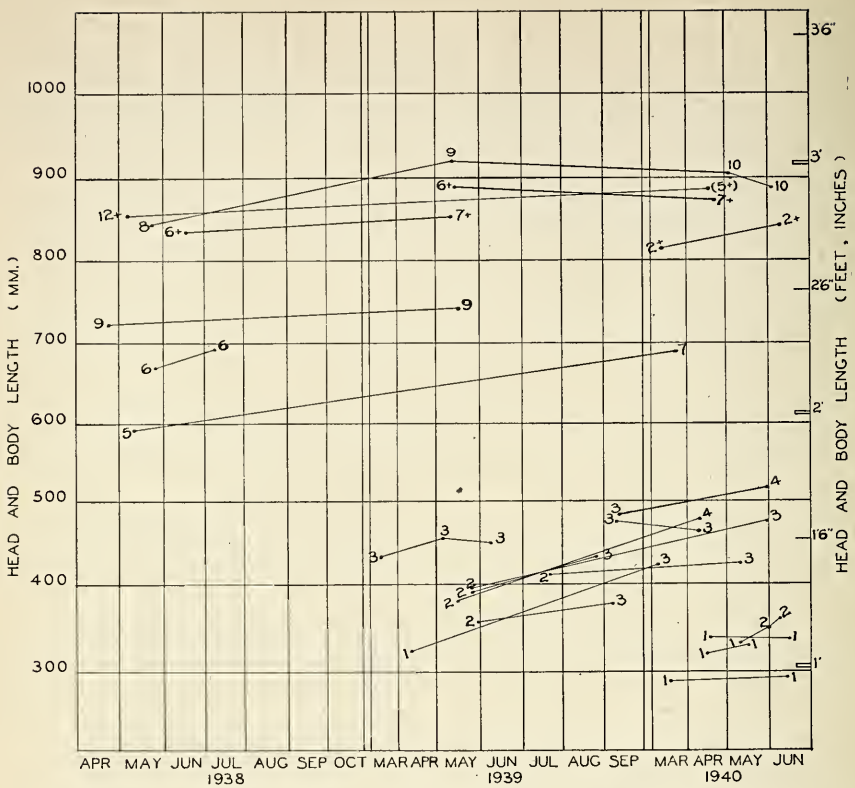

FIGURE 33. Repeat records of recaptured *female* snakes showing increment in length and rattle number. The lines indicate individual snakes. Figures (2, 3, etc.) indicate the total number of rattles. Figures followed by + indicate that the rattle string was broken but rattle increment is indicated by the use of the fine wire technique (see text). Figures in parentheses indicate increment not definitely known.

Decreased lengths were recorded for snakes recaptured in some instances, probably due to error in measuring arising from variation in amount of stretching, in attempts to straighten them out and obtain relaxation. Some relax easily, and might measure long, while slight and hardly noticeable contractions in others may make them measure short. Smaller snakes could be measured much more easily and accurately than large and muscular ones, in which measurements were subject to a greater margin of error.

TABLE 4

Variation in Growth in Young Snakes

Successful group	*Dates of capture*	*Head and body length in mm.*	*Weight in grams*	*Rattle number including button*
1.	May 17, 1939	373	24½	2
	April 5, 1940	485	49½	4
2.	May 10, 1940	340	27	1
	May 28, 1940	355	28½	2
	June 5, 1940	368	31½	2
3.	April 10, 1939	321	20½	1
	March 7, 1940	421	47	3
4.	April 7, 1939	293	17½	1
	June 22, 1939	383	33	2
5.	July 6, 1938	397	48	2
	August 9, 1938	465	70	3
Unsuccessful group				
1.	July 18, 1939	450	43½	3
	May 9, 1940	450	44	3
2.	April 12, 1940	367	30½	3
	May 9, 1940	367	25½	3
3.	May 22, 1939	360	22	1
	June 5, 1940	362	20	3
4.	October 26, 1938	286	18	1
	August 9, 1939	359	20½	3

Failure to obtain food probably accounts for the lack of growth shown by some of the small snakes, which in some instances also showed substantial loss of weight over periods of months. Such individuals probably represent an unsuccessful group destined to early elimination. Records of several repeats in Table 4, for several successful individuals, show relatively rapid increase in length, weight, and rattle number, and, in contrast, failure to make any notable gains over periods of months by individuals of a second group.

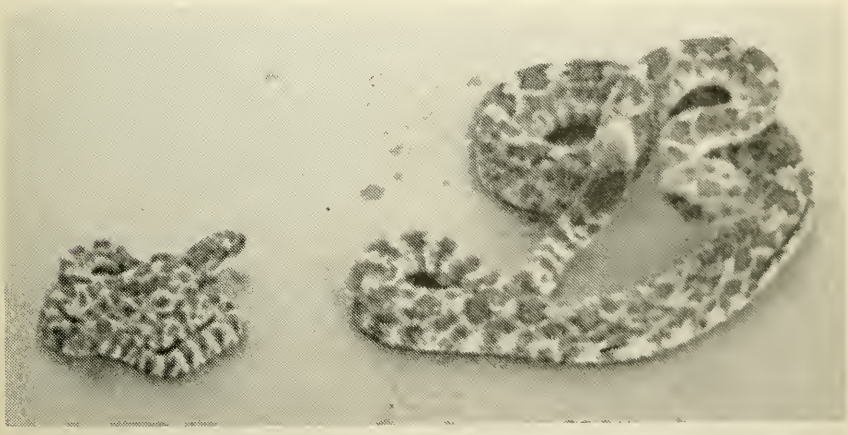

FIGURE 34. Unusually small newborn young (left), and recaptured year-old rattlesnake (right), showing amount of growth made in first year by some successful young.

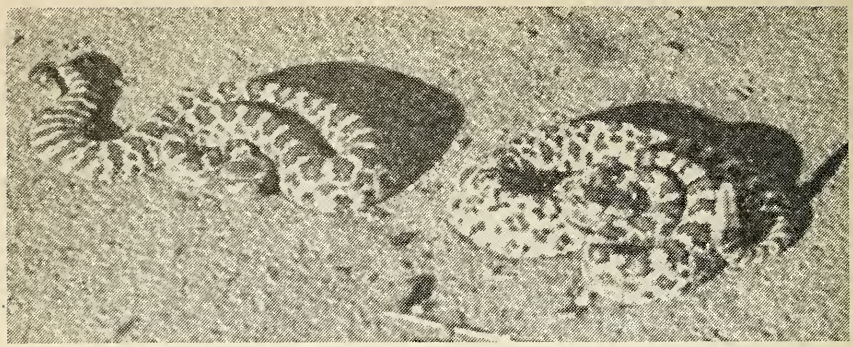

FIGURE 35. Newborn rattlesnake with one rattle (left) and recaptured, stunted individual one year old with three rattles (right), showing in the latter, slight amount of growth made by unsuccessful young.

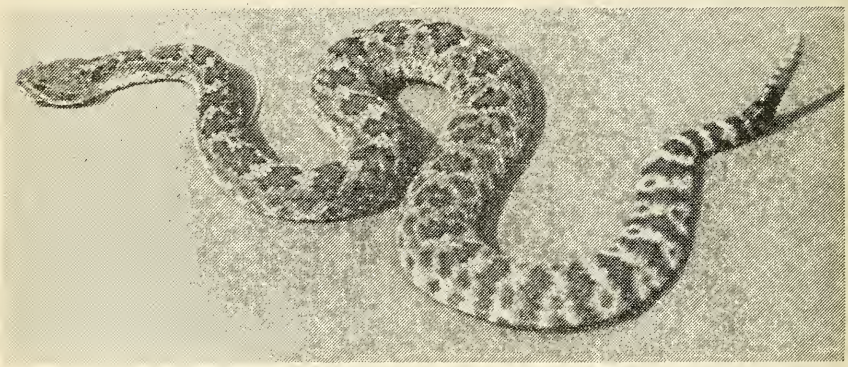

FIGURE 36. Recaptured rattlesnake which in about two years (May 31, 1938, to April 8, 1940) more than doubled in length and gained six rattles. This snake, three feet long at the age of 30 months, probably is representative of successful young in its development.

Significance of Number of Rattles

Popular supposition has it that the number of rattles borne by a snake indicates its age in years. Klauber (1940, pp. 29-30) has shown that a new rattle is acquired each time that a snake sheds its skin and that several rattles may be added annually. Our own studies indicate that young snakes in their first year of growth gain, besides the original button, two to four rattles, perhaps most frequently three. Medium-sized snakes, during their second or third year, often gain two rattles annually. Adults most frequently add only one rattle a year, but sometimes gain two. Thus rattle acquisition is irregular, tending to slow down as growth decreases with attainment of adult size. Varying numbers of rattles are apt to break off during the life of a snake, so that no assumption can be made as to the total number it might have acquired unless some marking technique is used.

On the areas studied newborn young rattlesnakes make their appearance annually in September or October, and during these months they have just the natal button which later becomes the terminal rattle. The young emerging from hibernation in the spring five or six months after their birth generally still have no other rattles than the button, and the

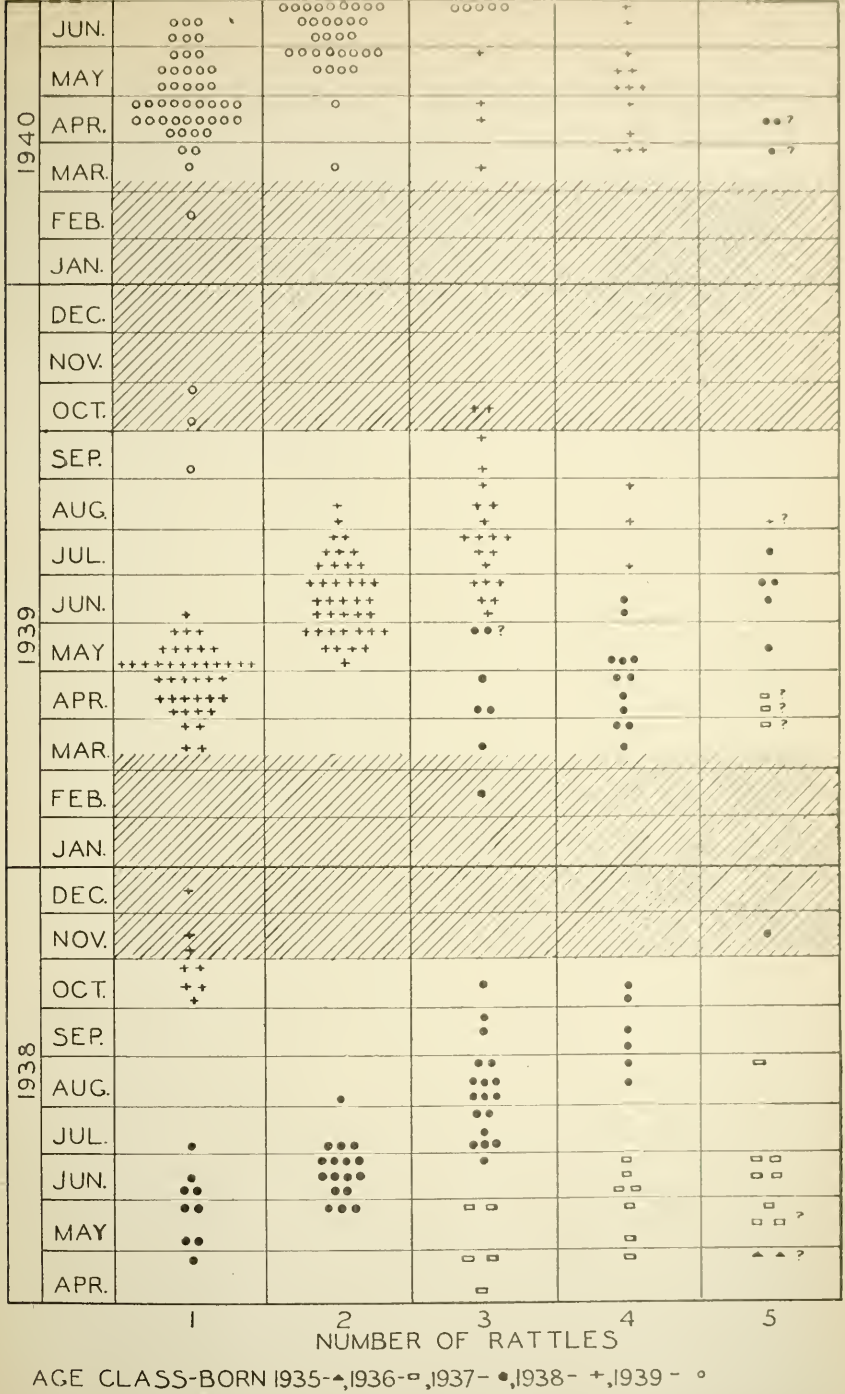

FIGURE 37. Seasonal occurrence of young rattlesnakes showing calendar grouping of rattle classes. This chart includes all records of observed snakes (dead and alive) having a total of five or less rattles. The year class designation is our approximation only. Snakes born in the fall have one rattle, and tend to emerge from hibernation in the spring in this same condition. A second rattle is added in May or June, and a third later in the summer. In the case of snakes with four or five rattles assignment of age class becomes difficult due to variations in growth rate. The shaded area denotes the hibernation period.

second rattle is most often acquired in May or June. During the summer still another rattle is acquired, for a total of three (2 + button). Our data indicate that the less successful or vigorous yearling snakes often go into their second hibernation period in this three-rattle stage; but others may then have acquired four or even five rattles.

Figure 36 shows the dates of capture of young snakes grouped according to rattle number. Those with three rattles or less can almost positively be put in proper age class if dates of capture according to season be considered. In the four- and five-rattle classes, however, so much variation in season of occurrence and size occurs that many snakes cannot be placed with certainty in their proper age class.

Records of recaptured marked young snakes (Figures 32 and 33) show gains of two or three rattles during their first summer and often about two the second. Many of these recaptured snakes appeared thin and undersized suggesting that handling during the process of capturing and marking had somehow adversely affected their subsequent growth.

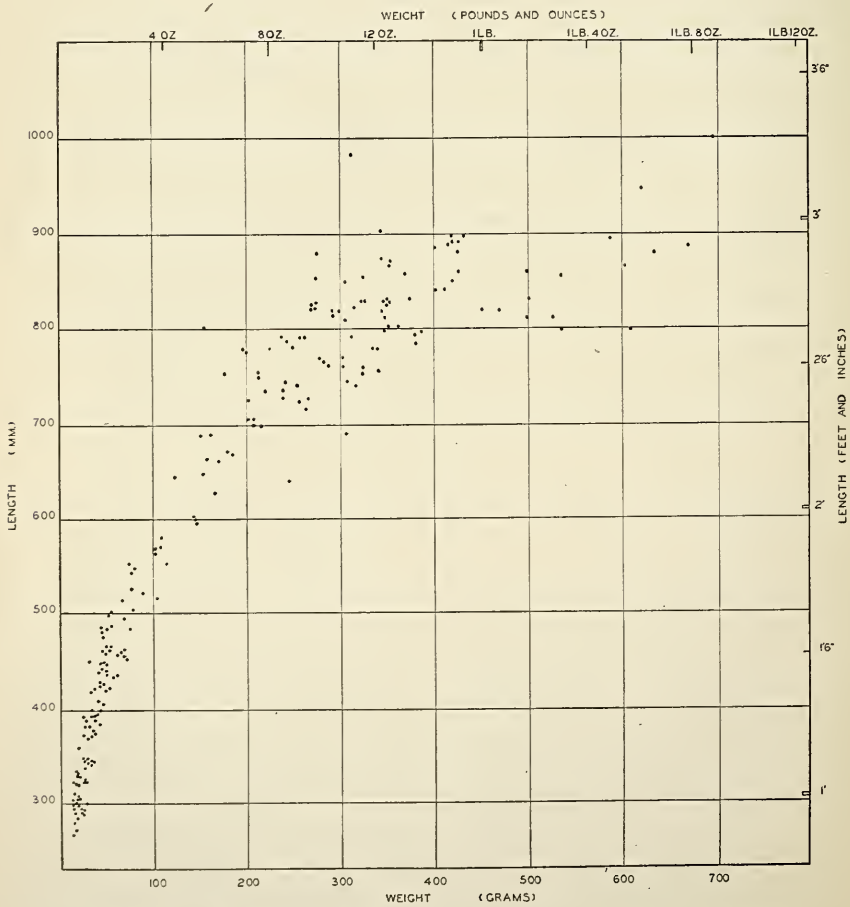

FIGURE 38. Correlation between weight and length in female rattlesnakes, San Joaquin Experimental Range, Madera County

Growth Correlations

Figure 37 shows a fairly close correlation between length and weight of female snakes. A similar pattern was shown by males (figure not included) but there was greater dispersion in the older snakes, partly because males attain greater length.

A fairly straight line relationship was shown in correlation between rattle number and age. All length and weight records for each rattle class were averaged to give the curves shown in Figure 38. A study of all three of the above correlations indicates that weight increment tends to continue as snakes get older, whereas length increment tends to slow down.

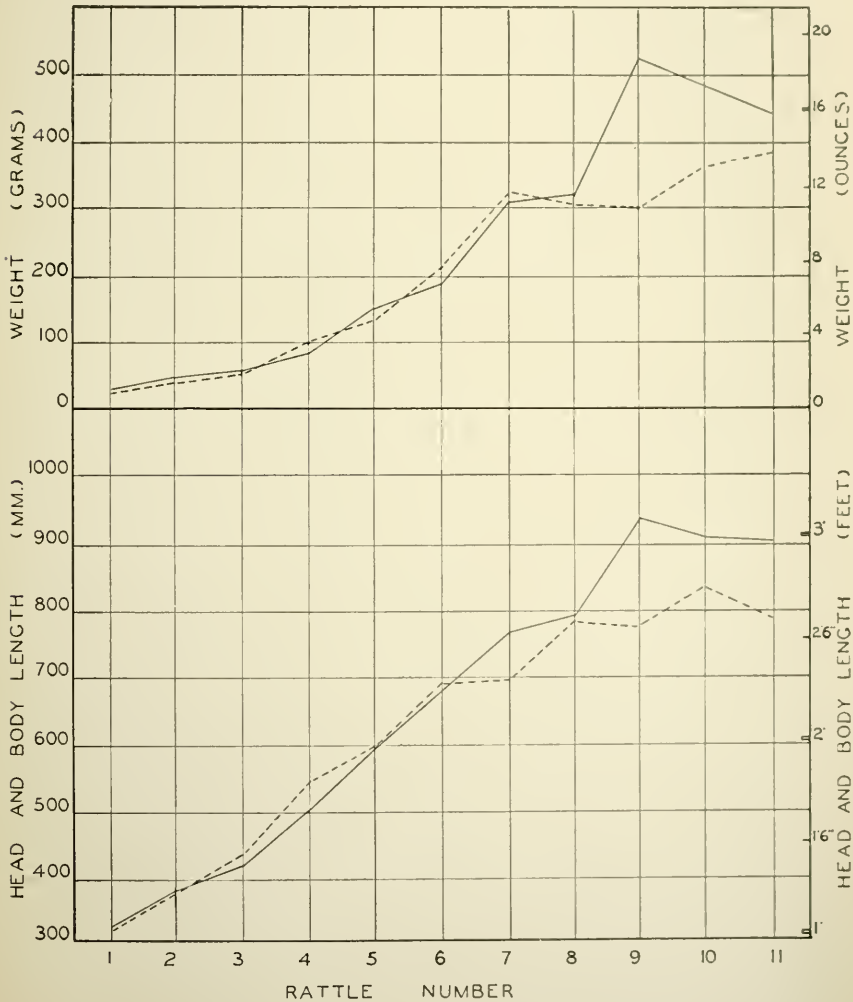

FIGURE 39. Correlation between rattle number and length and rattle number and weight. Solid lines represent male snakes; dotted lines represent female snakes. This graph represents only those individuals where the *total* number of rattles was definitely known.

Causes of Death

The most evident cause of rattlesnake mortality on the San Joaquin Experimental Range is destruction by man. Numbers killed were recorded as follows: 1935, 326; 1936, 185; 1937, 145; 1938, 58; 1939, 105. Variation in the annual kill reflects varying degrees of human activity in the field at the times and places where rattlesnakes were apt to be found, but it was not possible to obtain records of all the snakes killed by crews of laborers constantly in the field. Only snakes actually examined by us were recorded in 1938 and 1939. In the three preceding years, the snakes were tallied by the persons who killed them (members of the San Joaquin Experimental Range staff, Civilian Conservation Corps enrollees, and others) on sheets posted for that purpose. For the records from 1935 to 1937, inclusive, we are indebted to Dr. Biswell.

Presence of cattle on the San Joaquin Experimental Range constitutes a constant hazard of trampling to the rattlesnakes. In one instance, a small one was found crushed and dead in a fresh cow track. Evidently, this snake had been tightly coiled in the exposed situation where it was found, and had not moved before being trampled.

Numerous natural enemies of rattlesnakes occur on the area. King snakes *(Lampropeltis getulus)* are present in small numbers, and may prey on rattlesnakes occasionally in this locality, as they are known to do elsewhere, but no records were obtained. Roadrunners are common, and on three different occasions were seen carrying rattlesnakes. In two of these instances the birds were near roads and it seemed possible that the snakes were traffic mortalities rather than actual kills by the birds. In the third instance a roadrunner, at a distance from any road, was carrying a writhing rattlesnake about two feet long. A Cooper hawk on one occasion was seen flying with a small rattlesnake dangling from its talons. Other predators of the rattlesnake recorded on this area are the coyote, gray fox, horned owl, and red-tailed hawk. Scales and bones of the snakes have been identified in feces of the coyote and the fox. Of 944 food items identified in coyote "scats" from the area studied, three were rattlesnakes. On three occasions rattlesnakes were found as prey items in red-tailed hawk nests, comprising one-half of 1 percent of the total nest items recorded. Seventy pellets of the hawks were found to contain scales or rattles of the snakes, which comprised about 1.8 percent of the pellet items recorded. Mr. Spencer O'Neal told us he saw a red-tailed hawk flying and carrying a small rattlesnake, which still seemed to be writhing feebly. Remains of four rattlesnakes were found among a total of 1,014 food items identified in horned owl pellets.

Precisely how various predators catch and eat rattlesnakes with impunity to themselves is unknown. Probably in most instances successful capture involves taking the snake by surprise and delivering a fatal stroke before the snake has prepared to defend itself. Also, it may involve superior quickness of movement on the part of the predator, permitting it to elude the strokes of the snake and to seize or strike it from above or behind without being bitten. We believe that the quickness of rattlesnakes has been much exaggerated, and is exceeded by that of many birds and mammals.

There may be major causes of mortality other than predation, but these are undetermined. On March 31, 1939, a small adult female rattlesnake was discovered lying dead in the characteristic resting coil at the entrance of a squirrel burrow. A freshly eaten fence lizard was in its stomach. Dissection revealed that the walls of the stomach were discolored, with some hemorrhage, but otherwise no injury could be found, and the cause of death could not be determined.

On April 5, 1939, a large adult male rattlesnake was found lying dead in grass between two rock outcrops, and dissection revealed that the cause of death was apparently rattlesnake bite. Fang punctures through the body wall were found in the region of the heart, and there were characteristic hemorrhage and swelling. Ten feet from this dead snake among rocks, a mating pair of rattlesnakes was found. Snakes activated by sight or scent of prey are apt to strike at any moving object in the vicinity, and one might strike another unintentionally in an attempt to secure food.

A rattlesnake may occasionally be injured by a retaliating victim at the time a bite is delivered, despite its usual habit of immediately releasing the victim and waiting for the venom to take effect. One marked snake recorded in the field on both May 4 and 5, captured and ate a pocket gopher on the intervening night, and in doing so sustained bites from the gopher on the anterior part of the body. The wounds seemed to cause this snake no ill effects, and were healing rapidly on subsequent occasions of capture during the following week.

Summary

A population of rattlesnakes *(Crotalus viridis oreganus)* on the San Joaquin Experimental Range was studied by recording measurements, weight, sex, and location by individually marking (by scale clipping) and releasing at the points of capture all those taken alive. This work was begun in April, 1938. By the end of June, 1940, a total of 749 snakes had been recorded, and of these 515 were marked and released. One hundred and sixteen recaptures of marked snakes were recorded.

On the area where the study was made, snakes depend mainly on burrows of ground squirrels and kangaroo rats, and on loose piles of granite rock for shelter. Even at the season when snakes are active individuals spend most of their time underground. The hibernation period includes November, December, January, February, and part or all of March depending on the weather. The snakes may gather in small groups to hibernate, but many of them hibernate solitarily. A few may become active on unusually warm days in winter, but general emergence does not take place until almost immediately after the onset of warm weather in the spring. Frequency and extent of movement is extremely variable. The young snakes may wander at random. However, because of sluggish habits an individual may continue to use the same burrow or rock pile for shelter over periods of months before moving on to a new location. Adults apparently tend to remain within limited areas. The longest movements recorded for marked snakes recaptured after long periods were about a mile and a mile and a half, respectively, but these were extraordinary. Several movements of between one-fourth and three-

fourths of a mile were recorded. The greatest rate of movement was recorded for an adult male which moved a fourth of a mile overnight. The majority moved, on the average, less than 10 feet a day.

The breeding season begins in the spring (March and April), almost immediately after emergence from hibernation, and lasts from five to eight weeks. During the same period, rattlesnakes of all ages and sexes are most apt to be active above ground during the daytime, and adults are apt to be found in pairs. Young are born in September or October, and the gestation period is probably a little more than 170 days. During the summer period of pregnancy, females are exceedingly secretive. During hot summer weather, adult males and young of both sexes are less often seen than they are in spring, and tend to be mainly nocturnal. Breeding females contained from 2 to 11 ova (average 7.6 in a small sample). Ratio of small young to the entire population in the spring in four different years varied from 16.2 to 23.9 percent.

At birth the young are less than 300 mm. in head and body length. Many feed and grow rapidly before going into hibernation, but only a few exceptional ones acquire a rattle before the period of dormancy. In the growing season between the first and second hibernations the young snakes make notable growth. By late June most have acquired a rattle in addition to the original button, and by late August most have gained still another rattle. At the age of one year, shortly before entering the second hibernation, most have grown to lengths between 400 to 500 mm. and have strings of three, or four or sometimes five rattles (including the button). Records are too fragmentary to afford a clear idea of the usual growth beyond this age, but growth rate does not slow down abruptly, and the annual gain in length often amounts to more than 100 mm. until a length of 700 mm. has been attained. The medium-sized snakes gain one or two, or even three rattles annually; probably a gain of two is most frequent. Ordinarily, three or four years is required for a snake to reach full adult size (over 800 mm.) and acquire a string of eight or more rattles. Adult snakes add one or occasionally two rattles annually, and may not grow at all in the course of a year, or in some instances may make substantial growth comparable to that made by young. Rattlesnakes are delicate, and sensitive to handling; many of those marked seemed to be more or less permanently stunted by the operation.

The rather high reproductive potential of the species is apparently adjusted to a high death rate. Natural enemies of many kinds were present on the study area, and 85 instances were obtained of predation on rattlesnakes by the red-tailed hawk, Cooper hawk, horned owl, coyote, and roadrunner. Evidently, relatively few snakes survive much beyond the first year after birth. In late summer juveniles between 350 and 450 mm. in head and body length with two rattles and a button, are to be found in abundance, but frequently they are emaciated and appear to be in poor condition. Larger young with three or four rattles, in addition to the original button, are much less frequently found at any season, and it appears that the latter part of the first growing season and the succeeding hibernation may constitute a critical period when juveniles, excepting the hardy and vigorous ones, successful in securing prey, are apt to succumb.

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REPORTS

FISH CASES

October, November, December, 1946

Offense	Number arrests	Fines	Jail sentences (days)
Abalone: Taking from shell below high water, taking to sell commercially, undersized, overlimit	55	$2,315 00	25
Angling: Using set lines, no license, more than 1 rod, possession gaff 300 feet stream, illegal net, within 150 feet dam, closed area	102	2,827 50	
Bass: Undersize, overlimit, more than 1 rod, night fishing, possession for sale	62	1,765 00	
Catfish: Undersized, overlimit, sale of undersized	6	320 00	
Clams: Undersized, overlimit	94	3,771 50	40
Commercial: No license	13	120 00	
Crabs: Undersized, taking on Sunday	9	1,325 00	
Croakers: Illegal sale	4	200 00	
Lobster: Closed season, undersize, traps closed district, oversize, possession cooked Mexican	21	1,060 00	
Pollution	15	750 00	
Salmon: Undersize, within 150 feet of dam, snagging, taking in spawning area, shore limits spearing, closed area, drift gill net, shooting, gaffing, illegal possession	79	4,866 00	
Trout: Untagged, overlimit, set lines chumming, closed area	11	350 00	
Wholesaler: No license, failure to keep record	2	300 00	
Using more than 32½% of sardines in reduction	1	25 00	
Totals	474	$19,995 00	65

GAME CASES

October, November, December, 1946

Offense	Number arrests	Fines	Jail sentences (days)
Coots: Closed season	1	$25 00	
Deer: Closed season, illegal possession, unmarked, female, spike buck, take in refuge, altering tag, transferring tag, spotlighting, killing fawn, taking forked horn, 22 rifle, failure to keep hides, failure to fill out tags, 2d deer Dist. 1	244	16,614 50	32½
Deer meat: Illegal possession, no entry permit	16	1,200 00	360
Doves: Closed season, overlimit, no license, unplugged gun, taking from motor vehicle	54	1,765 00	
Ducks: Closed season, overlimit, shooting from motor boat, offering for sale, game refuge	84	4,512 50	
Elk: Illegal possession	1	200 00	
Frogs: Undersized	2	100 00	
Grey squirrel	9	360 00	
Geese: Overlimit, after hours, game refuge	15	450 00	
Grebe	1	25 00	
Hunting: No license, night hunting with spotlight, from motor vehicle, unplugged gun, in refuge, closed season, citizen's license, shooting from motor boat	430	10,677 50	
Hunting big game with full metal jacket bullets	7	265 00	
Illegal possession beaver skins	1	100 00	
Non-game birds	11	340 00	
Pheasants: Hen, closed season, no license, shooting from automobile	174	12,610 00	
Pigeon: Closed season	1	25 00	
Quail: Closed season, unplugged gun, trapping	22	812 50	
Rabbits: Taking at night, closed season, no license	10	285 00	
Shore Birds	16	682 50	
Swan	2	22 50	
Trapping: No license	3	32 00	
Trespass	1	25 00	
Totals	1,105	$51,129 00	392½

SEIZURES OF FISH AND GAME

October, November, December, 1946

Fish:	
Abalone	1,235
Bass	33
Bass, pounds	174
Catfish	43
Clams	1,573
Cockles	1,000
Crab	720
Lobster	1,563
Lobster, pounds	423
Salmon	62
Salmon, pounds	409
Trout	90
Trout, pounds	30
Game:	
Coots	2
Deer	67
Deer meat, pounds	2,772
Doves	326
Ducks	379
Frogs	377
Geese	67
Non-game birds	7
Pheasants	129
Pigeon	1
Quail	74
Rabbits	9
Seagulls	4
Shorebirds	25
Squirrels	7
Swan	1

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(Continued from inside front cover)

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