

MISCELLANEOUS PUBLICATIONS
MUSEUM OF ZOOLOGY, UNIVERSITY OF MICHIGAN, NO. 68

THE CYPRINODONT FISHES OF
THE DEATH VALLEY SYSTEM
OF EASTERN CALIFORNIA
AND SOUTHWESTERN
NEVADA

BY
ROBERT R. MILLER

ANN ARBOR
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THE CYPRINODONT FISHES OF THE DEATH VALLEY SYSTEM OF EASTERN CALIFORNIA AND SOUTHWESTERN NEVADA*

INTRODUCTION

THE fish fauna of the arid American West is characterized by relict populations limited in number of species but rich in material for the student of evolution. In order to understand the present distribution of this fauna it is necessary to study the Pleistocene geology of the region, for the Recent fish life reached the now widely separated springs and creeks when the desert was a well-watered land. In what is now one of the driest parts of the Great Basin, in eastern California and southwestern Nevada, several deep lakes and large streams existed, connecting the many isolated basins which now characterize this region (Maps 1 and 2). This former drainage basin has been named the Death Valley system (Miller, 1943b: 69). Its continuity is demonstrated not only by the physiographic evidence but also by a study of the relict fish populations scattered throughout the area. The segmentation which the drainage has undergone has resulted in the separation of these populations, and since the basins were cut off from each other at different times, the fishes have been isolated for varying periods, and all the minor systematic categories—races, subspecies, and species—are now represented among the remnant populations.

The present work has a dual purpose: first to classify the cyprinodont fishes of the Death Valley system and discuss their ecology, distribution, speciation, and probable relationships; and second, to correlate the Recent distribution of the fish fauna with the Pleistocene hydrography of the area. A detailed discussion of the Pleistocene connections and their zoogeographical significance has already been published (Miller, 1946), and only a brief summary is given herein. The fossil fish fauna has been treated separately (Miller, 1945).

Only 3 genera of cyprinodont fishes are represented in the Recent fauna of the interior and the Colorado River basins: *Cyprinodon*, *Empetrichthys*, and *Crenichthys*. Two species of *Fundulus* are known from the Pacific coast, and fossils referable to this genus have been found in the western Great Basin. The present study treats in detail the species, subspecies, and races of *Cyprinodon* and *Empetrichthys* inhabiting the Death Valley system. Two new species and 7 new subspecies are recognized. The remaining genus, *Crenichthys*, diagnosed by Hubbs (1932) and briefly re-

* A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan in 1944. The material presented here represents approximately two-thirds of the original.

viewed by Hubbs and Miller (1941: 1-2), remains to be analyzed for sub-specific and racial variation.

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During the course of this study, which extended over a period of 8 years, I have received financial aid, encouragement, and assistance from many individuals and institutions. The late Professor Joseph Grinnell and Professor Alden H. Miller, of the Museum of Vertebrate Zoology, Berkeley, California, encouraged the early work. Specimens were loaned from Stanford University by Professor George S. Myers and Miss Margaret Storey, and from the United States National Museum by Dr. Leonard P. Schultz. Beginning in 1939, financial support was given by the Museum of Zoology, University of Michigan, and in 1940 and 1942 by the Rackham School of Graduate Studies of this University. The late Miss Grace Eager, accomplished artist of the University of Michigan Museum of Zoology, made the accurate drawings, and Norman J. Wilimovsky served ably as research assistant in tracing the maps. Through the courtesy of Dr. Carl L. Hubbs, Miss Elizabeth Kampa made the excellent graphs (Figs. 3-5). I am also indebted to C. S. Scofield, Principal Agriculturist of the Rubidoux Laboratory of the United States Department of Agriculture at Riverside, California, for allowing me to publish the water analyses made by that laboratory. The United States National Park Service has extended the fullest co-operation in the field work in Death Valley National Monument. I am deeply grateful to Professor Carl L. Hubbs, formerly Curator of Fishes in the Museum of Zoology, University of Michigan, and now Professor of Biology at the Scripps Institution of Oceanography, for his generous aid, encouragement, and invaluable advice. I also owe a debt of gratitude to my father, Ralph G. Miller, who has not only constantly aided me in the field work, but has also made innumerable collecting trips into the desert solely for my benefit. To my wife, Frances H. Miller, much credit is due for aid in the statistical computations and for typing the many drafts of the manuscript. Publication of this study was made possible by a grant from the Horace H. Rackham School of Graduate Studies.

MATERIALS AND METHODS

This systematic study of desert fishes is based almost wholly on the collections deposited in the University of Michigan Museum of Zoology (U.M.M.Z.). Between 1936 and 1942 more than 10,000 specimens of *Cyprinodon* and *Empetrichthys* were collected during personal trips, expeditions from the University of Michigan, and by Ralph G. Miller. Specimens deposited in the United States National Museum (U.S.N.M.) and in the Stanford Natural History Museum (S.N.H.M.) have also been examined.

To enable others to use the measurements and enumerations of characters and to allow the accumulation of comparable data, the methods of counting and measuring which have been employed in the present study are stated in detail.

METHODS USED IN COUNTING

FIN RAYS.—The last ray of the dorsal and anal fins is always regarded as a double ray, divided to the base of the fin. In this respect, my counts for these fins of *Cyprinodon* are 1 less than those given by Wales (1930), who counted every element. All of the rays of both pectoral fins are counted, including the often minute rudiments along the lower edge of the fin; the lowermost ray is frequently joined to its neighbor and some dissection may be necessary to reveal it. Similarly, each ray of both pelvic fins is enumerated, with special caution to note the innermost one, which is rather frequently represented as a mere sliver of cartilage or a very minute stub. The count for the caudal fin is the number of principal rays, the branched rays plus 2 (1 unbranched ray on either side).

In samples from salty water or those including breeding males, removal of the surface mucous on the fins greatly aids in counting the rays. I have found that by keeping the fins wet and using reflected daylight very accurate results are obtained.

SCALES.—The scales in the lateral series are counted from the first 1 in contact with the shoulder girdle to the 1 at the structural base of the caudal fin. The first scale counted lies just above and a little behind the opercular angle (Fig. 1). The last 1 is determined by moving the tail back and forth and noting where the crease so formed is in contact with the scale. If the flexure lies near the middle of the scale or posteriorly, the scale is included in the count; otherwise it is excluded. Care should be exercised to note whether a scale is regenerated, for I have found in *Cyprinodon* that a single regenerated scale often occupies the space formerly covered by 2 scales. Counting such a scale results in a count that is too low.

In the cyprinodonts, which lack a definite lateral line, the dorsal to pelvic count is made from the scale (usually small) lying just in the angle of the pelvic fin to the 1 just beside (but not anterior to) the origin of the dorsal fin. The dorsal to anal count is made from the small scale (or scales) lying in the angle of the anal fin to this same scale (Fig. 1).

The predorsal count involves the scales which intersect a straight line along the back between the snout and the origin of the dorsal fin. The first scale (or, usually, a pair of 2 very small scales lying side by side and occasionally difficult to see) lies on the snout, the fourth scale (usually enlarged and nonimbricated) almost invariably lies partly over and partly behind the posterior rim of the orbit. All scales which definitely, unequivocally

cally overlap the mid-line of the back on their exposed surfaces are counted. If it is not certain that 2 closely approaching scales definitely overlap and hence cross the mid-line, they are not counted. Certain modifications are followed when necessary, such as shifting the mid-line when otherwise an obviously incorrect count (usually too high) would result.

The scale count around the body begins with the eighth scale of the lateral series (the seventh in *C. radiosus*), and is made in a zigzag fashion,

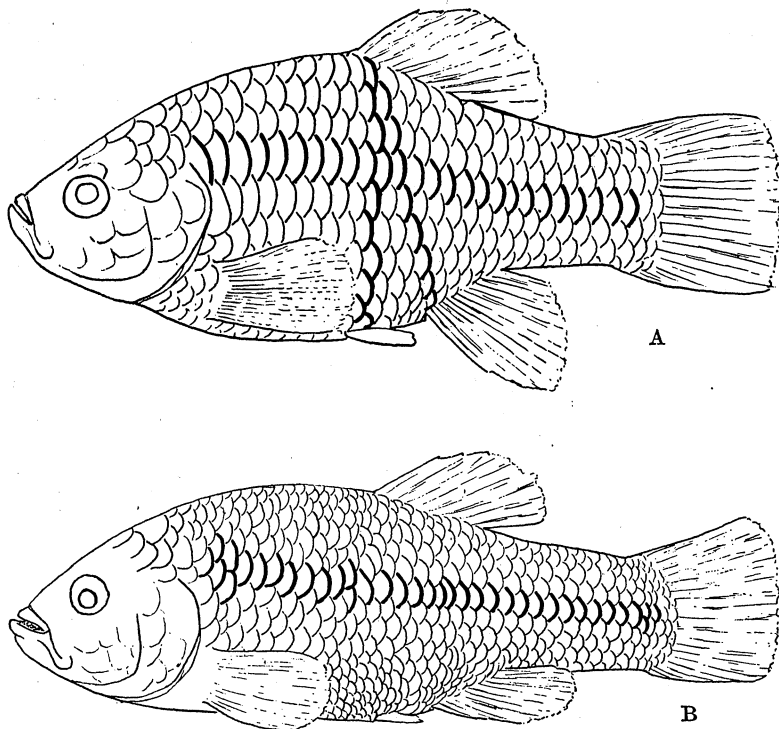


FIG. 1. Sketch of 2 species of *Cyprinodon*, to illustrate methods of counting scales in lateral, dorsal to pelvic, and dorsal to anal series. Drawn by Grace Eager. A. *Cyprinodon nevadensis nevadensis*: 26 lateral scales. B. *Cyprinodon salinus*: 33 lateral scales.

passing over the back about 1 scale row in front of the dorsal fin, and over the abdomen about 1 scale row in front of the pelvic fins.

The scales around the peduncle are counted according to the method followed for the count around the body; the count is started with about the sixth from the last scale in the lateral series.

SCALE RADII.—The scale radii are enumerated on the seventh to ninth scale of the lateral series on the right side, of adult specimens only. All

radii are counted, including the very minute ones. Injured or regenerated scales are not used.

GILL RAKERS.—The gill rakers of the first branchial arch are enumerated without a separate tabulation for the upper and lower limbs. All rudiments at either end of the arch are included in the count, even those that require high magnification and bright illumination to see.

HEAD PORES.—The lateral line system of pores on the head is of some taxonomic value in cyprinodonts. The preopercular pores are those lying along the lower and upper arms of the preopercle; the preorbital, those along the preorbital bone on the side of the snout; and the mandibular, those along the mandibles. The counts are recorded separately for each side, but are added together in the final presentation.

Reliability of Counts

All of the fin-ray counts are clear-cut, after due care is exercised in discerning the minute rays of the pectoral and pelvic fins. There may be some error in the counts for these 2 fins, but it is believed to be insignificant. The scale counts are generally precise, the least accurate being those of the predorsal and dorsal to anal series. The dorsal to anal count was mainly included as a basis for comparison of species of *Cyprinodon* with *C. diabolis*, which lacks pelvic fins. Only rarely is there some question of the number of scales in the lateral series in *Cyprinodon*, but this count is more difficult in *Empetrichthys*. Gill raker and scale radii counts offer no real difficulty if the precautions of proper light and sufficient magnification are exercised. The preopercular and preorbital pores are usually readily distinguishable when quickly dried by a jet of compressed air after the head of the fish has been dipped in liquid. The pores are best seen on larger individuals; fish smaller than 25 mm. in standard length were used only when necessary to fill the series. Rather uncommonly, it is difficult to tell whether a pore is open or not, and hence whether it should be counted.

The higher of 2 possible counts was always recorded, except in the predorsal scale count of *Cyprinodon*.

METHODS USED IN MEASURING

All measurements are made on the left side of the fish except the following: the preorbital margin to preopercular angle, eye margin to preopercular angle, upper jaw length, and mandible length, all of which were measured on the right side. On occasion it is necessary to measure a structure on the right side, for example, when the left pectoral is injured. The longer pelvic fin is measured.

The fish is not allowed to dry out, but is kept in good condition by occasionally immersing or spraying it with fluid. This practice is particularly

important with fin measurements. All fins are dipped in fluid just before they are measured. Good light is used, and the measurements are made, with very few exceptions, under a binocular microscope at a magnification which just includes the distance to be measured.

The calipers used are a precision instrument distributed by Glogau and Co. and record distances to 0.1 mm. Estimates to 0.01 are possible. Each fish measured is tagged. Considerable practice is required for accurate work, and all measurements on any particular genus should be made during one period. Thus, unconscious changes in techniques of measuring will be avoided.

STANDARD LENGTH.—The distance from the tip of the snout to the structural base of the caudal fin. The anterior limit of this measurement is the tip of the premaxillaries, in retracted position. Whenever the length is mentioned in this paper it refers to standard length.

PREDORSAL LENGTH.—Measured from the base of the first dorsal ray to the tip of the premaxillaries.

PREPELVIC LENGTH.—Measured from the inner base of the pelvic fin to the tip of the premaxillaries.

ANAL ORIGIN TO CAUDAL BASE.—The distance between the origin of the first anal ray and the structural base of the caudal fin on the mid-line of the body.

BODY, GREATEST DEPTH.—The greatest vertical distance between the back and the ventral surface of the abdomen, usually measured over the pelvics.

BODY, GREATEST WIDTH.—The greatest horizontal distance between the sides of the body, measured over the back usually just behind the head.

HEAD, LENGTH.—Measured from the posterior margin of the opercle (of the opercular flap when present) to the tip of the retracted premaxillaries.

HEAD, DEPTH.—The greatest vertical distance from the isthmus to the top of the head directly above the upper corner of the opercle.

HEAD, WIDTH.—The greatest horizontal distance across the opercles, measured from above.

CAUDAL PEDUNCLE, LENGTH.—The distance between the base of the last ray of the anal fin and the structural base of the caudal fin on the mid-line (in the fishes studied there is little or no membrane behind the last anal ray).

CAUDAL PEDUNCLE, LEAST DEPTH.—The vertical distance across the slenderest part of the caudal peduncle.

INTERORBITAL, LEAST BONY WIDTH.—The least distance between the bony rims of the orbits (in *Cyprinodon* and *Empetrichthys* the interorbital is narrowest between the middle of the pupils). The tips of the calipers are firmly pressed against the bony rim on each side.

PREORBITAL, LEAST WIDTH.—The least distance between the fleshy rim of the preorbital bone and the fleshy rim of the orbit.

PREORBITAL MARGIN TO PREOPERCULAR ANGLE.—Measured from a point on the preopercular margin about midway between the pore at the angle of the preopercle and the next one above, to the border of the preorbital at the corner of the mouth. A jet of air was used to remove the alcohol from this border just before measuring.

EYE MARGIN TO PREOPERCULAR ANGLE.—The distance between the angle of the preopercle at the level of the angular pore to the nearest point on the fleshy orbital rim. Both this and the preceding measurement are made on the right side of the head.

OPERCLE, GREATEST LENGTH.—The greatest distance across the opercle from the preopercular rim, which is marked by the series of preopercular pores, to the edge of the membrane (when present). Usually measured near the upper angle of the opercle.

SNOUT, LENGTH.—The distance between the fleshy orbital rim and the retracted premaxillaries. This is one of the most difficult of all the measurements because the premaxillaries are so often out of position, and it is frequently difficult to estimate how far back they should be pressed.

ORBIT, LENGTH.—The greatest horizontal distance across the fleshy orbital rims. This is a very precise measurement.

MOUTH, WIDTH.—The greatest distance between the fleshy corners of the lips with the mouth closed and the premaxillaries in the retracted position.

UPPER JAW, LENGTH.—The distance between the distal end of the right maxillary and the tip of the retracted premaxillaries.

MANDIBLE, LENGTH.—The distance between the posterior end of the right mandible and the fleshy tip of the lower jaw.

DORSAL FIN AND ANAL FIN, BASAL LENGTH.—Measured forward to the structural base of the first ray. This point is determined by sliding the tip of the calipers anteriorly along the prolongation of the dorsal origin until they "hook" into the structural base.

DORSAL FIN AND ANAL FIN, LENGTH.—The length of the depressed fin from the structural base of the first ray to the tip of the longest ray or rays.

MIDDLE CAUDAL RAYS, LENGTH.—The distance between the structural base and the tips of the middle caudal rays.

PECTORAL, LENGTH OF LONGEST RAY.—The distance between the base of the pectoral fin and the longest ray or rays. To determine the basal starting point, the fin is bent forward, and the marked crease at the base is noted. The measurement is taken from this crease.

PELVIC, LENGTH OF LONGER FIN.—The distance between the structural base, determined by bending the fin forward and noting the crease, and the tip of the longest ray or rays. Unless it is obvious which fin is the longer, both are measured to determine this point.

Reliability of Measurements

Considerable practice was necessary before accurate results in measuring were obtained. When preliminary trials were made, checked, and rechecked over a short period, most of the measurements gave consistent values. Some of the most difficult of the measurements, in my experience, were the length of the snout, the width of the mouth, and the basal length of the dorsal and anal fins. When the disagreement in readings on these measurements was notable, I often made 3 readings and took the average for the result. It was only after 3 months of more or less continual measuring that I attempted to record the values for *Cyprinodon diabolis*, as in this dwarfed species the specimens measured averaged only 19 mm. in standard length. It was, for instance, difficult to measure the width of the preorbital on a fish of this size, for this distance is only about three-fourths of a millimeter.

CHARACTER INDEX

Because of the varying degree of differentiation undergone by certain populations of *Cyprinodon* and *Empetrichthys*, it is not always possible to distinguish the subspecies on the basis of single traits. Some forms differ significantly from others on the average for a number of characters, but each character alone is not sufficient to make certain their identity. The combinations of such characters lead to more precise determinations, and for this reason the character index is used.

In any combination of traits, whether they be counts or measurements or both, the total index is obtained by summing each particular value for each individual. Thus, a character index (Table X) based on the scale counts of 2 races of *Cyprinodon nevadensis shoshone* shows the relations between these 2 populations much more clearly than does any 1 of the meristic characters considered alone (Tables XXII-XXIV). This index greatly decreases the amount of overlap which occurs when only a single trait is considered, and, consequently, gives a truer picture of the actual differences which exist between these 2 races.

A historical review of the character index and a justification of its use was recently presented by Hubbs, Hubbs, and Johnson (1943: 4-6).

STATISTICAL COMPUTATIONS

The statistical computations used in the biometric analyses made in this study are given in Hubbs and Kuhne (1937). The formula for t is the conventional one,

$$t = \frac{M_1 - M_2}{\sqrt{(\sigma_{M_1})^2 + (\sigma_{M_2})^2}},$$

in which M_1 is the mean value of the particular character of one sample, and

M_2 that for the sample which is to be compared. This formula is adequate when the number in each sample is approximately equal ($N_1 = N_2$) and the standard deviations (σ) are similar, as has been recently pointed out by Hubbs and Perlmutter (1942:588-92). However, if the number of specimens in the samples to be compared differs markedly, and the standard deviations are dissimilar, the following formula, favored by Simpson and Roe (1939:192-94), is to be applied:

$$t = \frac{M_1 - M_2}{\sqrt{\frac{N_1}{N_2} \sigma_{M_1}^2 + \frac{N_2}{N_1} \sigma_{M_2}^2}}$$

A t value of 2.5 is regarded as trustworthy, with the odds of significance 80 to 1. A value of 3.0 gives odds of significance of 369 to 1, and when the 6.0 level is reached there is only one chance in 500,000,000 that the result is due to chance alone (Hubbs and Perlmutter, 1942:586). The t values below 2.5 although less reliable, may be taken as evidence, valid to the degree indicated.

The calculation of the standard error of the mean ($\pm \sigma_M$) was not made for data which presented a markedly skewed or asymmetrical curve, since the derivation of this basic statistic assumes that the frequency curve is a "normal" one. Almost without exception, the pelvic fin rays in *Cyprinodon nevadensis* yielded frequencies which were asymmetrical (Table XVII). Hence, the standard error for these samples and the species as a whole was not computed. Such abnormal curves in biology might lead statisticians to view the systematic conclusions with suspicion, since, ordinarily, curves of this type indicate that one is dealing with combinations of different kinds of organisms or objects. There is, however, no reason to doubt that all of the fish analyzed in Table XVII belong to a single species. Moreover, that the frequency distributions as given are descriptive of each population is testified by the fact that repeated collections from the same locality give remarkably similar curves (Tables XLV-L).

On the evidence that these unusual curves are characteristic for these populations, one might justify the calculation of the standard error of the mean, if a formula for its computation could be devised, or if empirical tests should show that the observed fluctuation of the mean is consistent with expectations derived from a standard error computed by the standard formula. Wales (1930:63-65) apparently considered such a computation permissible, and it is significant that his "P.E." (probable error of the mean) for the highly asymmetrical curve of pelvic rays at King's Spring (= Point of Rocks Spring), and the values I later obtained, are remarkably alike. My values lie within the error calculated by Wales (Table XLVII). The evidence of consistency, however, in periodic samples is not entirely

conclusive, because more samples are needed for statistical reliability. Therefore, I have thought it unwise to calculate the standard error of the mean for such types of curves.

DESCRIPTIVE PHYSIOGRAPHY AND RECENT HYDROGRAPHY

The parts of California and Nevada included within the hydrographic boundary of the Death Valley system lie in the Great Basin division of the Basin-and-Range Province. This system is bounded on the west by the rugged crest of the Sierra Nevada, on the north by the hydrographic rim of Pleistocene Lake Lahontan and smaller adjacent interior basins, and on the east by the Spring Mountains, New York Mountains, and other isolated mountain blocks near the California-Nevada line. To the south it is sharply separated from the coastal drainage by the east-west San Gabriel and San Bernardino ranges of southern California and indefinitely set off from the Colorado River system (Map 2).

This desert region, embracing an area of approximately 30,000 square miles, is made up of arid basins, separated by steep, parallel, fault-block ranges which trend in a north-south direction. The basins and ranges are largely bare and have very few surface waters. Elevations vary from 280 feet below sea level in Death Valley to 14,495 feet at the peak of Mount Whitney, the lowest and highest points, respectively, in the United States. Crests of the major desert ranges generally vary in elevation from 6,000 to 8,000 feet, and the basins range from below sea level in Death Valley to 4,000 feet in Owens Valley. The higher parts of the ranges support restricted stands of piñon and juniper, and so-called "forests" of the Joshua tree occur in favorable localities, generally between 2,500 and 3,500 feet. The creosote bush, usually in pure stands, covers great expanses of the broad desert basins and is the most widely distributed, and hence the most conspicuous, plant in the desert, ranging from below sea level to 5,500 feet. Other areas, usually in the lowest parts of closed basins, are entirely devoid of vegetation. These flat, bare stretches are the sites, after storms, of shallow ephemeral lakes and are generally referred to as playas, dry lakes, or alkali flats.

The climate is characterized by high summer temperatures but comparatively cold winters, low humidity, and low rainfall. Over the desert the average annual precipitation is about 6 inches, varying from 35 or 40 inches in the higher mountains to 1.5 inches in Death Valley. At Bagdad, on the central part of the Mohave Desert, 36 consecutive months without a trace of rain have been recorded (Thompson, 1929: 69). Most of the precipitation falls as rain during the winter and early spring, but summer thunderstorms occur on the Mohave Desert. A moderate snowfall is not

uncommon in the higher ranges, and snow occasionally falls on the higher slopes of the southern Mohave Desert proper.

The much restricted natural water supply of this desert expanse consists largely of 2 categories: permanent streams and perennial springs (Lee, 1906; Mendenhall, 1909; Waring, 1915, 1920; Thompson, 1929). There are 3 major, permanent streams in the Death Valley system (Map 2). Owens River, the largest of these, rises in snow-fed lakes 9,000 to 10,000 feet high along the eastern escarpment of the Sierra Nevada and receives many tributaries during the 130-mile course south to its sump, Owens Lake. Much of the water of this river is diverted into the Los Angeles aqueduct long before it reaches this lake, but under natural conditions Owens Lake was a larger body of saline water, without Recent outlet. The Mohave River rises on the northern slopes of the San Bernardino Range and follows a winding course northward on the desert for about 120 miles, where it finally sinks into the porous sands. In the headwater region, above 3,000 feet in the East Fork (Deep Creek), and 3,250 feet in the West Fork, its tributaries are generally permanent, but Mohave River becomes intermittent as soon as it debouches from the mountains onto the Mohave Desert. The third major stream, the Amargosa River, contains the smallest water supply, though its catchment area is greater than that of the Mohave. It rises above the old mining town of Beatty, in Nye County, southwestern Nevada, and its wash continues south for about 100 miles, where it makes an abrupt about face to terminate some 50 miles to the north in Death Valley. In the headwater region there is permanent water of good quality, but at the few other perennial flows of this "river," the water is of poor quality. The name Amargosa, meaning "bitter," is very appropriate for the middle and lower parts of this stream. At intervals, however, the Amargosa is fed by many large, warm springs, most notably in Ash Meadows, Nye County, Nevada (Map 3). These springs support many forms of life and provide a welcome water source for the thirsty desert traveler. The few clear streams and small springs in the higher mountain ranges contain no native fish life and are not important to this paper.

The widely scattered springs of this desert region are the most important source of refuge for wild life, and they have saved the life of many an old prospector. Long before the advent of the white man they marked the camp sites of Indians and the watering places for the desert bighorn sheep. The lowland springs, largely on or near fault lines, are warm or hot, varying from 20° to 42° C. (Table XLI), but fish do not permanently inhabit those having a temperature much above 34° C. The temperature of each spring is remarkably constant. The springs vary from 1 foot to 50 feet in diameter and from a few to 30 or more feet in depth. None of them is bottomless and none contains blind fish—popular desert myths. Some have no

visible inlet or outlet, but nevertheless maintain a relatively steady flow and water level. Nearly all of the springs abound in plant and animal life, and most of them (at least 30) support fish populations. Those which do not are too hot, too saline, or too alkaline to contain fish, or they are above the level covered by Pleistocene waters and hence were never populated, or they lie in mountain canyons subject to irresistible floods.

PLEISTOCENE HYDROGRAPHY

During the latter part of Pleistocene time there existed in this desert region an integrated river system (Map 1) named the Death Valley system because Death Valley formed the sump for this drainage. The physiographic evidence for this river system is unmistakable, but the detailed history of the drainage appears to have been very complicated, and much of the story remains to be deciphered. The present knowledge of this past hydrography has been presented in detail elsewhere (Miller, 1946), and the present account is a condensed review.

The streams, rivers, and lakes portrayed on Map 1 were not all contemporaneous. At least 2 stages were represented, which Blackwelder (1933; 1941) has tentatively correlated with the Tahoe and Tioga stages of glaciation in the near-by Sierra Nevada. These stages in turn are thought to have been nearly coincidental with the earliest and latest stages of the Wisconsin or last continental glaciation of eastern North America (Blackwelder, 1931: 918). Still earlier phases were almost surely represented, but it is seldom possible to do more than speculate on conditions which may have existed during middle or early Pleistocene times.

Gale (1914) and Blackwelder (1933) have established that Owens River formerly overflowed its present sump, Owens Lake, and filled successive basins southward and eastward until it entered Lake Manly, the former body of water that covered most of Death Valley (Map 1). At the same time, Death Valley probably received the discharge of both the Amargosa and Mohave rivers, whose conjoined waters entered from the south. Lake Manly was about 100 miles long and 600 feet deep (Noble, 1926: 69-70; Blackwelder, 1933).

At this period, which Blackwelder has tentatively correlated with the Tahoe glacial stage, a continuous waterway probably connected Owens Valley with the Amargosa and Mohave river basins. It was, therefore, possible for fish life to move between these now isolated basins. Whether the lake in Pahrump Valley, in southern Nye County, Nevada, was also connected with this drainage is not known, although Free (1914: 43-44) claimed that this valley was tributary to Amargosa River during the existence of Pleistocene Lake Lahontan. The presence of the genus *Empetrichthys* in Pahrump

Valley and in Ash Meadows (of the Amargosa drainage) testifies to a connection at some time.

During the succeeding Tioga glacial stage, Blackwelder believed that Owens River was no longer tributary to Death Valley, and no doubt the flow from both the Mohave and Amargosa rivers had greatly diminished. It is even questionable if Mohave River then reached Death Valley at more than infrequent intervals. As a result, Lake Manly rapidly disappeared.

Fish life in the Mohave and Amargosa drainages was isolated from that in Owens Valley long before isolation was effective between and within those drainages. Within historic time, Mohave River has not overflowed its extreme sump basin, Silver Lake, but in January, 1916, a great flood filled that playa with 10 feet of water and raised its level to within 30 feet of overflowing through the old outlet of Lake Mohave (Thompson, 1929: 494, 564). It is obvious that a slight increase in rainfall would make it possible for the Mohave River to reach Death Valley again.

A hydrographic connection between Death Valley and the Colorado River has been suggested by geologists (Blackwelder, 1933; Blackwelder and Ellsworth, 1936). A series of troughs, which contained Pleistocene lakes (Map 1), extends south and east from Death Valley and may represent the route along which such a connection once existed. There is, however, no clear-cut physiographic evidence that these structural troughs were in the course of such a hydrographic connection, but there is good indirect evidence that a waterway once connected Death Valley and the Colorado River or its antecedent. The genus *Cyprinodon* is elsewhere known in the West only from the lower Colorado River basin, and the species of that drainage (*C. macularius*) was obviously derived from relatives to the east, where the genus reaches its maximum development. A fossil *Cyprinodon* (Miller, 1945) from late Pliocene or early Pleistocene beds in Death Valley indicates that the genus entered the valley from the lower Colorado River or its antecedent at an early time. When it is realized that the Grand Canyon probably has been cut since mid-Pleistocene time, it is not difficult to understand how the physiographic evidence for such a connection might have been erased. The occurrence of *Cyprinodon* in the Death Valley system demands a connection with the basin of the Colorado River.

There is also some direct and indirect evidence to indicate that the Death Valley system was united, for a time at least, with the basin of Lake Lahontan to the north by way of the Mono basin. Although Russell (1889: 300-301) found no evidence that the Mono and Lahontan basins were connected during the existence of Pleistocene Lake Mono, it seems quite likely that a waterway united the 2 basins during pre-Pluvial time by way of what are now the East Fork of the Walker River and Aurora Valley. After fish life entered the Mono basin, a connection was probably established, prior

to the formation of the Mono Craters, with the Owens River in Adobe Valley, and the species spread southward. W. C. Putnam, of the University of California at Los Angeles, who has studied this area, wrote (personal letter) that there is good physiographic evidence for such a connection. The presence of the cyprinid genus *Siphateles* in Owens Valley strengthens such a view, for this genus (also present in Mohave River) is unknown from the Colorado River basin, but is abundantly represented in the Lahontan basin and other systems to the north and west. In explanation for its presence in the Death Valley system it must be assumed that the Lahontan and Death Valley systems were once united.

Physiographic evidence for a stream capture between the Amargosa River basin and the upper part of Las Vegas Creek, a flood tributary to the Colorado River, has been described by Gilluly (1929: 682). An area of about 150 square miles between Charleston and Point of Rocks in Nevada (see United States Geological Survey, Las Vegas and Furnace Creek quadrangles) was formerly tributary to Indian Springs Valley, a northwestern extension of the Las Vegas trough, but has been captured by a tributary of Amargosa River. Minnows of the genus *Rhinichthys* inhabit both Las Vegas Creek and Amargosa River, and it is very possible that the ancestral Amargosa stock came from the Colorado River basin rather than from Owens Valley, the only other drainage in the Death Valley system in which this genus occurs. Owens River almost surely received its stock from the Lahontan basin. That *Cyprinodon* also entered the Death Valley system by the Las Vegas-Amargosa transfer is most unlikely, for this genus is not adapted for life in the current and never seeks the higher tributaries.

GENUS *CYPRINODON* LACÉPÈDE

Cyprinodon Lacépède, 1803: 486. Type, *Cyprinodon variegatus* Lacépède.

Lebia (Cuvier) Oken, 1817: 1182. Type, *Cyprinodon variegatus* Lacépède.

Trifarcus Poey, 1860: 306. Type, *Trifarcus riverendi* Poey.

The following generic diagnosis of *Cyprinodon* has been compiled after a study of nearly all of the known species and of the literature.

DIAGNOSIS.—Teeth trieuspid, incisor-like, in a single series in each jaw. Scales large, 20 to 34 from angle of opercle to caudal base, usually 25 or 26. Humeral scale slightly to greatly enlarged. Preorbital area below the level of the nostrils usually scaly, except in *rubrofluviatilis*, *salinus*, *diabolis*, and some populations of *nevadensis*. Free edges of the preorbital scales directed upward. Anterior edge of squamation of top of snout formed of several scales which are usually somewhat irregular, leaving a variable (often rather narrow) naked strip between them and the premaxillary groove. Scaly flap separating pelvic fins usually short and somewhat irregular, composed of 1 or 2 distal scales and 2 to 5 basal scales (exceptions in *radiusus*), all of which

are somewhat asymmetrical. Prepelvic scales about 15 to 30 or more (absent in *rubrofluviatilis*), usually 20 to 25. Dorsal moderate, rounded, with 8 to 13 rays. Anal short to very long (when depressed), with 8 to 12 rays. Caudal slightly emarginate, truncate, or lobate (*diabolis*). Pelvics usually present and 6- or 7-rayed in most species (range 0 to 9, absent in *diabolis* and frequently missing in *nevadensis* and *laciniatus*). Body rather chubby, usually short and deep in the males, slenderer in the females, the back elevated. Predorsal profile usually curved or angulate (long and straight in *bondi*). Intestine much longer than body, extensively convoluted. Sexual dimorphism commonly pronounced. Scales of nuptial males with contact organs or ctenii; those of females entire. Breeding season from May to September, probably throughout the year in warm-spring populations. Small fishes, generally between 30 and 50 mm. long but reaching 60 to 66 mm. in *nevadensis*, *variegatus variegatus*, and *bondi*, and only about 20 mm. in *diabolis*.

RANGE.—Eastern, southern, and western United States to northern South America and the West Indies; replaced by *Aphanius* in Europe, Africa, and Asia Minor to India and by *Tellia* in North Africa.

HABITAT.—Fresh, brackish, and salt waters, including saline desert warm springs. *Cyprinodon* prefers quiet water, as these small fishes are not adapted for swimming against a strong current. They select the backwaters in streams and do particularly well in springs, marshes, and sloughs or ponds.

The only other known New World genera of cyprinodont fishes having tricuspid teeth are *Floridichthys* of Florida and Yucatan, *Jordanella* of Florida, and *Garmanella* of Yucatan (Hubbs, 1936: 212–23). Of these, *Jordanella* and *Garmanella* can be immediately distinguished from *Cyprinodon* by the greater number of dorsal fin rays (15 to 18). *Floridichthys* differs from *Cyprinodon* in having: (1) 2 large, wide, regular scales in tandem order between the pelvic fins, the posterior 1 elongated; (2) the free edges of the scales about the head directed downward; (3) the anterior edge of squamation of the top of the snout formed of a single, large scale, leaving a rather broad naked strip anteriorly; (4) squamation heavy and very regular; (5) prepelvic scales fewer than 15; and in a few other details. Most of these characters were first pointed out by Myers (1935: 202–3) and have been discussed recently by Hubbs and Miller (1942: 203). Otherwise, *Floridichthys* is very similar to *Cyprinodon*, and the type species (*carpio*) was originally placed in that genus.

The Old World genera, *Aphanius* (formerly called *Lebia* or *Lebias*, a synonym of *Cyprinodon*), *Tellia* (which lacks pelvic fins), and *Anatolichthys*, resemble *Cyprinodon* in possessing tricuspid teeth. They differ markedly, however, in general shape, squamation, position of dorsal and anal fins, and

probably in other features. As represented by its genotype (*A. calaritanus*), *Aphanius* differs considerably from *Cyprinodon* in having (1) the pelvic fins inserted well in advance of the dorsal, which is more posterior; (2) the scales between the pelvic fins and the isthmus larger and weakly imbricated, only 9 to 12 between insertion of pelvics and isthmus; (3) the body more elongate; (4) the coloration different in both sexes; (5) the scales between the pelvic fins much as in *Floridichthys*; and in other details. I have examined specimens of *calaritanus*, *iberus*, *desioi*, and *darrorensis* (all deposited in the National Museum) and *dispar* (at the University of Michigan) and find these to be readily separable from *Cyprinodon* by some or all of the above characters. *Anatolichthys* (Kosswig and Sözer, 1945) is an aberrant form with degenerate squamation. These Old World types and *Cyprinodon* may have been derived independently through parallel evolution. There are numerous instances of similar ecologic types of animals that have developed in widely separated regions of the earth from unrelated stocks.

Despite the work of Garman (1895: 18, 29-34), Jordan (1917: 121), Hubbs (1926b: 16), and Myers (1931: 12; 1935: 303), species of *Aphanius* are still referred by some authors to *Cyprinodon*.

The kinds of *Cyprinodon* herein considered are the western American species: *macularius* (of the lower Colorado River basin), *nevadensis*, *diabolis*, *salinus*, and *radiosus*. The last 4 occur in the isolated basins of the Death Valley system, and *radiosus* is described for the first time in this contribution. The diagnostic characters distinguishing these 5 species are given in Table I and are based on an examination of large series of each species. Additional characters, based on measurements, of the 4 species inhabiting the Death Valley system, are given in Table XXVIII.

Cyprinodon macularius Baird and Girard

The systematic status, range, and synonymy of this species has been discussed recently in detail (Miller, 1943a). As now understood, *Cyprinodon macularius* is confined to the basin of the lower Colorado River, from southern Arizona to eastern Lower California, and the Sonoyta River of northern Sonora, Mexico. It is discussed herein only for comparative purposes, since this species and *nevadensis* have been confused for years. The principal characters distinguishing *macularius* from the other western species of *Cyprinodon* are set forth in Table I. These characters do not necessarily distinguish it from the many eastern species, to which *macularius* is probably more closely related than it is to those of the Death Valley system.

Cyprinodon nevadensis Eigenmann and Eigenmann

A preliminary account of this variable species (Miller, 1943a) indicated the specific distinctiveness of *nevadensis* and *macularius* and included a

detailed synonymy of *nevadensis*. The primary purpose of that paper was to clear up the confusion which existed concerning the validity and range of *nevadensis*. No attempt was made to analyze statistically the many populations of this species which are scattered throughout the springs and creeks of the Amargosa basin in eastern California and southwestern Nevada.

TABLE I
COMPARISON OF FIVE WESTERN SPECIES OF *Cyprinodon*

CHARACTER AND SPECIES	
Scale structure:	
<i>macularius</i>	Circuli with spinelike projections; interspaces between circuli without conspicuous reticulations (Miller, 1943a: Pl. V and Pl. VII, Fig. 1)
<i>nevadensis</i>	Circuli without projections; interspaces between circuli densely reticulate (Miller, 1943a: Pl. VI and Pl. VII, Fig. 2)
<i>diabolis</i>	Like <i>nevadensis</i>
<i>salinus</i>	Like <i>nevadensis</i>
<i>radiosus</i>	Like <i>nevadensis</i>
Size of scales:	
<i>macularius</i>	Large and regular; usually 26 in lateral series; average, about 28 around body
<i>nevadensis</i>	Like <i>macularius</i> but somewhat larger in many populations; usually 25 or 26 in lateral series; average, 24 around body
<i>diabolis</i>	Large and regular; usually 24 or 25 in lateral series; average, about 26 around body
<i>salinus</i>	Small and much crowded; usually 28 or 29 in lateral series; average, 39 or 40 around body
<i>radiosus</i>	Like <i>macularius</i> ; usually 26 or 27 in lateral series; average, about 28 around body
Tricuspid teeth:	
<i>macularius</i>	Central cusp broad, spatulate; outer cusps much narrower, more pointed, with shallow incision; shaft constricted basally (Fig. 2A)
<i>nevadensis</i>	Central cusp moderately to very much narrower, truncate or pointed; outer cusps relatively broader, more rounded, with deeper incision; shaft gradually tapering (Fig. 2B)
<i>diabolis</i>	Like some populations of <i>nevadensis</i> ; central cusp not much larger than lateral cusps, bluntly to sharply pointed
<i>salinus</i>	Outer face with prominent, median ridge; central cusp slightly to moderately broad, spatulate to bluntly pointed (Fig. 2C)
<i>radiosus</i>	Like <i>macularius</i> , but the central cusp truncate rather than spatulate
Prehumeral length* stepped into predorsal length:	
<i>macularius</i>	1.3 to 1.7, average 1.5
<i>nevadensis</i>	1.6 to 2.0, average 1.8
<i>diabolis</i>	1.4 to 1.6, average 1.5
<i>salinus</i>	1.7 to 1.9, average 1.8
<i>radiosus</i>	1.4 to 1.7, average 1.5 to 1.6
Body, shape and size:	
<i>macularius</i>	Large males very deep-bodied, females slenderer; maximum size about 60 mm. (standard length)
<i>nevadensis</i>	Like <i>macularius</i>
<i>diabolis</i>	Moderately slender-bodied; a dwarfed species, usually averaging only about 18 mm. (standard length)
<i>salinus</i>	Slender-bodied, especially the females; size as in <i>macularius</i>
<i>radiosus</i>	Like <i>macularius</i>

TABLE I (Cont.)

CHARACTER AND SPECIES

Male nuptial coloration:

<i>macularius</i>	Body intense light blue except over caudal peduncle and caudal fin, which are lemon yellow to brilliant yellow orange; black terminal band on caudal fin†
<i>nevadensis</i>	Body intense deep blue throughout; never yellowish on caudal peduncle and caudal fin; black terminal band on caudal fin
<i>diabolis</i>	Body bluish, the back dark brownish; dorsal with golden iridescence, anal whitish toward base; caudal fin with a black border
<i>salinus</i>	Body colored like <i>nevadensis</i> , the back with a purplish blue iridescence; black terminal band on caudal fin
<i>radiosus</i>	Body blue, the dorsal and anal fins with an orange amber margin; caudal fin with a broad milky or amber edge, black band absent

Position of dorsal

fin in males:

<i>macularius</i>	With few exceptions about equidistant between caudal base and tip of snout
<i>nevadensis</i>	With only rare exceptions, nearer caudal base than tip of snout
<i>diabolis</i>	Very much nearer caudal base than tip of snout
<i>salinus</i>	Much nearer caudal base than tip of snout
<i>radiosus</i>	Equidistant between caudal base and tip of snout

Pelvic rays:

<i>macularius</i>	Usually 7-7; fins large, always present
<i>nevadensis</i>	Usually 6-6; fins small, occasionally lacking on one or both sides
<i>diabolis</i>	0-0; with very rare exceptions, fins never developed
<i>salinus</i>	Usually 6-6; fins small, very rarely absent
<i>radiosus</i>	Almost always 7-7; fins intermediate in size between <i>macularius</i> and <i>nevadensis</i> , never absent

Vertical bars of females:

<i>macularius</i>	Generally disrupted, forming a discontinuous lateral band along the mid-line (Miller 1943a: Pls. I-II)
<i>nevadensis</i>	Generally continuous; no marked band, often very faint or absent (Pls. I, III-VI)
<i>diabolis</i>	Absent in mature adults (Pl. VII)
<i>salinus</i>	Like <i>nevadensis</i> (Pl. VIII)
<i>radiosus</i>	Like <i>macularius</i> (Pl. IX)

* Distance between tip of snout and posterior margin of humeral scale.

† This color description was based on populations from Salton Sea basin (California) and El Doctoro (Sonora, Mexico), about 66 miles south of Yuma, Arizona.

The present account treats of these isolated stocks in detail. Each subspecies and race is discussed in geographic sequence from the lower Amargosa River basin upstream. Of the 6 subspecies recognized, 4 occur in the lower Amargosa drainage, California, and 2 are confined to Ash Meadows, Nevada. All except the typical subspecies are described as new in this paper.

Cyprinodon nevadensis nevadensis Eigenmann and Eigenmann

(Pls. I and II)

DIAGNOSIS.—This subspecies is characterized by a deep, broad body, anterior pelvic fins, a deep and rather narrow scale with very dense and extensive reticulations (Pl. II), a high number of scale radii, and an average number of fin rays and scales for the species (Tables III, XIII-XXV).

DESCRIPTION.—In the high number of scale radii *nevadensis* is similar to both *C. nevadensis calidae* from Tecopa Hot Springs and *C. n. shoshone* from Shoshone Spring. It differs from *calidae* in having more anterior pelvics, a broader interorbital, a longer caudal peduncle, a deeper head and body, and in a few other characters (Table XIII). The sharp difference in the width of the interorbital space and the large average difference in position of pelvic fins can be utilized in obtaining ratios which afford a ready means of distinguishing *nevadensis* and *calidae*. These ratios were derived from stepping the width of the interorbital space into the prepelvic length, with results shown in Table II. An equal number of males and females was used, and since the character shows no sexual dimorphism the sexes are

TABLE II

WIDTH OF INTERORBITAL SPACE IN PREPELVIC LENGTH IN TWO SUBSPECIES OF
Cyprinodon nevadensis

Expressed in terms of the width of the interorbital space (between the bony rims at the level of the middle of the pupils) stepped into the distance between the insertion of the left (or right) pelvic fin and the tip of the lower jaw.

Subspecies	Prepelvic Interorbital															No.	Ave.
	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4		
<i>nevadensis</i>																	
Spring	1	2	3	3	2	5	2	2	...	...	...	...	...	...	...	20	4.4
Lake .....	...	1	2	4	3	4	4	2	...	...	...	...	...	...	...	20	4.4
<i>calidae</i>																	
V: 30: 42 ...	...	...	...	...	...	...	1	2	5	3	7	3	2	1	1	25	5.0
IX: 26: 42 ...	...	...	...	...	...	...	1	3	2	2	5	2	...	...	...	15	4.9
Totals*																	
<i>nevadensis</i>	1	3	5	7	5	9	6	4	...	...	...	...	...	...	...	40	4.4
<i>calidae</i> .....	...	...	...	...	...	...	2	5	7	5	12	5	2	1	1	40	4.9

* 93 per cent identifiable, based on a line of separation between 4.6 and 4.7.

treated together. The standard lengths for *nevadensis* varied from 31 to 44 mm.; average, 36 mm.; and for *calidae*, 31 to 46 mm.; average, 35 mm.

This subspecies is easily distinguished from *shoshone* by the greater width and depth of the body, and to a lesser extent, by the depth of the head. The caudal peduncle is much deeper also, particularly in the females (Table XIII). Expressed in thousandths of the standard length, the width of the body in males of *nevadensis* is 260–291, average, 274; in *shoshone* males, 215–246, average, 231; in *nevadensis* females, 245–288, average, 269; in *shoshone* females, 215–249, average, 229. Since these figures show virtually no overlap, it is possible to separate almost every specimen of these 2 subspecies.

Cyprinodon n. nevadensis differs further from *shoshone* (outlet population) in having a higher average number of pelvic rays, 5.74 rather than 5.04, fewer caudal rays, average 17.40 against 17.74, more scales between

TABLE III
COMPARISON OF NUMBER OF SCALE RADII IN TWO SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Number of Scale Radii																			No.	M ± σ _M	Length		Per Cent Identifiable*		
	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29			30	Range		Ave.	
<i>amargosae</i>																										
Death Valley ...	1	.....	1	5	9	10	7	2	4	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	43	16.33 ± .32	31-52	37	91
Amargosa Canyon .....	.....	.....	1	.....	5	4	4	3	7	3	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	30	17.73 ± .41	32-44	36	80
Tecopa .....	.....	.....	.....	3	4	5	7	5	2	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30	17.03 ± .35	31-41	36	87
<i>nevadensis</i>																										
Saratoga Springs .....	.....	.....	.....	.....	.....	.....	.....	1	5	6	4	9	8	12	7	2	2	1	.....	.....	2	59	22.98 ± .34	31-43	36	90
Saratoga Lake .....	.....	.....	.....	.....	.....	.....	1	1	2	2	4	7	6	3	2	1	1	.....	.....	.....	.....	30	22.13 ± .40	32-41	36	87
Totals																										
<i>amargosae</i>	1	.....	2	8	18	19	18	10	13	7	5	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	103	16.94 ± .21	31-52	36	87
<i>nevadensis</i> .....	.....	.....	.....	.....	.....	.....	1	2	7	8	8	16	14	15	9	3	3	1	.....	.....	2	89	22.70 ± .27	31-43	36	89

* Based on a line of separation between 19 and 20.

dorsal and pelvic fins, average 9.96 versus 9.39, and more scales around the body, average 25.09 in contrast to 23.24 (Tables XVII–XVIII, XX, XXIV).

In comparison with *amargosae*, the lower Amargosa River subspecies, *nevadensis* differs principally in scale characteristics. The reticulations on the exposed field are much more dense and extensive in *nevadensis*, and the scale is longer and narrower (Miller, 1943a: Pl. II and Pl. VI, Figs. 1–2). The radii are more numerous, as shown in Table III.

The pelvics are more anterior in position, especially in the females, than in *amargosae*, and the head averages longer. The width of the body is greater in males of *nevadensis* but is the same in the females of the 2 subspecies (Table XIII).

In the number around the body, the scales of *nevadensis* average fewer than in *amargosae*, but the counts overlap widely: 21 to 28, average, 25, in *nevadensis*, and 23 to 32, average, 27, in *amargosae*. The scales between dorsal and pelvic fins, the predorsal scales, and the caudal rays also average fewer in *nevadensis* (Tables XXIV, XX, XXII, XVIII).

HABITAT.—Saratoga Springs and the adjoining lake or lakes lie in the extreme southeastern corner of Death Valley National Monument at an elevation of about 215 feet. They are in T. 18 N., R. 5 E., San Bernardino County, California, less than three-eighths of a mile north of the flood channel of Amargosa River (see U. S. Geological Survey, Avawatz Mountains Quadrangle). These springs are among the largest in the California deserts and are well known to travelers in this region. There are 4 principal springs, but only the largest contains fish. This spring is a nearly circular pool about 30 feet in diameter and 4 or 5 feet deep. The bottom consists of quicksand continuously agitated here and there by circular patches of bubbling springs. The very clear water is largely devoid of vegetation in the central area, but sedge (*Scirpus americanus*), rush (*Juncus cooperi*), and tules (*Typha*) grow about the margins. Both *Ruppia maritima* and *Ceratophyllum demersum*, as well as scattered algae, grow in the pool, and bits of decaying vegetation lie over the sandy bottom.

The temperature of the main spring pool is remarkably constant from season to season and from year to year, usually varying between 28° and 29° C. (Table XLI). The greatest variation is 80° to 85° F. (26.5° to 29.5° C.), recorded by Mendenhall (1909: 47), and the highest temperature I have noted was 29.7° C. at 4:15 P.M. on May 16, 1939, with the air at 33° C.

This pool has an overflow to the north of many gallons per minute into another, larger pond which in turn drains north to form 2 or more shallow lakes. The combined lakes cover, at maximum height, an area of 10 to 15 acres, and are a few inches to about 1.5 feet deep along shore—probably not more than 4 or 5 feet deep anywhere. The bottom is grassy, with mud

and sand, and the shore is a grassy (*Distichlis*) meadow bordered locally by tules. These ponds are the breeding place for the single species of fish inhabiting Saratoga Springs and also provide a haven for migrating waterfowl. The fish keep to the shallow shores and move into the marshy meadows rather than into deeper water when alarmed. The lake temperature doubtless has a great range, fluctuating according to air temperatures, which vary seasonally from at least 50° to 120° F. On May 31, 1942, at 11:30 A.M., the water was 31.0° C.; air, 30.5° C.

The fact that we have never seen or collected any young fish in the main spring pool indicates that *Cyprinodon nevadensis nevadensis* spawns exclusively in the near-by lake or lakes. Literally millions of young fish were observed there in March, 1936, and R. G. Miller collected a large sample of both young and adults on May 31, 1942. The fact that this subspecies does not spawn in the constant temperature of its spring habitat is significant in an interpretation of any local variations in meristic characters. Time did not permit a careful comparison of small and large fish from each habitat and of young and large adults from the lake. Some such variations as have occurred in *Cyprinodon nevadensis amargosae* in Death Valley may also be discovered in this subspecies.

ETYMOLOGY.—Why this species was called *Cyprinodon nevadensis* is not clear, for the type locality, the only one recorded by Eigenmann and Eigenmann (1889), is in California.

Cyprinodon nevadensis amargosae, new subspecies

(Pl. III)

TYPES.—The holotype, a nuptial male 39 mm. in standard length, was collected by Ralph G. Miller in the Amargosa River near Acme, San Bernardino County, California, on May 30, 1942; U.M.M.Z. No. 141777. Nine hundred and thirty paratypes, U.M.M.Z. No. 139006, were collected with the holotype, and 1128 paratypes, U.M.M.Z. No. 139011, were taken on the same date about one-half mile upstream in San Bernardino County, just below the Inyo-San Bernardino County line. Large samples from the Amargosa River at Tecopa and in Death Valley are also referred to this subspecies, and each population is discussed in the following pages.

DIAGNOSIS.—*C. n. amargosae* is characterized by numerous scales, particularly in the count around the body (Table XXIV), which enables the identity of more than 70 per cent of the specimens of *amargosae* from any other population of *Cyprinodon nevadensis* examined, usually about 80 per cent or more. The low number of scale radii also distinguishes *amargosae* (Table III).

HABITAT.—This rather variable subspecies is confined to the Amargosa River in California. The only other region of permanent flow of this river

is in the headwater area about Beatty, Nevada, where only the minnow *Rhinichthys* has been found. Two permanent flows occur in the lower Amargosa. One begins shortly above Tecopa and continues through Amargosa Canyon for about 7 or 8 miles to the vicinity of Sperry (see U. S. Geological Survey, Avawatz Mountains Quadrangle). The second flow lies in Death Valley, northwest of Saratoga Springs, approximately 20 miles below Sperry, and is about 2 miles long.

The upper flow, between Tecopa and Sperry, traverses a narrow, steep-walled canyon in which the Amargosa River is deeply entrenched. In the canyon the stream maintains a fairly swift current between pools, over a bed of rocks, sand, and gravel. The water is clear but saline, and vegetation is rather abundant. The shore is bordered by abrupt, high sedimentary bluffs, and low trees and brush line the stream. The river is not much more than 6 feet wide, generally narrower, and is a few inches to about 4 feet deep. Pools are rather numerous not only in the river bed proper but also in areas reached only by flood waters. The largest are about 25 feet long and 15 feet wide. The bottom is mud and clay, and vegetation is usually absent. The water temperature on May 30, 1942, between 10:00 and 11:30 A.M., at the 2 places where fish were collected varied between 20° and 21° C.; the air ranged between 24° and 27° C.

The lower, Death Valley flow represents the terminal, perennial source of water in the Amargosa River and lies in T. 19 N., R. 4 E., in extreme northern San Bernardino County, California, at an elevation of about 100 feet (probably varying from 85 to 115 feet). The surface water rises in spring-like flows occupying marshy areas. These "springs" were named Valley Springs by Mendenhall (1900:46), who wrote:

Their waters are so salt as to be unfit for use. As the springs form a clear, sparkling stream for a short distance before the waters sink again, travellers are inclined to let their stock drink from them. . . . The ground about them appears to be firm, and in most places will support a light wagon, but it is really only a crust underlain by a deep ooze in which both men and teams may sink. . . . The springs are probably nothing more than a part of Amargosa River coming to the surface, as a rock reef extends across the valley half a mile below them.

Valley Springs constitute at least 4 saline springs which rise west of the main channel of Amargosa River in an area which was overgrown with reeds (*Phragmites*) when visited in April, 1939. Alkali bluffs and dunes, some 6 to 8 feet above the stream bed, border these source springs.

An analysis of the Valley Springs water, given by Mendenhall, indicates that the water of this flow is chemically similar to that at Salt Creek (Table LIII), Death Valley, about 75 miles to the northwest, except that carbonates and silica have a much higher concentration here.

The predominant plants along the river, which is generally less than 6

feet wide, are the pickleweed, *Allenrolfea occidentalis*, and salt grass, *Distichlis spicata*. In the stream itself there is virtually no vegetation, and the bottom is of fine silt, sand, mud, and clay. Pools 2 to 4 feet deep occur all along the river, and the current is moderate to fairly swift.

Water temperature variations are great, as at Salt Creek. The probable yearly range is at least from 10° to 38° C. A temperature of 37° C. was recorded at 1:45 P.M. on August 4, 1939, with the air temperature at 41° C. As water temperatures rather closely follow those of the air, and the latter are known to reach 49° C. during the summer, the water temperature doubtless goes above 38° C. locally. In severe winters air temperatures may fall close to freezing.

The daily fluctuation, especially in summertime, is also great, as indicated by a reading of only 19° C. at 6:15 A.M. on August 30, 1940. Early morning water temperatures during this season of the year commonly fall under 21° C., but afternoon recordings are rather consistently around 31° C. or more. It should further be pointed out that readings at a given time vary according to whether they are taken in shallow water, sluggish side channels, or near the bottom of the deeper pools. There is no indication that large fish endure local temperatures much above 31° C., but young fish probably remain in water of higher temperature for at least several hours a day during the hottest part of the summer. Such a temporary exposure cannot be compared with the yearly conditions in warm springs of the region, but may well explain local responses in meristic characters, such as those discussed below.

This section of Amargosa River is subject to heavy floods during winters of exceptional rainfall. Such a flood in the winter of 1936-37 carried a continuous stream of water from Ash Meadows, Nevada, to an unknown distance north of this terminal flow of the river. Such disturbances probably account, in part at least, for the virtual absence of vegetation in the stream at this point.

The country intervening between these 2 flows is a barren desert, and the 2 flows are connected only during floods. The fish in Amargosa Canyon are probably isolated by falls from those to the north around Tecopa, as Bailey (1902: fig. opposite p. 76) pictured a falls near the head of the canyon. Individuals, however, apparently pass regularly downstream over the barrier, for the samples from Tecopa and Amargosa Canyon are very similar (Tables XIII-XXIV).

There is no tangible evidence that members of the large population of *Cyprinodon* in Amargosa Canyon pass downstream during floods to the Death Valley flow. The counts for the 3 samples (April, 1939, June, 1939, and May, 1942) from Death Valley are rather consistent. When they disagree the shift is rarely in the direction of the upstream stocks (Table IV).

TABLE IV
 COMPARISON OF FIN-RAY AND SCALE COUNTS IN TWO RACES
 OF *Cyprinodon nevadensis amargosae*
 In the enumeration of pelvic rays both fins were counted.

Race	Dorsal Rays				No.	$M \pm \sigma_M$
	9	10	11	12		
Death Valley						
April 8, 1939	10	31	9	.....	50	9.98 ± .09
June 4, 1939	26	67	7	.....	100	9.81 ± .05
May 31, 1942	13	33	4	.....	50	9.82 ± .08
Amargosa Canyon						
In canyon						
May 30, 1942*	5	66	28	1	100	10.25 ± .06
Tecopa						
May 16, 1939	1	31	16	2	50	10.38 ± .08
May 30, 1942	2	33	15	.....	50	10.26 ± .07
Totals						
Death Valley race	49	131	20	.....	200	9.85 ± .04
Amargosa Canyon race ..	8	130	59	3	200	10.29 ± .04

Race	Pelvic Rays									No.	M	
	0	1	2	3	4	5	6	7	8			9
Death Valley												
April 8, 1939	4	.....	.....	.....	1	15	74	5	.....	1	100	5.67
June 4, 1939	26	1	3	2	1	37	180	9	.....	1	260	5.21
May 31, 1942	1	.....	.....	.....	1	23	72	3	.....	.....	100	5.72
Amargosa Canyon												
In canyon												
May 30, 1942*	2	.....	.....	.....	3	19	167	9	.....	.....	200	5.86
Tecopa												
May 16, 1939 .....	.....	1	.....	.....	3	18	70	7	1	.....	100	5.80
May 30, 1942 .....	.....	.....	.....	1	3	11	81	4	.....	.....	100	5.84
Totals												
Death Valley race ..	31	1	3	2	3	75	326	17	.....	2	460	5.41
Amargosa Canyon race	2	1	.....	1	9	48	318	20	1	.....	400	5.84

Race	Caudal Rays							No.	$M \pm \sigma_M$
	15	16	17	18	19	20	21		
Death Valley									
April 8, 1939 .....	.....	2	11	14	13	9	1	50	18.38 ± .17
June 4, 1939 .....	.....	1	3	25	29	38	4	100	19.12 ± .10
May 31, 1942 .....	.....	1	8	19	11	8	3	50	18.52 ± .17
Amargosa Canyon									
In canyon									
May 30, 1942*	1	5	20	42	21	10	1	100	18.11 ± .11
Tecopa									
May 16, 1939 .....	.....	5	10	21	10	3	1	50	17.98 ± .16
May 30, 1942 .....	.....	4	8	23	9	6	.....	50	18.10 ± .15
Totals									
Death Valley race .....	.....	4	22	58	53	55	8	200	18.79 ± .08
Amargosa Canyon race	1	14	38	86	40	19	2	200	18.07 ± .08

* Based on 2 collections taken about one-half mile apart.

TABLE IV (Cont.)

Race	Dorsal to Pelvic Scales					No.	$M \pm \sigma_M$
	9	10	11	12	13		
Death Valley							
April 8, 1939 .....	.....	12	32	4	1	49	10.88 \pm .09
June 4, 1939 .....	.....	14	26	6	.....	46	10.83 \pm .09
May 31, 1942 .....	.....	14	20	12	4	50	11.12 \pm .13
Amargosa Canyon							
In canyon							
May 30, 1942*	2	67	30	1	.....	100	10.30 \pm .05
Tecopa							
May 16, 1939	6	33	11	.....	.....	50	10.10 \pm .08
May 30, 1942	2	29	18	1	.....	50	10.36 \pm .08
Totals							
Death Valley race .....	.....	40	78	22	5	145	10.94 \pm .06
Amargosa Canyon race	10	129	59	2	.....	200	10.27 \pm .04

Race	Dorsal to Anal Scales				No.	$M \pm \sigma_M$
	8	9	10	11		
Death Valley						
April 8, 1939	2	22	19	7	50	9.62 \pm .11
June 4, 1939 .....	.....	22	17	11	50	9.78 \pm .11
May 31, 1942 .....	.....	26	15	9	50	9.66 \pm .11
Amargosa Canyon						
In canyon						
May 30, 1942*	1	70	29	.....	100	9.28 \pm .05
Tecopa						
May 16, 1939 .....	.....	35	14	1	50	9.32 \pm .07
May 30, 1942 .....	.....	35	14	1	50	9.32 \pm .07
Totals						
Death Valley race	2	70	51	27	150	9.69 \pm .06
Amargosa Canyon race	1	140	57	2	200	9.30 \pm .03

Race	Predorsal Scales									No.	$M \pm \sigma_M$
	16	17	18	19	20	21	22	23	24		
Death Valley											
April 8, 1939	1	2	8	6	9	10	10	3	1	50	20.22 \pm .26
June 4, 1939 .....	.....	4	10	12	9	9	3	3	.....	50	19.60 \pm .23
May 31, 1942	1	6	16	29	29	13	5	1	.....	100	19.43 \pm .13
Amargosa Canyon											
In canyon											
May 30, 1942* .....	.....	14	30	26	14	11	4	1	.....	100	18.94 \pm .14
Tecopa											
May 16, 1939 .....	.....	3	22	11	9	3	1	.....	1	50	18.90 \pm .19
May 30, 1942 .....	.....	6	17	14	8	3	2	.....	.....	50	18.82 \pm .18
Totals											
Death Valley race	2	12	34	47	47	32	18	7	1	200	19.67 \pm .11
Amargosa Canyon race .....	.....	23	69	51	31	17	7	1	1	200	18.90 \pm .10

* Based on 2 collections taken about one-half mile apart.

TABLE IV (Cont.)

Race	Circumference of Body Scales										No.	$M \pm \sigma_M$
	23	24	25	26	27	28	29	30	31	32		
Death Valley												
April 8, 1939	.....	.....	.....	2	8	17	11	9	3	.....	50	28.52 \pm .17
June 4, 1939	.....	.....	1	6	24	38	43	14	3	1	130	28.35 \pm .10
May 31, 1942	.....	1	2	1	8	17	11	7	2	1	50	28.30 \pm .21
Amargosa Canyon												
In canyon												
May 30, 1942*	.....	7	19	37	42	30	11	4	.....	.....	150	26.79 \pm .11
Tecopa												
May 16, 1939	1	5	12	13	13	5	1	.....	.....	.....	50	26.02 \pm .18
May 30, 1942	1	7	5	11	13	7	4	2	.....	.....	50	26.50 \pm .24
Totals												
Death Valley												
race .....	.....	1	3	9	40	72	65	30	8	2	230	28.37 \pm .08
Amargosa Can-												
yon race	2	19	36	61	68	42	16	6	.....	.....	250	26.58 \pm .09

* Based on 2 collections taken about one-half mile apart.

Furthermore, the cyprinid *Rhinichthys osculus* is common in Amargosa Canyon, but we have not taken this genus in the Death Valley flow. The latter flow, however, has not been fully investigated, and this fish may occur there. Even if *Rhinichthys* should prove to be absent in Death Valley, it would not follow that *Cyprinodon* is not washed downstream from Amargosa Canyon, since the minnow can certainly withstand floods far better than can *Cyprinodon*. In addition, the waters of Amargosa River in Death Valley may be chemically intolerable to *Rhinichthys*.

VARIATION.—The 2 rather distinct races (Table IV) of *amargosae* further testify to a lack of mixing between the populations of the upper and lower flows of the lower Amargosa. The Death Valley race averages significantly higher in number of caudal rays, dorsal to pelvic scales, dorsal to anal scales, predorsal scales, and body circumference scales. The dorsal fin rays, however, average fewer. The lower average for pelvic rays is discussed below. The racial distinctness of the 2 stocks (the Death Valley and Amargosa Canyon races) can be well expressed by using a character index for certain fin and scale counts (Table V). In certain measurements the Death Valley race also stands out. The distance between anal origin and caudal base is greater, the caudal peduncle is longer in females, and the mouth is somewhat narrower (Table XIII). Those 2 races are on the borderline of the subspecies level, for the percentage of specimens identifiable (Table V) is close to 80—the degree of differentiation which may be regarded as indicative of subspecific status.

An unusual contrast in certain measurements appears when comparison is made between the males in 2 collections of the Death Valley race (Table

TABLE V

FREQUENCY DISTRIBUTION OF THE CHARACTER INDEX FOR CERTAIN FIN-RAY AND SCALE COUNTS OF *Cyprinodon nevadensis amargosae*
 The index is derived by adding the caudal rays and the dorsal to pelvic, predorsal, and body circumference scales.

Race	Character Index															No.	$M \pm \sigma$					
	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80			81	82	83	84	85
Death Valley	1	1	2	3	.....	7	5	8	10	1	3	4	2	2	.....	49	78.10 ± .43
April 8, 1939	2	1	.....	3	5	5	4	11	9	1	3	1	1	2	.....	46	77.30 ± .38
June 4, 1939	2	2	.....	3	2	6	12	7	5	5	1	.....	.....	2	.....	50	77.28 ± .49
May 31, 1942	1	.....	.....	.....	.....	.....	.....	.....	3	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Amargosa Canyon
In canyon
May 30, 1942	1	2	2	2	6	5	6	6	10	3	3	2	1	1	.....	.....	.....	.....	.....	50	73.46 ± .41
May 30, 1942*	1	.....	3	2	4	10	3	8	5	4	5	2	1	1	1	.....	.....	.....	50	74.78 ± .42
Tecopa
May 16, 1939	7	8	10	4	3	4	2	1	.....	2	.....	.....	.....	.....	.....	49	72.96 ± .39
May 30, 1942	1	.....	6	7	5	3	9	5	1	2	6	2	.....	2	.....	.....	.....	.....	50	73.78 ± .46
Totals
Death Valley race	1	.....	.....	.....	.....	5	4	2	9	7	18	21	26	24	7	7	5	3	4	2	145	77.57 ± .26
Amargosa Canyon race	2	5	6	14	22	22	29	22	26	13	11	14	5	4	3	1	.....	.....	.....	199	73.75 ± .22

Statistical Computations on Totals

	$M \pm \sigma$	\bar{V}	t	Per Cent Identifiable
Death Valley race	77.57 ± .26	3.96	11.4	81
Amargosa Canyon race	73.75 ± .22	4.12	.....	74

* Collected about one-half mile upstream from other collection.

† Based on a line of separation between 75 and 76.

VI). The males collected on April 8, 1939, differ from those taken on May 31, 1942, in having much larger dorsal and anal fins and in being more slab-sided than is usual in this subspecies. These differences are probably directly correlated with breeding conditions, for the 1939 males have high nuptial colors whereas those taken in 1942 do not. Moreover, the females do not have corresponding features, for the dorsal and anal fins do not become noticeably enlarged during the breeding season in that sex. Smaller males collected in April also have big dorsal and anal fins. The extreme slab-sided bodies of the larger males are likely due to prolonged intense activity on the spawning site and to cessation of feeding. The smaller males were not so slab-sided. Some condition necessary for the production of high males was evidently effective in April, 1939, but not in May, 1942.

TABLE VI

COMPARISON OF CERTAIN MEASUREMENTS FOR TWO COLLECTIONS OF MALES OF
C. n. amargosae FROM DEATH VALLEY

The standard lengths are 34 to 44, with an average of 37 for the first collection and of 38 for the second.

Date	Length of Dorsal	Length of Anal	Body Width	No.
	Range (Ave.)	Range (Ave.)	Range (Ave.)	
April 8, 1939	303-339 (318)	233-257 (245)	220-259 (239)	10
May 31, 1942	284-306 (293)	216-247 (226)	236-279 (262)	10

The factors determining a peak nuptial condition probably operate on a delicate balance, and since this flow of the Amargosa River is subject to severe washouts, variability in the environmental factors is not unexpected.

Another unusual situation was found in the Death Valley race of *Cyprinodon nevadensis amargosae*. The larger and smaller adults collected in June, 1939 (U.M.M.Z. No. 133177), showed significant differences in certain meristic characters. The number of rays of the dorsal, pelvic, and caudal fins, and the number of lateral and body scales, all averaged fewer in the large adults than in the small adults (Table VII). This exceptional situation may be explained as follows. The large adults, probably about 1.5 to 2 years old (with 1 to 2 winter marks on the scales), developed in an isolated pool cut off from the main river. Such pools are common and by their desiccation thousands of fish are killed each year. In such a pool these fish may have been subjected to a high temperature during the critical stage of development when certain meristic characters were determined. All of the counts average fewer in this 1 population than they do for the Death Valley race as a whole (Tables XIV-XXIV) and some evidence indicates that low counts result from development under warm temperatures (see the section "Relation of Characters to Environ-

ment," pages 129-48). On the other hand, the small adults, which were very probably born early in the spring (there is no winter mark on the scales), presumably developed at a lower temperature than the average, since most of the young are born later in the spring and summer. The cooler water may have directly affected the meristic characters, resulting in an increased number. All of the averages for these fish are higher than they are for the race as a whole (Tables XIV, XVII-XIX, XXIV).

TABLE VII

COMPARISON OF CERTAIN FIN-RAY AND SCALE COUNTS OF LARGE AND SMALL ADULTS OF THE DEATH VALLEY RACE OF *C. n. amargosae* COLLECTED JUNE 4, 1939
Standard length of large adults, 30-45 mm.; small adults, 22-27 mm.

Age Group	Dorsal Rays									No.	$M \pm \sigma_M$	t
	9			10			11					
Large adults	15			33			2			50	$9.74 \pm .07$	1.3
Small adults	11			34			5			50	$9.88 \pm .08$	
	Pelvic Rays											
	0	1	2	3	4	5	6	7	8	9		
Large adults	26	1	3	2	1	25	98	3	.....	1	160	4.75
Small adults .....	.....	.....	.....	.....	.....	12	82	6	.....	.....	100	5.94
	Caudal Rays											
	16		17		18		19		20		21	
Large adults	1		3		14		19		12		1	
Small adults .....	.....		.....		11		10		26		3	
	Lateral Scales											
	25		26		27		28					
Large adults	17		57		5		1		80	$25.87 \pm .06$	5.5	
Small adults	1		28		19		2		50	$26.44 \pm .09$		
	Body Scales											
	25	26	27	28	29	30	31	32				
Large adults	1	5	18	23	25	8	.....	.....	80	$28.13 \pm .13$	2.7	
Small adults .....	.....	1	6	15	18	6	3	1	50	$28.70 \pm .17$		

ETYMOLOGY.—This subspecies is named *amargosae* after the Amargosa River, in which it lives.

Cyprinodon nevadensis calidae, new subspecies

TYPES.—The holotype, a nuptial male 39 mm. in standard length, was seined by Ralph G. Miller on May 30, 1942, from the outlet ditch of South Tecopa Hot Spring, one-fourth to one-half mile below the spring source, Inyo County, California; U.M.M.Z. No. 141778. One hundred and forty-five paratypes, U.M.M.Z. No. 139014, were taken with the holotype, and 34

additional paratypes, U.M.M.Z. No. 139015, were taken at the same time about 75 yards below the spring source.

DIAGNOSIS AND COMPARISONS.—A large scaled form of *C. nevadensis* with a rather narrow interorbital and short caudal peduncle. *C. n. calidae* resembles *C. n. shoshone* in having large scales, but differs strikingly from that subspecies in the much wider body (Tables XIX–XXIV, XIII). As has been shown by Table II the new subspecies can readily be separated from *C. n. nevadensis* on the basis of the ratio between the width of the interorbital and the prepelvic length. In *calidae* the interorbital is narrower, and the pelvic fins are more posterior in position. The new subspecies is easily distinguished from *amargosae* by the much larger scales, especially those around the body (Tables XIX–XXIV).

HABITAT.—The Tecopa Hot Springs lie in the southern part of T. 21 N., R. 7 E., about 7 miles south of Shoshone, Inyo County, California, at an elevation of approximately 1400 feet. They are tributary to the Amargosa River, which is generally a dry channel at this point.

The 2 hot springs (Pl. XII, Fig. 1), designated as the North and South Tecopa Hot Springs, rise about 10 yards apart at the base of a steep hill on the east side of the road leading north from Tecopa. The 2 have a combined flow of approximately 225 gallons a minute (Waring, 1915: 137). The northern spring is warmer, 42.2° to 42.8° C. according to our readings and those given by Waring. The southern spring varies between 41.1° and 42.2° C.

No fish occur in the spring sources or in the small enclosed bathing pools just below. They first appear immediately below the bathhouse of the southern spring, but are not present in the upper outflow of the northern spring. Their absence there is presumably due to a low but impassable waterfall about 100 yards below the source. In September, 1942, fish were present in this outflow up to 200 feet below the base of this barrier.

The 2 springs discharge separately to the west over a white, barren alkali flat, and finally unite, somewhat less than a mile distant, to form a marshy area, thick with tules, adjacent to the bed of Amargosa River. Fish in the marshy area probably cannot move up the outlet of South Tecopa Hot Spring, for the water from this spring is carried to a water tower on the Tonopah and Tidewater Railroad. The gradient of water temperature and abundance of fish in these 2 springs is outlined in Table VIII.

The outlet ditch of South Tecopa Hot Spring is about 2 feet wide and varies in depth from a few inches to 1 foot. The bottom consists of silt, rocks, and rubbish, with much thick green algae locally. The water is clear, sulfurous, and easily roiled, and the current is moderate to swift, for the fall, in less than a mile, is at least 80 feet. Much of this drop takes place, however, below a settling box (over 800 yards below the spring source), where the railroad has built an intake to supply water for a water tower.

The chemical content of the water of these 2 springs is very similar. Both are high in boron, low in calcium and magnesium, and rather salty (Table LIII).

South Tecopa Hot Spring is designated as the type locality of *C. n. calidae*.

ABERRANT SERIES—On September 26, 1942, a sample of *Cyprinodon nevadensis* also was obtained from a pool in the course of the outlet of North Tecopa Hot Spring. This series, comprising 199 individuals

TABLE VIII
CORRELATION BETWEEN TEMPERATURE AND ABUNDANCE OF FISH IN TECOPA HOT SPRINGS

Specific Location	Abundance of Fish	Temperature	Date
South Tecopa Hot Spring:			
Source	None	42.0° C.*	May 30, 1942
		41.3° C.	Sept. 26, 1942
3 feet below bath house	Scarce	40.0° C.	Sept. 26, 1942
(10 yards below source)			
25 yards below source	Uncommon	39.0° C.	Sept. 26, 1942
60 yards below source	Few	38.5° C.	May 30, 1942
85 yards below source	Fairly common	36.5° C.	May 30, 1942
140 yards below source	Abundant	36.0° C.	Sept. 26, 1942
400 yards below source	Abundant	36.0° C.	Sept. 26, 1942
500-700 yards below source	Common	34.8°-33.0° C.	Sept. & May, 1942
800 yards below source	Scarce	32.5° C.	Sept. 26, 1942
North Tecopa Hot Spring:			
Source	None	42.5° C.*	May 30, 1942
		42.1° C.	Sept. 26, 1942
15 yards below source	None	41.7° C.	Sept. 26, 1942
110 yards below source	None	38.1° C.	Sept. 26, 1942
(waterfall)			
175 yards below source	3 seen	Not taken	Sept. 26, 1942
300 yards below source	Abundant	32.0° C.	Sept. 26, 1942
(pool in tules)			

* The source temperatures were given by Waring (1915: 137) as 108° F. (42.2° C.) for South Tecopa Hot Spring and as 109° F. (42.8° C.) for North Tecopa Hot Spring.

(U.M.M.Z. No. 140459), was seined about 300 yards below the source of North Tecopa Hot Spring, from a circular pool about 8 feet in diameter and 3 feet deep and surrounded by a dense growth of *Scirpus*. On the date of collection, the water was clear, sulfurous, and easily roiled because the bottom was of fine silt. The temperature was 32.0° C. Algae were the only plants noted in the pool.

The fish of this sample are abnormal in appearance. They are tentatively referred to *C. n. calidae*, but are not designated as types. Many are thin and emaciated with disproportionately enlarged heads. No reliable measurements could be made. The meristic characters show 2 noteworthy differences in comparison with the specimens from South Tecopa Hot Spring.

The number of pelvic fin rays in the abnormal series is greatly reduced—the average is 3.99 rather than 5.33; whereas the caudal rays average significantly more—18.02 versus 17.24 for South Tecopa Hot Spring (Tables XVII–XVIII). The cause for these differences and the abnormalities in body proportions may be associated with high temperature and isolation. A genetic, rather than direct environmental basin is suggested, for the South Tecopa Hot Spring fish inhabit water of even higher temperature, but do not show a corresponding loss in pelvic fins or an increase in number of caudal rays. The sample taken in September, 1942, from South Tecopa Hot Spring, has some of the abnormalities in body form exhibited by the aberrant series, suggesting that high temperature may play a direct role in determining the proportions.

POPULATION DISTRIBUTION.—Nine half-grown to adult specimens of both sexes were caught just below the 3-foot vertical concrete barrier of the bath house of South Tecopa Hot Spring in water having a temperature of 40.0° C. To my knowledge this is the second highest recorded temperature in which fish have been taken (see pages 130–31). Most of this population of *Cyprinodon nevadensis calidae* occurs about 125 to 350 yards below this barrier at a temperature of about 36.0° C. Here the fish were very abundant in May and September, 1942, and were represented by all size and age groups. Scattered individuals were seen all along the ditch, numbers of them in water having a temperature of 36.5° to 38.5° C.

ETYMOLOGY.—The name *calidae* is the genitive of *calida*, meaning “warm spring.”

Cyprinodon nevadensis shoshone, new subspecies

(Pl. IV)

TYPES.—The holotype is a mature male, 43 mm. in standard length, collected on January 9, 1939, by Robert R. and Ralph G. Miller from the outlet of Shoshone Spring (just above or below the highway), near Shoshone, Inyo County, California; U.M.M.Z. No. 141780. Six hundred and fifty-six paratypes, U.M.M.Z. No. 132936, were collected with the holotype.

DIAGNOSIS AND COMPARISONS.—A large-scaled subspecies of *C. nevadensis* with a slab-sided and rather slender body, and with the arch of the ventral contour much less pronounced than that of the dorsal contour (Pl. IV). In the narrow body *shoshone* differs from all of the subspecies in the lower Amargosa River basin (Table IX). The range of figures for *shoshone* definitely overlaps only those for the males of *amargosae*, and that subspecies is readily distinguished from *shoshone* by a much greater number of scales around the body (Table XXIV). In the light of the experience with exceptionally thin-bodied males collected from the Amargosa River in Death Valley (pages 33–35), the possibility that the specimens measured for *shoshone* were simi-

larly emaciated was disproven on examination of all material available (collections of 1891, 1930, 1936, 1939, and 1942). Not only does this material show the character, but measurements on larger (average 38 mm.) and smaller (average 32 mm.) males and larger (average 35 mm.) and smaller (average 32 mm.) females gave almost identical results. A narrow body is definitely a consistent trait in this subspecies, as it is to a lesser extent in the subspecies next to be described. As compared with the other subspecies of the lower Amargosa basin, *shoshone* further differs in having a lower average number of several fin-ray and scale counts, but is equaled or closely approached in these counts by *calidae*, its nearest geographic relative (Tables XIV, XVII, XXI, XXIII-XXIV).

HABITAT.—Shoshone Spring and its outlet creek lie about 700 yards north of Shoshone, Inyo County, California. The spring source is at an elevation of approximately 1700 feet, but the end of the creek, less than a

TABLE IX
COMPARISON OF BODY WIDTH IN SUBSPECIES OF *Cyprinodon nevadensis*
IN THE LOWER AMARGOSA RIVER BASIN

Subspecies	Body Width				Standard Length
	Males		Females		
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)
<i>amargosae</i>	231-279 (256)	35	243-294 (265)	35	28-44 (35)
<i>nevadensis</i>	260-291 (274)	20	245-288 (269)	20	34-45 (40)
<i>calidae</i>	240-301 (269)	10	248-303 (267)	10	32-44 (35)
<i>shoshone</i>	215-246 (231)	20	215-249 (229)	20	28-44 (34)

mile distant, is below 1600 feet. The spring rises about 175 yards above state Highway 127, on the east slope of a rocky, lava hill. This headwater area is hidden among a dense growth of mesquite. The outflow forms a small swiftly flowing stream in its upper reaches, but decreases in velocity and increases in width as it enters the meadowland below. Adjacent to the highway is a concrete swimming pool into which part of the stream is often diverted.

The temperature, from a short distance below the highway to the source region, varies between 28° and 34° C. according to records made over a period of years (Table XLI). These data indicate a slight seasonal fluctuation in temperature as well as a temperature gradient from the source spring to the lower reaches of the creek. The average temperature at which the bulk of the fish population occurs (just above and below the highway) is probably about 31.0° C. or 31.5° C. The temperature of 82° F. (27.8° C.) recorded by Wales (1930: 62) seems a little low, considering that my minimum reading of 29.0° C. was observed at a time, January 8, 1939, when a low reading would be expected (air temperature, 5.0° C.).

In the area just above and below the highway, the stream is about 3 to 6 feet wide, and is bordered by *Typha*, mesquite, and meadowland and desert flat. The clear water, up to 2 feet deep, maintains a slight to moderately strong current, with many side pockets of nearly still water. The chief aquatic plant is green algae. The bottom is of fine gravel and fine sand, with a thin coating of silt which readily roils the water when one walks over the bottom.

On June 4, 1939, I traced the creek downstream to the dry bed of the Amargosa River. The creek is fully three-quarters of a mile long, and on this date the last 300 yards were dry, for the water sank into the big meadow just east of Shoshone. In wintertime, during rains, the creek presumably continues as a surface flow to the river, which, at such a time, would also contain water. Along the lower course of the creek I saw numbers of young fish. No record was made of the decrease of water temperature in this section.

In the part of the creek well above the highway there appear to be only 2 holes close together where fish can exist out of the swift current. The upper and larger one of these is known locally as "Squaw Hole." This pool, reinforced by a rock dam and wooden planks, is near the source of Shoshone Spring, about 160 yards above the highway. This is the place designated as the "source" sample in this account. The spring source is some 50 feet above, but is enclosed and contains no fish life. In Squaw Hole the water is clear, the bottom muddy, with overhanging banks, and the shore consists of dense mesquite thickets. The pool is circular, about 3 feet in diameter and 1 to 2 feet deep. On May 29, 1942, R. G. Miller recorded a water temperature of 34.0° C. at 6 P.M. (air, 30° C.), and on September 26, 1942, I found it to be 33.3° C. at 3 P.M. (air, 31.7° C.). Whether a natural pool in the swift outlet of Shoshone Spring occurred at or near this point prior to the artificial structure is not positively known, but presumably it did.

In this upper section of the creek, a few fish were also taken from an old Indian washing hole, formerly covered with boards, about 50 feet downstream from Squaw Hole. We have not carefully examined the area of creek intervening between this pool and the head of the concrete swimming pool about 130 yards below. This region was densely covered by thorny mesquite, and since no knowledge of the remarkable differences (described below) between the fish of the source and outlet regions were known when the field work was conducted, no attempt was made to determine whether fish occurred in the intervening stretch of the creek. However, the decrease in gradient is rapid here, and unless more holes are present it is not likely that fish inhabit the swift creek.

Shoshone Spring is less saline than other springs in the region and has a comparatively low boron content. It is rather high in calcium and magnesium (Table LIII).

As suggested by Wales (1930: 62), Shoshone Spring is the locality listed by Gilbert (1893: 233) under the name of Medbury Springs. The late Vernon Bailey, one of the members of the Death Valley Expedition and the person who collected fish at Shoshone Spring, wrote to Joseph Grinnell on April 28, 1917, that the location of Medbury Spring is about 10 miles north of the Amargosa Borax Works. According to Thompson (1929: 575), the latter are approximately 1.5 miles southwest of Zabriskie (see U. S. Geological Survey, Avawatz Mountains Quadrangle). Here, Bailey wrote, "there was an old adobe house built by Nelse Medbury, where I camped for

TABLE X
FREQUENCY DISTRIBUTION OF THE CHARACTER INDEX FOR CERTAIN SCALE COUNTS
IN TWO RACES OF *Cyprinodon nevadensis shoshone*

The index is derived by adding the following scale counts: predorsal, around caudal peduncle, and around body.

Locality	Character Index for Scale Counts															
	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Shoshone Spring																
Source	1	2	9	8	9	6	4	6	5	4	.....	.....	.....	.....	.....	.....
Outlet .....	.....	1	2	.....	.....	1	3	4	14	17	12	11	7	4	2	2
	Statistical Computations															
	No.		$M \pm \sigma_M$		V		t		Per Cent Identifiable*							
Shoshone Spring																
Source	54		52.67 \pm .33		4.55		10.9		83							
Outlet	80		57.45 \pm .29		4.45				86							

* Based on a line of separation between 55 and 56.

the night. . . . This spring came out of the base of a black lava hill on the west side of Amargosa River, and a large stream of water—92°—flowed from it and spread out over a considerable area of ground that was covered with *Scirpus olneyi*, cat-tails, reeds, arrow-weed, and other plants of that nature. It was in the midst of a barren alkali-crusted area." This description leaves no doubt that Medbury Spring is the old name for Shoshone Spring.

RACIAL DIFFERENTIATION.—In the analysis of the samples of this subspecies collected from the source region of Shoshone Spring and from the outlet, just above to just below the highway, striking differences in meristic characters came to light. In comparison with the fish collected in the outlet, those from the source average fewer in dorsal, anal, pectoral, and pelvic rays, particularly the latter (average 1.15 in contrast to 4.98). The caudal

rays, however, average slightly higher in the source than in the outlet samples. All of the scale counts average less at the source, particularly those before the dorsal, around the caudal peduncle, and around the body (Tables XIV-XXIV). A clear-cut demonstration of the reduced count for the predorsal, caudal peduncle, and body scales is presented by the character index in Table X.

These data show that the differences are highly significant and that it is possible to identify more than 80 per cent of the individuals taken from each habitat. Ordinarily, such a separation warrants subspecific recognition. However, in this comparison the wide overlap in the index and the lack of detailed information concerning the ecology and distribution of each race cautions me against giving the source stock nomenclatural recognition. As pointed out in the habitat description, the region between the source and outlet collections has not been fully investigated. Perhaps intermediate stocks may occur there or this stretch of the creek (about 150 yards in length) may be barren of fish life.

The relative uniformity of the atypical race which occurs near the spring source is indicated by the counts obtained for the 13 fish collected there in 1936 and the 50 specimens taken in 1942. The averages for fin-ray and scale counts of these 2 samples, respectively, are as follows: dorsal, 9.46 and 9.56; anal, 9.77 and 9.79; pectorals, 15.81 and 15.86; pelvics, 0.38 and 1.35; caudal, 17.69 and 18.02; lateral scales, 25.15 and 25.12; dorsal to anal, 8.46 and 8.42; predorsal, 16.15 and 17.07; around peduncle, 14.23 and 14.39; and around body, 20.69 and 21.59. Three pronounced differences between the samples are evident: caudal rays, predorsal scales, and body circumference scales. The lower average for the caudal rays is probably due in part to the small size of some of the 13 individuals, since the rays become fully differentiated in this fin later in development than in the other fins. At least 2 of the original counts for this fin are definitely questionable. The lower average for predorsal scales was brought about in part by the difficulty of obtaining an accurate count on small specimens and also by the fact that at least 4 (or nearly one-third of the specimens collected in 1936) had some of these scales rubbed off. The fewer number of body scales is very likely influenced by an error in counting due to the small size of the fish. One of the 13 counts is definitely questionable. The difference in number of pelvic rays is attributed to the small size of the 1936 collection. Apart from these variations, the similarity of the 2 samples, taken about 5½ years apart, is rather remarkable, indicating either a genetic consistency in the stock or a uniform effect of the environment, or both.

A solution to this problem will require both field and experimental work. It will be necessary to revisit Shoshone Spring and determine whether *Cyprinodon* regularly inhabits any part of the stretch of creek separating

the source region from the big population of fish just above and below the highway. Controlled experiments should be undertaken on both stocks as follows: a sample from each locality should be collected, at the same time preserving a series for further scale and fin-ray counts; these 2 stocks should be raised under identical conditions of water and temperature. If differences, or modified differences in the same direction, persist under such conditions in succeeding generations, then the characters can be attributed to genetic processes. If, on the contrary, the resultant offspring do not maintain their distinctiveness, a direct environmental effect is indicated.

It will be noted in Table X that 3 individuals from the outlet fall within the lower range of those from the source, and below any others from the outlet population. They may have been washed out of the pools in the head-water area. Marking experiments could be used to prove or disprove this possibility, and it should be a relatively simple matter to mark the fish in the source region because only a very small population exists there. By cutting off the dorsal or anal fins, such fish, if they soon passed downstream, would readily be identified. Determining whether fish from downstream make their way up to the source pools would be far more difficult. The swiftness of the creek argues against any extensive migration upstream, but if intermittent pools occur between the source pools and the outlet population, movement upstream might occasionally take place.

If it is assumed that *Cyprinodon* cannot or does not ascend to the source region, the origin of the upstream race must date back to a time when the gradient of the outlet was such that *Cyprinodon* could swim against it. It is known that tilting has occurred in this region, for the beds of Pleistocene Lake Tecopa dip toward the center of the basin of Amargosa River (Noble, 1931: 65). The gradient of Shoshone Spring has presumably been influenced by this tilting, but the present accentuated slope in the upper course may date back earlier than Lake Tecopa. In all events, if this assumption is correct, the source and outlet stocks have been isolated as long as or longer than have the populations in Amargosa River between Tecopa and Sperry and between Amargosa Canyon and Death Valley.

ETYMOLOGY.—The name *shoshone*, taken from the name of the spring where this subspecies lives, is an Indian word meaning "warm water."

Cyprinodon nevadensis mionectes, new subspecies

(Pl. V)

TYPES.—The holotype, a mature male 34 mm. long, was seined on September 27, 1942, by Robert R., Ralph G., and Frances H. Miller in Big Spring, north-central Ash Meadows, Nye County, Nevada; U.M.M.Z. No. 141775. Four hundred and twenty-two paratypes, U.M.M.Z. No. 140460,

were collected with the holotype. An additional 17 paratypes were taken by R. R. and R. G. Miller on June 5, 1937, U.M.M.Z. No. 132900.

DIAGNOSIS.—*C. n. mionectes* is characterized by having scale and fin-ray counts lower than average for the species; a reduced size; a short, deep, and slab-sided body with a greatly arched and rather compressed predorsal profile; and a very long head and opercle, and a greater than usual distance between the preorbital margin and the preopercular angle (Tables XIII–XXIV). Among the low counts, the count of the scales around the caudal peduncle particularly stands out. The dorsal is posterior, its origin varying from directly over the origin of the pelvics to well behind it.

COMPARISONS.—*C. n. mionectes* differs from all other subspecies of *Cyprinodon nevadensis* in the characteristics outlined above. Since some of these features are difficult to measure and no single count or measurement will separate all individuals of this subspecies from any other subspecies, it is advisable to employ a character index for distinguishing *mionectes* from other forms. By adding together the head length, opercle length, and the distance between the preorbital margin to the preopercular angle (all expressed in hundredths of the standard length), and subtracting the number of scales around the body, indices result which enable one to separate *mionectes* readily from nearly all of the other subspecies of *C. nevadensis*. The results are given in Table XI.

Although *amargosae* is included in Table XI, that subspecies and *mionectes* can easily be distinguished by counting the scales around the body (Table XXIV). With a line of separation between 25 and 26 scales, 92 per cent of the individuals of *mionectes* and 87 per cent of those of *amargosae* can be identified on this basis.

The character index enables the identification of 87 per cent of the specimens of *nevadensis* and 95 per cent of those of *mionectes*. These are by no means the only characters in which these 2 subspecies differ. As compared with *mionectes* from Big Spring, *nevadensis* has a more anterior dorsal (especially in males), a greater distance between anal origin and caudal base (virtually no overlap), a greater body width (overlap only in females), and a longer caudal peduncle (virtually no overlap, Table XIII).

The types of the new subspecies differ further from *calidae* in having a more posterior dorsal (less so in females), a narrower body, a longer head (no overlap), a longer opercle (virtually no overlap), and a larger eye.

In comparison with *C. n. shoshone*, *mionectes* differs strikingly in body form. The body is deeper and shorter, and the back is more arched in the new subspecies. The dorsal is more posterior in position and the pelvics are also farther back. The head is longer (no overlap) and the orbit is larger in *mionectes* (Table XIII).

VARIATION.—The many Ash Meadows populations of *Cyprinodon neva-*

TABLE XI

FREQUENCY DISTRIBUTION OF THE CHARACTER INDEX FOR CERTAIN MEASUREMENTS AND COUNTS OF SUBSPECIES OF *Cyprinodon nevadensis*

The index is derived by adding the lengths of the head and opercle and the distance between the preorbital margin to preopercular angle (expressed in hundredths of the standard length) and subtracting the number of scales around the body.

Subspecies and Locality	Character Index																		No.	$M \pm \sigma_M$	Per Cent Identifiable*						
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41				42	43	44	45	46	
	<i>amargosae</i>	1	4	2	5	11	5	4	4	4
Death Valley
<i>amargosa</i>	1	3	6	2	3	8	6	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	30	29.87 ± .35	100
Amargosa Canyon	1	5	5	5	5	6	8	2	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	29.20 ± .36	100
Tecopa	110	29.09 ± .20	100
Total	1	5	8	13	22	12	13	20	12	2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	32.30 ± .31	87
<i>nevadensis</i>	1	2	3	10	5	8	6	3	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40	32.30 ± .31	87
Saratoga Springs
<i>calidae</i>
South Tecopa Hot Springs	2	1	6	3	3	3	1	1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20	32.10 ± .41	93
<i>shoshone</i>
Shoshone Spring O.t	1	1	1	2	4	7	8	5	5	3	2	1	.....	.....	.....	.....	.....	.....	.....	.....	40	34.03 ± .38	60
<i>mionectes</i>
Eagle Spring S.†	18	38.78 ± .43	100
Eagle Spring O.	2	.....	2	2	5	5	1	1	.....	.....	.....	.....	.....	20	36.20 ± .39	80
Point of Rocks O.
Forest Spring	20	35.85 ± .37	75
Big Spring	20	38.55 ± .48	95
Hidden Spring O.	20	38.30 ± .58	95
Total	40	37.47 ± .43	90
Total	138	37.50 ± .21	89

* Based on a line of separation between 34 and 35. † S. = Source; O. = Outlet.

densis are variable in meristic characters, but uniform in head and other measurements and in the characteristic chubby body form (Pl. V). Some of them constitute rather distinct races, and no 2 are identical (Tables XIII-XXIV). It seems best at this time, however, to refer all but 1 of these populations to *mionectes*, pending experimental analysis of some of the particular traits to determine if they have a genetic basis.

HABITAT.—Big Spring, also called Crystal Spring, lies about 2 miles north and slightly west of Tubb's Spring, Nevada, at an elevation of approximately 2175 feet (Map 3). It is the largest and one of the best-known springs in Ash Meadows. The water issues from a deep, chalky blue hole which was estimated to be 25 to 30 feet deep. The spring pool (Pl. XII, Fig. 2) is oval, about 50 feet in diameter at the more or less circular upper end, and approximately 75 feet in length to the point where it constricts, forming a narrow outlet ditch. The spring is about 5 feet below the level of the adjacent desert flat.

The only vegetation noted in the water in 1942 was a blebby, green alga, and sporadic clumps of *Scirpus* grew around the margin. The adjacent land is a desert sage flat, with a few screw-bean mesquite near the banks of the spring.

On September 27, 1942, the water temperature at 10:15 A.M. was 30.7° C., air 28.5° C. Adrian Vanderhorst, collecting in this spring on February 8, 1942, obtained a reading of 88° F. (31.1° C.). Constant temperature is again indicated.

An undercut shelf flanks the central hole, and the banks of the pool are also deeply undercut. The water over the shelf is generally less than 5 feet deep. Here, as well as in the outlet, the bottom consists of fine silt and some marl, and the clear water is fairly easily roiled. The current from the bubbling spring is strong in the central hole, moderate at the edges of the pool.

According to the chemical analysis the water of Big Spring is very similar to that of Point of Rocks Spring. Both are high in calcium, magnesium, and bicarbonates, and low in salinity (Table LIII).

On the Furnace Creek Quadrangle 2 springs in Ash Meadows bear the name, Big Spring. The southern 1 is now known as Eagle Spring. The acceptance of this name not only conforms to local usage, but eliminates the confusion resulting from 2 springs having the same name.

Big Spring is selected as the type locality of *mionectes* for several reasons. Its population has characters which very closely approach the average for the subspecies as determined by an analysis of all populations. Big Spring is well known in Ash Meadows and is readily reached by road. The population is large, and samples can be obtained without much difficulty. Furthermore, there is little likelihood that the population will become extirpated by man's interference.

ETYMOLOGY.—The name *mionectes* is derived from the Greek *μιολεκτες*, meaning "one who has less," in reference to the reduced size and lowered number of fin rays and scales.

Races of *Cyprinodon nevadensis mionectes*

Fourteen local populations referred to *Cyprinodon nevadensis mionectes*, in large part probably constituting distinct races, have been analyzed for differential meristic characters (Tables XIV–XXIV). These populations are discussed on the following pages, in order from south to north. The location of each spring is shown on Map 3.

ISAAC RANCH POPULATION.—A single, small ditch running through the ranch grounds was sampled in 1942. The water source is reported to be Deep Spring, about $1\frac{1}{4}$ miles to the east (Map 3). Isaac Ranch (now called Ranch-O) is in the southern part of Ash Meadows, about 8 miles northeast of Death Valley Junction, at an elevation of approximately 2150 feet. Since no large specimens are represented in this collection, no measurements were made. In fin-ray and scale counts, this population agrees fairly well with the sample taken in Deep Spring. It is more closely approached, however, by the sample taken about 1 mile northeast of Isaac Ranch, in what is apparently the outlet of Eagle Spring. Since the Deep and Eagle Spring stocks are very much alike, one would expect that the populations of their outlets would also be similar. Consequently, the close resemblance in meristic characters between the Isaac Ranch sample and that from the outlet of Eagle Spring does not necessarily mean that there is a waterway connection between the 2 ditches.

As compared with the population inhabiting Deep Spring (next to be described), the Isaac Ranch sample averages significantly fewer in dorsal rays but higher in pelvic rays and in lateral, dorsal to pelvic, predorsal, peduncle, and body scales (Tables XIV, XVII, XIX–XX, XXII–XXIV).

DEEP SPRING POPULATION.—This spring, also known as Eastern Spring (and named Bole's Spring on the Furnace Creek Quadrangle), about 50 feet in diameter and of unknown depth, lies on the dry, alkali flat of the southern part of Ash Meadows. Its temperature (1939 and 1942) is about 27° C. The elevation here is somewhat less than 2200 feet.

Deep Spring is so named because it is considered to be the deepest in Ash Meadows—certainly not less than 30 feet. The water is clear, chalky blue, with a sulfurous odor. Vegetation noted in 1942 was dense algae, *Chara*, *Naias marina*, a fine-leaved *Potamogeton*, *Typha*, *Caryx*, and *Eleocharis*. The bottom along the marginal shelf on the south side consisted of silt, mud, and thick *Chara*. Here the water was not more than 3 feet deep. No current was perceptible in the pool, but there was a slight flow in the outlet ditch, which leaves the pool on the western side. One collection in 1939 was

made in this outlet, but in 1942 no fish were seen there, the collection being made along the shallow shelf. No fish life was seen in the chalky blue hole where the water rises.

This population of *Cyprinodon nevadensis mionectes* is very similar in meristic characters to that inhabiting Eagle Spring, which lies about 1 mile to the north (Map 3). The few differences lie in the slightly but rather significantly lower average number of pectoral, pelvic, and caudal rays, and in circumference of peduncle and circumference of body scales in the Deep Spring race (Tables XIV-XXIV). The differences are all in the same direction. The cause of the distinction is not apparent. Whether the similarities indicate genetic relationship or are due wholly or in part to the almost identical temperature of the 2 springs cannot be stated. Unfortunately, the sample collected from Deep Spring did not contain fish of suitable size for comparative measurements, so that it is not known whether this population is distinctive in any body proportions. A visual comparison of the 2 populations, however, fails to reveal any obvious differences in body proportions. The Deep Spring race appears to have a somewhat more compressed body. This could be caused by differences in amount and kind of food at the 2 springs. In this respect it may be noted that Eagle Spring had far more abundant vegetation than did Deep Spring and supported a much larger fish population.

Cyprinodon was fairly common in 1942 in the thick *Chara* which largely covered the shallow shelf on the southern side of the pool. Some of the young captured at this time (September 28) were estimated to be only a few days old, clearly indicating that spawning was still in progress. In addition to *Cyprinodon*, specimens of *Empetrichthys* and *Rhinichthys* were secured.

EAGLE SPRING POPULATION.—Eagle Spring (named Big Spring on the Furnace Creek Quadrangle) lies about 1 mile north of Deep Spring at an elevation slightly less than 2200 feet (Map 3). It is about 20 feet in diameter, nearly circular, and approximately 8 feet deep. Although there are 2 outlet ditches, 1 to the south and 1 to the northwest, only the main outlet is shown on the map. The water is clear but very easily roiled because of the silt bottom and has a slightly sulfurous odor. Vegetation present in the spring in 1942 was green algae, *Naias marina*, and *Chara*. The shore was a marshy meadow of *Eleocharis*, *Scirpus*, and mesquite trees. The current was very slight. The temperature (1942), very similar to that of Deep Spring, was 27.6° C. The similarities between this spring race and the preceding one have been discussed.

This population is characterized by a rather high average number of pectoral rays and a fairly low average number of pelvic rays, predorsal scales, scales around caudal peduncle, and body circumference scales (Tables

XVI-XVII, XXII-XXIV). No outstanding features are revealed by the restricted number of measurements made, but some proportional measurements made with dividers show that the mouth is rather wide.

As compared with the sample secured from the presumed outlet of Eagle Spring, well over a mile below, the source population has a slightly higher average number of dorsal, pectoral, and caudal rays, but distinctly fewer pelvic rays. In the outlet sample the averages are significantly higher for the following scale counts: dorsal to anal, dorsal to pelvic, predorsal, around caudal peduncle, and around body. In the last 2 enumerations there is a difference of over 1 and over 2 scales, respectively.

It is tempting to correlate the increase in these scale counts and in the pelvic rays for the outlet population with the cooler temperature, which was about 4 degrees lower than that of Eagle Spring on the date of collection.

A visual comparison of these 2 collections shows some contrasts which are, however, attributed to differences in breeding condition. The males of the outlet stock have larger dorsal and anal fins, but are much nearer spawning condition as evidenced by higher nuptial colors and more prominent contact organs on the scales. The females are very similar to those from Eagle Spring except that, like the males, they are lighter in color than are the fish of the spring. This difference is presumably due to difference in habitat. The fish of both samples have in common a rather wide mouth, wider than in most of the other races in the Meadows, but are equaled or exceeded in this respect by *C. n. pectoralis*, the subspecies inhabiting Lovell's Spring (described below). This character strengthens the view that the collection from the cooler water is from the outlet of Eagle Spring.

POINT OF ROCKS, MAIN SPRING POPULATION.—The main spring at Point of Rocks (called King's Spring on the Furnace Creek Quadrangle) is the most northerly of a series of spring heads at this locality (Map 3). It is about 30 feet long, 2 to 6 feet wide, and not over $1\frac{1}{2}$ feet deep. The clear water, rather easily roiled, contains some green algae, and the pool is margined by *Scirpus*. The bottom consists of silt, sand, marl, and rocks. The water is rather shallow, from a few inches to $1\frac{1}{2}$ feet deep. At the pool outlet the current is extremely swift. The temperature varies narrowly between 31.1° and 31.8° C. (Table XLI).

The spring water has a high content of calcium, magnesium, and bicarbonates, but is of low salinity (Table LIII).

The fish move in schools over the sandy pockets of the 3 bubbling springs which feed the pool, taking refuge among the *Scirpus* along the border of the pool when disturbed. They avoid the swift outlet of the spring pool. During a brief examination of this outlet in January, 1939, I occasionally attempted to locate fish (by seining) for a distance of at least a half mile below this source spring, but caught only 2 individuals and saw no others.

Careful examination of the ditch at different times of year would be necessary to give conclusive evidence that the swift outlet creek is not generally frequented by *Cyprinodon*. I suspect that it forms a more or less complete ecological barrier, preventing the migration of members of near-by populations of this genus to this source spring. *Empetrichthys* and *Rhinichthys* have also been collected here.

The race of *Cyprinodon nevadensis* inhabiting this source spring is distinguished from all others in the Meadows which I have studied by the great reduction in number of pelvic fin rays (Table XVII). Among the 306 counts on 153 individuals,¹ 126 or 41 per cent gave a value of zero. The counts were made on 2 samples, one collected in January, 1939, the other in September, 1942. The averages for 50 counts were as follows: 3.18 in the 1939 collection, and 2.78 and 2.83 in the 1942 collection. The grand average is 2.99. This is very close to the average of 3.25 which Wales (1930: 64) recorded for his sample ("King's Spring") of 400 counts, and indicates the consistency of the character over a period of years.

In addition to the reduced number of pelvic fin rays, this race has a low average for dorsal rays and for dorsal to anal scales and scales around the caudal peduncle. It has the lowest average of any population examined for anal rays, and for lateral, dorsal to pelvic, predorsal, and body circumference scales (Tables XIV-XV, XIX-XXIV).

This general reduction in meristic characters may be correlated with the rather high temperature at this locality. The fish from Lovell's Spring, however, inhabiting water of 32.5° to 33.0° C., show some striking increases in these counts. If temperature alone were responsible for such reductions one would expect the population at Lovell's Spring to have even lower averages. That this is not true is shown by Tables XIV-XXIV.

POINT OF ROCKS, OUTLET DITCH POPULATION.—In the tables, the Point of Rock Springs samples are labeled "source" and "outlet" for convenience. The source sample, just discussed, is that from the main spring, the outlet sample that from the ditch to the south, which enters the outlet of the main spring well below its source pool (Map 3). No comparable spring pool was discovered in the investigation of this outlet ditch, which originates from the confluence of several small springs (represented on the map as a single spring) east of the main Point of Rocks Spring. The point of collection lies about 220 yards south of that spring. Like the spring pool described above, the water here is clear and easily roiled, the bottom being silt and mud, with *Chara* locally abundant. The shore has a border of *Scirpus*, and algae grow in the water. The creek itself is about 2 feet wide, but is locally expanded to form marshy areas as wide as 40 feet. The water is shallow,

¹ One hundred counts were omitted in Table XVII to avoid an overemphasis on the low average for this race.

from a few inches to about one-half foot deep. Largely because of the smaller volume of water from source springs, the current here is moderate. The major difference in habitat is the cooler temperature which, on September 28, 1942, was 4 degrees lower than that recorded at the same time in the main spring (Table XLI).

The samples taken in the outlet ditch show a number of outstanding differences when compared with the spring race. The pelvic fin rays average 5.69, and the average number of scales around the caudal peduncle and around the body is much higher than in the spring race. All other fin-ray and scale counts also average more in the tributary ditch populations than in those of the spring source. The lower temperature of the ditch presumably has a bearing on these characters. A visual comparison failed to reveal any apparent differences in body proportions between these 2 races, so that the measurements given for the outlet sample (Table XIII) may be taken as a reliable indication for the main spring stock as well.

At a point about 100 feet below this locality the spring-fed ditch enters another ditch coming down from the main spring pool (Map 3). I saw no fish in either ditch at their junction. Here, as above and below, the current in the main spring ditch is very swift, and probably few if any fish from the tributary ditch attempt its ascent. The great bulk of the population in the tributary ditch occurred well above the junction of the 2 outlet creeks. The sample collected in 1939 was from a similar section of the tributary ditch.

FOREST SPRING POPULATION.—This remarkable spring, also called Forest Pool, is 0.7 miles west of the main spring at Point of Rocks and directly east of Tubb's Ranch. It lies 10 or more feet below the level of the surrounding desert flat and is without surface outlet.

The water level, which fluctuates slightly between winter and summer, lies fully 10 feet (formerly 13 feet) below the level of the adjacent desert flat. The pool is about 75 feet in diameter and deepens abruptly from the edge to an unknown depth. Great beds of *Najas marina* grow in the clear water, and there is a dense growth of green algae along shore. In 1942, samples of *Utricularia* were also present and *Scirpus* was growing about the margin of the pool. The bottom along shore is composed of fine sand, silt, and mud, much of which is probably washed into the pool during heavy rains. The banks are rather steep clay bluffs.

The temperature of Forest Spring varies little. On January 9, 1939, it was 26.0° C. at 10:15 A.M., with the air at 12.0° C.; on September 28, 1942, at 4 P.M., it was 26.7° C., the air 29.5° C. In comparison with the other springs analyzed in Ash Meadows, the waters of Forest Spring are higher in boron, lower in calcium and magnesium, and have a somewhat greater salinity (Table LIII).

Fish life is particularly abundant in this spring. On at least 4 visits,

between 1936 and 1942, *Cyprinodon* and *Rhinichthys* were always common, especially the former. *Empetrichthys* is rare here, as it is everywhere in Ash Meadows.

This race of *Cyprinodon nevadensis* resembles the one inhabiting the tributary ditch at Point of Rocks Spring in the rather high fin-ray counts and somewhat above-average scale counts. It has a rather low average number of predorsal scales and one of the lowest averages for scales around the peduncle and around the body. In these 3 counts it is similar to the race at the main Point of Rocks Spring (Tables XXII-XXIV). The Forest Spring population thus combines certain characters, elsewhere correlated with cooler temperatures, with other traits associated with warmer temperatures. It is difficult to interpret such combinations as the result of other than genetic factors.

In measurements, this sample stands out in the rather wide and deep head and the broad interorbital and is less deep bodied than most of the other races (Table XIII, Pl. V). A visual comparison of this population with the one from the outlet ditch at Point of Rocks shows that the Forest Spring fish are not so deep bodied because the ventral profile, as in *C. nevadensis shoshone*, is less arched than is the dorsal.

The complete isolation of this spring has no doubt played an important role in the differentiation of this race.

TUBB'S SPRING POPULATION.—Tubb's Spring, on the ranch of R. M. Tubb (designated Davis Ranch on the Furnace Creek Quadrangle), is one of the coolest in Ash Meadows. The temperature varied from 23.8° to 24.1° C. in the winter and spring of 1939. The source pool, about 6 feet wide and 6 feet deep, has an outlet which joins the ditch coming eastward from Point of Rocks Spring (Map 3). The assistance given our party by Mr. Tubb, and his kind permission to collect on his ranch is gratefully acknowledged.

Cyprinodon nevadensis is not common in the spring or its outlet, possibly because the spring is boarded and not entirely in a natural state. *Rhinichthys* was more numerous than *Cyprinodon* in 1939.

This race has the highest average number of dorsal, anal, and pelvic rays of any *Cyprinodon nevadensis* sampled in the Meadows. It is second lowest in average number of pectoral rays. High also are the averages for caudal rays, and for lateral, dorsal to pelvic, and dorsal to anal scales (Tables XIV-XXI). A comparison of this sample with that from near-by Bradford's Spring is given in the description of that population which follows.

A visual comparison with fish from near-by Big Spring indicates that those from Tubb's Spring have a shorter head, which is bluntly rounded rather than pointed, and a smaller eye. Such differences may be directly influenced by the much cooler temperature of Tubb's Spring. The deep, short, slab-sided body, so characteristic of *mionectes* (especially the males),

is well developed in the Tubb's Spring race and the dorsal fin is also posterior in position.

BRADFORD'S SPRING POPULATION.—This spring, on the Bradford Ranch (Map 3), is apparently tributary to the outlet ditch from Point of Rocks Spring. I have never collected here, but Wales (1930: 61) has briefly described the locality.

The population of *Cyprinodon* sampled at this spring by Myers and Wales in 1930 forms the basis of the present study. This sample stands out in the low number of pectoral and caudal fin-ray counts, both of which average fewer than in any other population of *Cyprinodon* in Ash Meadows. The average number of lateral and predorsal scales is high, whereas that of the dorsal to anal scales is low (Tables XVI–XVII, XIX, XXI–XXII).

TABLE XII

FREQUENCY DISTRIBUTION OF THE CHARACTER INDEX FOR CERTAIN FIN-RAY COUNTS OF *Cyprinodon nevadensis mionectes*

The index is derived by adding the left (or right) pectoral and caudal rays.

Locality	Character Index for Fin-ray Counts										No.	$M \pm \sigma_M$
	28	29	30	31	32	33	34	35	36	37		
Isaac Ranch				6	7	14	15	7	1		50	33.26 ± .18
Deep Spring			1	5	12	28	16	4	1		67	33.03 ± .15
Eagle Spring source				3	2	15	21	6	2		49	33.63 ± .15
Eagle Spring outlet?		1	1	2	8	17	14	6	1		50	33.20 ± .19
Point of Rocks source			1	6	12	30	32	8	5		94	33.38 ± .13
Point of Rocks outlet			1	2	13	29	29	15	9		98	33.67 ± .13
Forest Spring ..			1	3	7	41	52	22	5	1	132	33.75 ± .09
Tubb's Spring ..				1	4	17	9	10	3	1	45	33.80 ± .19
Big Spring				2	5	20	18	13	8		66	33.89 ± .15
Hidden Spring source				2	4	10	10	1	4		31	33.52 ± .24
Hidden Spring outlet					1	11	15	13	10		50	34.40 ± .15
Fairbanks Spring				1	6	16	20	6	1		50	33.54 ± .14
Total		1	5	33	81	248	251	111	50	2	782	33.59 ± .04
Bradford's Spring	1	2	7	16	13	4					43	31.16 ± .17

Statistical Computations on Totals

	$M \pm \sigma_M$	V	t	Per Cent Identifiable*
Bradford's Spring	31.16 ± .17	3.52	12.7	91
Other localities...	33.59 ± .04	3.65		85

* Based on a line of separation between 32 and 33.

A character index, obtained by adding together the counts of pectoral and caudal rays, emphasizes the distinctiveness of this race in comparison with all others in Ash Meadows (Table XII). The t value of over 12 indicates that the differences are highly significant. On this basis, 91 per cent of the individuals from Bradford's Spring and 86 per cent of those from all other localities combined can be identified. Such a high percentage of identifiability would be more convincing if a larger sample from Bradford's Spring were available. Not only should more specimens be examined but larger ones as well, for the series on which these counts are based is composed of small individuals. Size is not a problem in the pectoral ray counts, but may be involved in the enumeration of the caudal rays, for these rays become fully differentiated at a later stage of development than do the rays of the other fins, and the lowered count may be due in part to this phenomenon. At least 4 of the 63 caudal ray counts are definitely questionable. For these reasons I hesitate to give this apparently distinctive race taxonomic recognition.

Although Bradford's Spring and Tubb's Spring are only a few hundred yards apart, and the water temperature at each is very similar (22° and 24° C., respectively), the 2 populations are very different in certain meristic characters. For example, the fish at Tubb's Spring have the highest average number of dorsal and anal fin rays in the Meadows, whereas those at Bradford's Spring average among the lowest. The number of pectoral rays is similar in both, but the number of caudal rays (if correct for Bradford's) is very different. The average number of dorsal to anal scales is also different (Tables XIV-XVI, XVIII, XXI).

Such data demonstrate rather convincingly that the differences between these 2 races can scarcely be accounted for on the basis of a 2-degree difference in temperature. In fact, many of the fin-ray and scale enumerations obtained for the Bradford's Spring sample are remarkably like those for some of the warmest springs in Ash Meadows. The explanation of the distinctive characters of this race therefore strongly suggests a genetic interpretation.

BIG SPRING POPULATION.—Big Spring has already been described (page 47). It is the type locality of *Cyprinodon nevadensis mionectes*, which was the only fish seen or collected there. In 1942, yearlings to large adults were abundant on the marginal shelf that flanks the central hole and were especially numerous beneath the undercut banks. They were also common in the outlet ditch, which is about 3 feet wide. The fish rarely ventured into water more than 5 feet deep.

The diagnosis of the type series of *mionectes* has already been given, and only the local characteristics of the population inhabiting Big Spring are discussed here. The meristic characters of this race average neither high

nor low. Among the fin-ray counts, however, the pectorals average somewhat fewer than do those of most populations in Ash Meadows (Table XVI). The proportionate measurements show that this population is similar to the one at Lovell's Spring (*C. n. pectoralis*), only one-half mile to the east, in having a more posterior dorsal fin in the female, a longer head, a larger eye, and with the base and length of the dorsal fin shorter in females than in the other samples measured (Table XIII).

HIDDEN SPRING POPULATION.—This spring lies about a mile southeast of Fairbanks Ranch (Map 3) and is surrounded by a dense border of *Scirpus*. The spring head is about 8 by 3 feet and 10 feet deep, and its water temperature in September, 1942, was 28.0° C.

The outlet near the spring and for some distance below was densely overgrown with *Scirpus* and saw grass and in places was roofed over with sod. The ditch continues westward to what is known locally as "the slough" or "Carson Slough," which carries the run-off from the Specter Range east of Fairbanks Ranch. It was dry at the time of our visit (September 27, 1942). About 250 yards below Hidden Spring a collection was made in the outlet ditch where it expanded to form a shallow marshy area.

The collections of *Cyprinodon* from the source and outlet of Hidden Spring were, unfortunately, mixed in the field. The habitat at the source, however, was much darker than where the outlet sample was obtained, about 250 yards below. Also, the approximate number of fish taken from the spring source was known. I therefore separated all the dark individuals from the light ones, and the subsequent counts on the 2 samples seem to bear out the reliability of the separation. Thirty-two individuals are represented in the source collection and 437 in the sample from the outlet ditch, where *Cyprinodon* was abundant.

A comparison of meristic characters shows that the spring population consistently averages fewer in fin rays and scales (Tables XIV–XXIV). The greatest of these differences lie in the dorsal to anal, caudal peduncle, and body circumference scales.

A visual comparison of the 2 samples reveals that the fish from the source are thicker bodied, particularly through the head region, and generally are more chunky. The darker color of the spring fish is very striking.

Unfortunately, the water temperature where the sample from the outlet ditch was collected was not recorded. It was definitely cooler than in the spring source, and I estimate that it was about 25° C.

FAIRBANKS RANCH POPULATION.—Young to small adults of *Cyprinodon* were found sporadically in the small spring and outlet on Fairbanks Ranch. This ranch, now owned by Mr. Hamilton, who kindly allowed us to collect on his ranch, lies at the western edge of a large playa in the northern end of Ash Meadows, at an elevation of nearly 2300 feet (indicated on Map 3 as "Spring on Fairbanks Ranch").

A spring and outlet ditch were sampled on this ranch in 1942. This is not Fairbanks Spring, which lies about one-half mile to the west. The spring head is about 3 feet wide, 12 feet long, and 3 feet deep, with an outlet ditch 2 feet wide. The clear water is very easily roiled because of the bottom of silt and mud. The only vegetation seen in the water was green algae. The current was slow in the spring source, but fairly swift in the outlet. The shore is an extensive meadowland.

Fish were not abundant in this habitat. According to Mr. Hamilton the outlet from this spring eventually is joined by water from the outlet of Fairbanks Spring, described below.

The small sample obtained does not permit a detailed analysis of the population. The counts (Tables XIV–XXIV) for 20 specimens are very similar to those for Fairbanks Spring. A visual comparison of these 2 samples is not conclusive, because no large specimens are available from Fairbanks Ranch, but those of comparable size from Fairbanks Spring seem to agree very well. The temperature here is about 22° C., nearly 5 degrees cooler than in Fairbanks Spring.

FAIRBANKS SPRING POPULATION.—Fairbanks Spring, about one-half mile west of the spring on Fairbanks Ranch, lies near the base of clay bluffs which appear to represent dissected lake beds (Map 3 and Pl. XIII, Fig. 1). It has a large volume of water rising in 2 springs at the head of a long outlet ditch. A thick growth of *Scirpus* borders the spring and the outlet, and in the latter the bottom consists of thick silt and mud. The water is clear and the current rather swift, except where the ditch is dammed for irrigation to form short sloughlike situations. The water temperature in the spring source and along the outlet was uniformly 26.6° C. in late September, 1942.

The water of this spring is chemically like that of both Big and Point of Rocks springs—high in calcium, magnesium, and bicarbonates and low in salinity (Table LIII).

Young to adults of *Cyprinodon nevadensis* were fairly abundant in the spring, more so in the outlet ditch. They far outnumbered *Rhinichthys*, a change in relative abundance since June, 1937, when this cyprinid was much more common (Miller, 1938). As at many of the other springs in the Meadows, introduced crayfish and bullfrogs were present; the crayfish were abundant.

The fish of this population, like those from Fairbanks Ranch and the outlet of Hidden Spring, have a high average number of pelvic rays. The average number of scales around the caudal peduncle and body is also greater than in most populations of *mionectes* (Tables XVII, XXIII–XXIV).

This race was not measured, but a visual comparison between it and the sample taken in the outlet of Hidden Spring shows no apparent differences.

The populations from the outlet of Hidden Spring, Fairbanks Ranch, and Fairbanks Spring presumably form a related group, since the waters from all 3 are tributary to "Carson Slough." It is not known whether actual mixing between the stocks takes place at the present time.

Cyprinodon nevadensis pectoralis, new subspecies

(Pl. VI)

TYPES.—The holotype, a mature male 36 mm. in standard length, was collected by Robert R. and Ralph G. Miller on January 9, 1939, in the concrete pool just below Lovell's Spring, Ash Meadows, Nye County, Nevada; U.M.M.Z. No. 141779. Two hundred and fifty-five paratypes were collected with the holotype; U.M.M.Z. No. 132908.

DIAGNOSIS AND COMPARISONS.—*C. n. pectoralis* is characterized principally by a high number (usually 17) of pectoral rays. Otherwise, it is very similar to *C. n. mionectes*. It differs further from that subspecies on the average in having more scales between dorsal and pelvic fins, around peduncle, and around body, and more preopercular pores. In measurements, it has a deeper, broader body, a longer and deeper head, a greater distance between preorbital margin and preopercular angle, and a wider mouth. The pectoral and pelvic fins of the females appear to be shorter than they are in females from other populations in Ash Meadows. This may result from the fact that these fish were not in peak spawning condition, for longer pectoral and pelvic fins in both males and females characterize the specimens taken by Sumner and Sargent in May, 1939, when the fish were near the height of spawning. The shorter basal length of the dorsal and anal fins of the females may be due in part to the same situation or may represent a true reduction in these measurements (Tables XIII–XXVI).

On the basis of the number of pectoral rays alone, 86 per cent of the individuals of this subspecies are identifiable (using a line of separation between 16 and 17 rays). Of all populations of *mionectes* combined 93 per cent are identifiable on this character, and the percentage does not fall below 85 for any single population of that subspecies. In 2 populations of *mionectes*, Bradford's Spring and Fairbanks Spring, 100 per cent of the specimens examined can be separated from *pectoralis* by this 1 character (Table XVI).

The wider head of this subspecies accounts in part for the wider mouth. It will be recalled, however, that the races inhabiting Eagle Spring and its outlet also have a wide mouth.

When compared with the nearest population of *mionectes* in Big Spring, *pectoralis* agrees rather closely in measurements, except that the body is deeper, and the head and mouth are wider than in the Big Spring sample. Of the individuals from Big Spring 95 per cent can be identified on the

TABLE XIII

PROPORTIONAL MEASUREMENTS OF ADULTS OF *Cyprinodon nevadensis*, EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH

Subspecies and Locality	Standard Length	Predorsal				Prepelvic			
		Males		Females		Males		Females	
		Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>									
Death Valley	28-44 (35)	577-605 (591)	10	602-625 (613)	10	552-572 (562)	10	589-619 (602)	10
Amargosa Canyon	33-44 (37)	.....	.....	.....	.....	.....	.....	.....	.....
Tecopa	27-44 (35)	580-623 (605)	10	602-624 (614)	10	560-589 (574)	10	570-617 (586)	10
Total	27-44 (36)	577-623 (598)	20	602-625 (613)	20	552-589 (568)	20	570-619 (594)	20
<i>nevadensis</i>									
Saratoga Springs	34-45 (40)	564-607 (589)	20	584-625 (607)	20	532-583 (558)	20	553-589 (573)	20
<i>calidae</i>									
Tecopa Hot Springs	32-44 (35)	585-609 (596)	10	587-617 (604)	10	550-581 (572)	10	571-597 (586)	9
<i>shoshone</i>									
Shoshone outlet	28-44 (34)	585-607 (598)	10	602-629 (614)	10	539-575 (557)	18	555-580 (570)	17
<i>mionectes</i>									
Eagle Spring source	27-40 (33)	.....	.....	.....	.....	.....	.....	.....	.....
Eagle Spring outlet?	28-37 (32)	.....	.....	.....	.....	.....	.....	.....	.....
Point of Rocks outlet	27-38 (31)	596-625 (611)	10	597-628 (615)	10	566-601 (575)	10	563-591 (582)	10
Forest Spring	27-39 (33)	589-629 (612)	10	594-635 (613)	10	536-591 (572)	10	561-603 (577)	10
Big Spring	26-34 (30)	603-635 (617)	10	598-647 (624)	10	564-589 (578)	10	566-607 (587)	10
Hidden Spring	26-39 (32)	591-626 (608)	10	587-636 (611)	10	564-606 (579)	10	559-610 (580)	10
Total	26-40 (32)	589-635 (612)	40	587-647 (616)	40	536 606 (576)	40	559-610 (581)	40
<i>pectoralis</i>									
Lovell's Spring	27-37 (31)	603-636 (613)	10	611-641 (626)	6	577-605 (589)	10	583-612 (597)	6
Species total	26-45 (34)	564-636 (603)	110	584-647 (613)	106	532-606 (570)	118	553-619 (581)	112

TABLE XIII (Cont.)

Subspecies and Locality	Anal Origin to Caudal Base				Body, Greatest Depth			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>								
Death Valley	378-410 (395)	30	319-369 (338)	30	391-457 (440)	10	376-419 (397)	10
Amargosa Canyon	375-392 (383)	15	339-363 (351)	15	.....	.....	.....	.....
Tecopa	367-402 (380)	20	338-364 (353)	20	385-458 (425)	10	373-424 (393)	10
Total	367-410 (388)	65	319-369 (346)	65	385-458 (432)	20	373-424 (395)	20
<i>nevadensis</i>								
Saratoga Springs	376-424 (394)	20	349-377 (362)	20	409-519 (463)	20	361-449 (409)	20
<i>calidae</i>								
Tecopa Hot Springs	361-393 (376)	10	331-355 (342)	10	391-462 (431)	10	353-413 (382)	10
<i>shoshone</i>								
Shoshone outlet	352-390 (371)	20	343-369 (355)	20	361-439 (389)	20	336-384 (359)	20
<i>mionectes</i>								
Eagle Spring source	348-375 (365)	10	337-355 (347)	8	.....	.....	.....	.....
Eagle Spring outlet?	354-382 (371)	10	323-356 (339)	10	.....	.....	.....	.....
Point of Rocks outlet	332-376 (364)	10	330-358 (345)	10	408-460 (438)	10	364-433 (403)	10
Forest Spring	352-385 (368)	10	331-357 (344)	10	398-449 (424)	10	365-422 (390)	10
Big Spring	352-378 (364)	10	313-355 (339)	10	399-446 (430)	10	376-431 (399)	10
Hidden Spring	341-377 (365)	20	337-369 (349)	20	396-458 (419)	10	379-437 (401)	10
Total	332-385 (366)	70	313-369 (344)	68	396-460 (428)	40	364-437 (398)	40
<i>pectoralis</i>								
Lovell's Spring	337-382 (360)	10	317-349 (332)	6	435-473 (452)	10	388-418 (404)	6
Species total	332-424 (377)	195	313-377 (348)	189	361-519 (430)	120	336-449 (392)	116

TABLE XIII (Cont.)

Subspecies and Locality	Body, Greatest Width				Head, Length		Head, Depth			
	Males		Females				Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>										
Death Valley	236-279 (262)	10	246-291 (269)	10	289-327 (304)	40	305-334 (320)	10	281-305 (291)	10
Amargosa Canyon	233-270 (254)	15	243-281 (261)	15	297-323 (307)	30	327-374 (343)	15	295-333 (316)	15
Tecopa	231-273 (254)	10	255-294 (269)	10	290-322 (305)	40	303-347 (322)	10	284-311 (300)	10
Total	231-279 (256)	35	243-294 (265)	35	289-327 (305)	110	303-374 (330)	35	281-333 (304)	35
<i>nevadensis</i>										
Saratoga Springs	260-291 (274)	20	245-288 (269)	20	297-334 (312)	40	332-403 (367)	20	321-370 (343)	20
<i>calidae</i>										
Tecopa Hot Springs	240-301 (269)	10	248-303 (267)	10	288-319 (306)	10	307-339 (324)	10	276-308 (291)	10
<i>shoshone</i>										
Shoshone outlet	215-246 (231)	20	215-249 (229)	20	281-319 (307)	40	318-358 (331)	10	290-322 (311)	10
<i>mionectes</i>										
Eagle Spring source	.....	.....	.....	.....	314-340 (330)	18	.....	.....	.....	.....
Eagle Spring outlet†	.....	.....	.....	.....	309-341 (322)	20	.....	.....	.....	.....
Point of Rocks outlet	239-271 (248)	10	237-263 (248)	10	302-335 (321)	20	333-383 (355)	10	315-342 (330)	10
Forest Spring	223-251 (244)	10	235-270 (249)	10	314-339 (327)	20	342-374 (361)	10	318-355 (341)	10
Big Spring	219-241 (234)	10	230-256 (244)	10	322-349 (334)	20	320-362 (346)	10	304-337 (320)	10
Hidden Spring	232-255 (247)	10	232-265 (248)	10	307-359 (327)	40	327-382 (351)	10	319-356 (337)	10
Total	219-271 (243)	40	230-270 (247)	40	302-359 (327)	138	320-383 (353)	40	304-356 (332)	40
<i>pectoralis</i>										
Lovell's Spring	242-257 (252)	10	245-269 (255)	6	324-349 (337)	16	354-389 (373)	10	325-355 (342)	6
Species total	215-301 (252)	135	215-303 (254)	131	281-359 (316)	354	303-403 (346)	125	276-370 (321)	121

TABLE XIII (Cont.)

Subspecies and Locality	Head, Width				Caudal Peduncle, Length			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>								
Death Valley	222-252 (237)	10	241-277 (261)	10	241-276 (263)	20	215-237 (227)	20
Amargosa Canyon	232-255 (243)	10	249-268 (257)	10	252-278 (266)	15	226-259 (246)	15
Tecopa	222-255 (240)	20	241-277 (259)	20	251-284 (263)	20	223-251 (239)	20
Total					241-284 (264)	55	215-259 (237)	55
<i>nevadensis</i>								
Saratoga Springs	246-272 (257)	20	240-272 (256)	20	257-296 (277)	20	241-267 (253)	20
<i>calidae</i>								
Tecopa Hot Springs	236-264 (247)	10	234-269 (250)	10	244-263 (253)	10	221-250 (237)	10
<i>shoshone</i>								
Shoshone outlet	222-242 (233)	10	221-246 (231)	10	245-278 (263)	20	237-269 (251)	20
<i>mimoneetes</i>								
Eagle Spring source	.....	.....	.....	.....	239-265 (253)	10	230-255 (243)	8
Eagle Spring outlet?	.....	.....	.....	.....	245-271 (258)	10	214-249 (233)	10
Point of Rocks outlet	233-260 (243)	10	226-246 (234)	10	238-262 (251)	10	231-248 (241)	10
Forest Spring	233-254 (246)	10	237-267 (253)	10	239-278 (256)	10	235-254 (244)	10
Big Spring	224-258 (239)	10	227-258 (239)	10	230-260 (250)	10	218-247 (232)	10
Hidden Spring	228-264 (247)	10	224-258 (244)	10	230-269 (253)	20	228-250 (240)	20
Total	224-264 (244)	40	224-267 (243)	40	230-278 (253)	70	214-255 (239)	68
<i>pectoralis</i>								
Lovell's Spring	247-262 (254)	10	243-262 (251)	6	230-260 (248)	10	219-244 (232)	6
Species total	222-272 (246)	110	221-277 (248)	106	230-296 (260)	185	214-269 (241)	179

TABLE XIII (Cont.)

Subspecies and Locality	Caudal Peduncle, Depth				Interorbital, Least Bony Width		Preorbital, Least Width	
	Males		Females		Range (Ave.)	No.	Range (Ave.)	No.
	Range (Ave.)	No.	Range (Ave.)	No.				
<i>amargosae</i>								
Death Valley	200-222 (211)	10	164-180 (173)	10	104-126 (116)	20	42-56 (50)	20
Amargosa Canyon .....	.....	.....	.....	.....	.....	.....	.....	.....
Tecopa	190-215 (201)	10	171-196 (181)	10	103-119 (111)	20	45-57 (50)	20
Total	190-222 (206)	20	164-196 (177)	20	103-126 (113)	40	42-57 (50)	40
<i>nevadensis</i>								
Saratoga Springs	190-222 (207)	20	182-202 (190)	20	110-134 (119)	40	44-56 (49)	40
<i>calidae</i>								
Tecopa Hot Springs	183-209 (196)	10	162-176 (169)	10	97-113 (103)	20	43-51 (47)	20
<i>shoshone</i>								
Shoshone outlet	182-205 (194)	10	159-184 (173)	10	103-121 (111)	20	42-54 (46)	20
<i>mionectes</i>								
Eagle Spring source .....	.....	.....	.....	.....	.....	.....	.....	.....
Eagle Spring outlet? .....	.....	.....	.....	.....	.....	.....	.....	.....
Point of Rocks outlet	177-205 (192)	10	165-188 (177)	10	104-123 (113)	20	42-56 (48)	20
Forest Spring	188-209 (198)	10	174-188 (182)	10	114-130 (120)	20	45-55 (50)	20
Big Spring	184-207 (195)	10	168-186 (175)	10	102-124 (113)	19	40-57 (48)	20
Hidden Spring	182-221 (192)	10	170-198 (186)	10	107-125 (115)	20	41-53 (47)	20
Total	177-221 (194)	40	165-198 (180)	40	102-130 (115)	79	40-57 (48)	80
<i>pectoratis</i>								
Lovell's Spring	188-215 (201)	10	160-183 (176)	6	104-125 (115)	16	41-55 (48)	16
Species total	177-222 (200)	110	159-202 (179)	106	97-134 (114)	215	40-57 (48)	216

TABLE XIII (Cont.)

Subspecies and Locality	Preorbital Margin to Preopercular Angle		Eye Margin to Preopercular Angle				Opercle, Greatest Length	
	Range (Ave.)	No.	Males		Females		Range (Ave.)	No.
			Range (Ave.)	No.	Range (Ave.)	No.		
<i>amargosae</i>								
Death Valley	144-172 (156)	40	121-135 (129)	10	108-127 (115)	10	97-115 (105)	40
Amargosa Canyon	147-163 (157)	30	.....	.....	.....	.....	93-107 (98)	30
Tecopa	145-166 (154)	40	118-135 (125)	10	110-123 (118)	10	89-114 (101)	40
Total	144-172 (155)	110	118-135 (127)	20	108-127 (117)	20	89-115 (102)	110
<i>nevadensis</i>								
Saratoga Springs	149-169 (161)	40	111-139 (127)	20	107-129 (119)	20	97-113 (103)	40
<i>calidae</i>								
Tecopa Hot Springs	139-164 (151)	20	108-127 (116)	10	93-111 (102)	10	91-105 (99)	20
<i>shoshone</i>								
Shoshone outlet	144-175 (161)	40	111-135 (124)	10	103-121 (113)	10	93-111 (104)	40
<i>mionectes</i>								
Eagle Spring source	163-184 (171)	18	.....	.....	.....	.....	90-121 (111)	18
Eagle Spring outlet?	156-185 (169)	20	.....	.....	.....	.....	99-113 (107)	20
Point of Rocks outlet	157-178 (167)	20	110-128 (118)	10	103-123 (113)	10	95-113 (106)	20
Forest Spring	159-179 (168)	20	119-133 (124)	10	115-126 (122)	10	102-118 (109)	20
Big Spring	155-177 (166)	20	113-135 (122)	10	106-122 (112)	10	104-121 (113)	20
Hidden Spring	153-179 (167)	40	105-129 (118)	10	108-125 (117)	10	97-147 (113)	40
Total	153-185 (167)	138	105-135 (121)	40	103-126 (116)	40	90-147 (110)	138
<i>pectoralis</i>								
Lovell's Spring	166-191 (179)	16	120-147 (134)	10	111-125 (119)	6	106-121 (114)	16
Species total	139-191 (162)	364	105-147 (124)	110	93-129 (115)	106	89-147 (106)	364

TABLE XIII (Cont.)

Subspecies and Locality	Snout, Length		Orbit, Length		Mouth, Width		Upper Jaw, Length	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>								
Death Valley	94-104 (100)	20	66-83 (72)	40	101-119 (110)	30	99-119 (110)	40
Amargosa Canyon .....	.....	.....	68-79 (74)	30	110-132 (120)	30	108-125 (114)	30
Tecopa	97-109 (102)	20	71-85 (77)	40	115-132 (125)	20	104-121 (113)	40
Total	94-109 (101)	40	66-85 (75)	110	101-132 (117)	80	99-125 (112)	110
<i>nevadensis</i>								
Saratoga Springs	90-104 (97)	40	69-82 (75)	40	104-133 (115)	40	105-122 (113)	40
<i>calidae</i>								
Tecopa Hot Springs	83-104 (94)	20	74-83 (79)	20	111-132 (121)	20	102-119 (109)	20
<i>shoshone</i>								
Shoshone outlet	81-99 (89)	40	68-85 (76)	40	104-127 (114)	16	102-119 (111)	40
<i>mionectes</i>								
Eagle Spring source	.....	.....	77-88 (82)	18	.....	.....	108-127 (117)	18
Eagle Spring outlet†	.....	.....	73-86 (79)	20	.....	.....	113-130 (121)	20
Point of Rocks outlet	93-110 (100)	20	76-89 (81)	20	108-121 (116)	20	103-128 (114)	20
Forest Spring	91-107 (101)	20	73-83 (79)	20	106-127 (114)	20	107-124 (117)	20
Big Spring	91-107 (100)	20	80-94 (86)	20	109-127 (117)	20	113-128 (118)	20
Hidden Spring	90-112 (98)	20	75-91 (82)	40	102-122 (112)	20	106-124 (113)	40
Total	90-112 (100)	80	73-94 (81)	138	102-127 (115)	80	103-130 (116)	138
<i>pectoralis</i>								
Lovell's Spring	89-107 (100)	16	72-91 (83)	16	116-133 (126)	16	114-135 (123)	16
Species total	81-112 (97)	236	66-94 (78)	364	101-133 (117)	252	99-135 (114)	364

TABLE XIII (Cont.)

Subspecies and Locality	Mandible, Length		Dorsal Fin, Basal Length				Dorsal Fin, Length						
	Range (Ave.)	No.	Males		Females		Males		Females				
			Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.			
<i>amargosae</i>													
Death Valley	88-103 (97)	20	198-226 (211)	10	172-191 (182)	10	284-339 (305)	20	245-266 (257)	10			
Amargosa Canyon	92-103 (98)	20	177-204 (194)	10	178-202 (192)	10	267-303 (286)	10	234-279 (263)	10			
Tecopa	88-103 (98)	40	177-226 (203)	20	172-202 (187)	20	267-339 (295)	30	234-279 (260)	20			
Total													
<i>nevadensis</i>													
Saratoga Springs	87-106 (95)	40	183-217 (201)	20	165-196 (179)	20	277-337 (304)	20	238-278 (257)	20			
<i>calidae</i>													
Tecopa Hot Springs	85-103 (94)	20	192-227 (211)	10	161-193 (177)	10	292-328 (308)	10	243-274 (256)	10			
<i>shoshone</i>													
Shoshone outlet	83- 99 (93)	20	175-219 (191)	10	162-188 (179)	10	270-309 (287)	10	238-264 (249)	10			
<i>mionectes</i>													
Eagle Spring source													
Eagle Spring outlet?													
Point of Rocks outlet	90-110 (100)	20	173-216 (194)	10	161-211 (180)	10	263-308 (283)	10	247-278 (258)	10			
Forest Spring	91-107 (99)	20	187-218 (199)	10	172-197 (182)	10	284-308 (298)	10	262-277 (266)	10			
Big Spring	93-111 (103)	20	167-194 (182)	10	159-183 (168)	10	270-307 (288)	10	228-257 (247)	10			
Hidden Spring	93-106 (100)	20	163-197 (184)	10	170-196 (185)	10	259-304 (280)	10	257-283 (269)	10			
Total	90-111 (101)	80	163-218 (190)	40	159-211 (179)	40	259-308 (287)	40	228-283 (260)	40			
<i>pectoralis</i>													
Lovell's Spring	91-114 (103)	16	171-201 (187)	10	153-176 (161)	6	277-316 (297)	10	241-263 (253)	6			
Species total	83-114 (98)	216	163-227 (196)	110	153-211 (179)	106	259-339 (294)	120	228-283 (257)	106			

TABLE XIII (Cont.)

Subspecies and Locality	Anal Fin, Basal Length				Anal Fin, Length			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>								
Death Valley	103-131 (119)	20	97-110 (103)	10	216-280 (244)	30	174-225 (199)	20
Amargosa Canyon					205-234 (221)	15	183-213 (196)	15
Tecopa	103-123 (111)	10	99-115 (106)	10	206-247 (224)	20	180-219 (201)	20
Total	103-131 (116)	30	97-115 (105)	20	205-280 (233)	65	174-225 (199)	55
<i>nevadensis</i>								
Saratoga Springs	101-123 (111)	20	97-121 (105)	20	203-246 (227)	20	171-215 (195)	20
<i>calidae</i>								
Tecopa Hot Springs	110-121 (115)	10	92-102 (98)	10	213-237 (226)	10	183-207 (193)	10
<i>shoshone</i>								
Shoshone outlet	102-115 (108)	10	96-108 (101)	10	200-236 (217)	20	166-215 (190)	20
<i>mionectes</i>								
Eagle Spring source					206-235 (225)	10	173-203 (187)	8
Eagle Spring outlet?					216-247 (232)	10	178-202 (192)	10
Point of Rocks outlet	95-115 (107)	10	93-106 (100)	10	210-233 (221)	10	179-201 (190)	10
Forest Spring	99-111 (106)	10	90-110 (101)	10	206-247 (229)	10	173-203 (194)	10
Big Spring	101-113 (109)	10	99-112 (107)	10	227-248 (235)	10	186-206 (195)	10
Hidden Spring	100-121 (108)	10	98-115 (105)	10	213-244 (227)	20	182-215 (198)	20
Total	95-121 (107)	40	90-115 (103)	40	206-248 (228)	70	173-215 (194)	68
<i>pectoralis</i>								
Lovell's Spring	101-117 (105)	10	86- 95 (91)	6	220-247 (234)	10	184-201 (191)	6
Species total	95-131 (111)	120	86-121 (103)	106	200-280 (229)	195	166-225 (195)	179

TABLE XIII (Cont.)

Subspecies and Locality	Caudal, Length Middle Rays				Pectoral, Length Longest Ray			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>								
Death Valley	197-233 (211)	10	180-210 (194)	10	213-251 (229)	20	171-208 (189)	20
Amargosa Canyon					198-232 (217)	15	189-220 (199)	15
Tecopa	192-213 (201)	10	180-211 (197)	10	194-224 (207)	20	182-204 (192)	20
Total	192-233 (206)	20	180-211 (196)	20	194-251 (218)	55	171-220 (193)	55
<i>nevadensis</i>								
Saratoga Springs	190-217 (204)	20	187-209 (196)	20	198-239 (217)	16	181-204 (192)	19
<i>calidae</i>								
Tecopa Hot Springs	206-226 (214)	10	177-213 (193)	10	215-239 (222)	10	178-210 (193)	10
<i>shoshone</i>								
Shoshone outlet	187-227 (210)	10	187-213 (202)	9	201-233 (219)	20	174-222 (200)	20
<i>mionectes</i>								
Eagle Spring source					218-233 (224)	10	191-213 (203)	7
Eagle Spring outlet?					214-242 (233)	10	189-220 (206)	10
Point of Rocks outlet	194-227 (211)	10	192-207 (199)	10	220-240 (228)	10	203-223 (212)	10
Forest Spring	210-237 (223)	10	193-233 (217)	10	218-234 (227)	10	197-221 (211)	10
Big Spring	209-222 (216)	10	184-209 (200)	9	218-242 (232)	10	195-216 (207)	10
Hidden Spring	208-222 (215)	10	193-221 (207)	10	216-245 (229)	19	195-235 (218)	20
Total	194-237 (216)	40	184-233 (206)	39	214-245 (229)	69	189-235 (211)	67
<i>pectoralis</i>								
Lovell's Spring	214-231 (222)	10	200-214 (209)	6	215-239 (227)	10	193-210 (201)	6
Species total	187-237 (212)	110	177-233 (200)	104	194-251 (223)	180	171-235 (201)	177

TABLE XIII (Cont.)

Subspecies and Locality	Pelvic, Length Longer Fin			
	Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.
<i>amargosae</i>				
Death Valley	85-120 (103)	30	81-101 (92)	20
Amargosa Canyon	88-103 (96)	15	80- 95 (88)	15
Tecopa	84-105 (93)	20	80- 94 (86)	20
Total	84-120 (98)	65	80-101 (89)	55
<i>nevadensis</i>				
Saratoga Springs	73-108 (95)	20	75- 99 (87)	20
<i>calidae</i>				
Tecopa Hot Springs	94-107 (99)	10	75- 91 (82)	9
<i>shoshone</i>				
Shoshone outlet	83-104 (90)	18	43- 86 (77)	17
<i>mionectes</i>				
Eagle Spring source	82-102 (92)	10	74- 90 (83)	8
Eagle Spring outlet?	90- 98 (93)	10	76- 90 (83)	10
Point of Rocks outlet	86- 93 (90)	10	79- 89 (83)	10
Forest Spring	88- 98 (93)	10	79- 91 (86)	10
Big Spring	83- 97 (91)	10	37- 89 (79)	10
Hidden Spring	88-110 (97)	20	83- 99 (93)	20
Total	82-110 (93)	70	37- 99 (86)	68
<i>pectoralis</i>				
Lovell's Spring	77-102 (90)	10	73- 84 (79)	6
Species total	73-120 (95)	193	37-101 (85)	175

number of pectoral rays. The difference in temperature between these 2 springs is only about 2 degrees Centigrade.

C. n. pectoralis differs further from the subspecies of *Cyprinodon* in the lower Amargosa River by the same measurements which distinguish *mionectes* (Table XI). The values for the character index derived by adding the lengths of the head and opercle and the distance between the pre-orbital margin to preopercular angle (expressed in hundredths of the standard length) and subtracting the number of scales around the body varied from 34 to 41, average $37.94 \pm .56$. These figures, based on the measurements derived from 16 specimens, enable the identification of 94 per cent of the individuals of *pectoralis* (using a line of separation between 34 and 35, see Table XI).

HABITAT.—The types were collected from the concrete pool or reservoir about 50 yards below the spring source on the ranch of Mr. Ora Lovell, about one-half mile eastward from Big Spring at an elevation of nearly 2200 feet (Map 3). This pool, 20 feet wide, 25 feet long, and 8 feet deep, had a layer of fine silt over the concrete bottom. The slightly sulfurous spring water entered through a 5-inch pipe at the upper end. I appreciate very much the

TABLE XIV
DORSAL FIN-RAY COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Dorsal Rays					No.	$M \pm \sigma_M$
	8	9	10	11	12		
<i>amargosae</i>							
Death Valley .....	.....	49	131	20	.....	200	9.85 ± .04
Amargosa Canyon .....	.....	5	66	28	1	100	10.25 ± .06
Tecopa .....	.....	3	64	31	2	100	10.32 ± .06
Total .....	.....	57	261	79	3	400	10.07 ± .03
<i>nevadensis</i>							
Saratoga Springs and lake .....	.....	23	151	39	1	214	10.08 ± .04
<i>calidae</i>							
South Tecopa Hot Springs .....	.....	11	75	14	.....	100	10.03 ± .05
North Tecopa Hot Springs	1	3	37	9	.....	50	10.08 ± .08
Total	1	14	112	23	.....	150	10.05 ± .04
<i>shoshone</i>							
Shoshone Spring S.*	1	28	33	1	.....	63	9.54 ± .07
Shoshone Spring O.* .....	.....	28	94	12	.....	134	9.88 ± .05
Total	1	56	127	13	.....	197	9.77 ± .04
<i>mionectes</i>							
Isaac Ranch	1	18	29	2	.....	50	9.64 ± .08
Deep Spring .....	.....	8	54	12	.....	74	10.05 ± .06
Eagle Spring S.	1	6	37	6	.....	50	9.96 ± .08
Eagle Spring O. ? .....	.....	16	27	7	.....	50	9.82 ± .09
Point of Rocks S.	1	47	52	3	.....	103	9.55 ± .06
Point of Rocks O. ....	.....	33	58	8	1	100	9.77 ± .06
Forest Spring .....	.....	18	103	11	1	133	9.96 ± .04
Tubb's Spring .....	.....	1	31	18	.....	50	10.34 ± .07
Bradford's Spring .....	.....	21	29	.....	.....	50	9.58 ± .07
Big Spring	2	17	46	2	.....	67	9.72 ± .07
Hidden Spring S. ....	.....	6	23	3	.....	32	9.91 ± .09
Hidden Spring O. ....	.....	7	34	9	.....	50	10.04 ± .08
Fairbanks Ranch .....	.....	9	11	.....	.....	20	9.55 ± .11
Fairbanks Spring	1	14	34	1	.....	50	9.70 ± .08
Total	6	221	568	82	2	879	9.83 ± .02
<i>pectoralis</i>							
Lovell's Spring .....	.....	49	51	.....	.....	100	9.51 ± .05
Species total	8	420	1,270	236	6	1,940	9.90 ± .01

* S. = Source ; O. = Outlet.

kindness of Mr. Lovell in allowing us to carry out our investigations on his ranch.

This is one of the warmest of the springs in the region, and is very constant in temperature. On January 9, 1939, at 1:45 P.M., it was 33.0° C., the air 12.5° C. Between April 28 and May 1, 1939, it varied from 32.5° to 33.0° C., and did not fall appreciably between the spring source and the concrete pool (Sumner and Sargent, 1940: 47).

ETYMOLOGY.—This subspecies is named *pectoralis* in reference to the increased number of pectoral fin rays.

TABLE XV
ANAL FIN-RAY COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Anal Rays				No.	$M \pm \sigma_M$
	8	9	10	11		
<i>amargosae</i>						
Death Valley	2	107	41	150	10.26 ± .04
Amargosa Canyon	2	74	24	100	10.22 ± .05
Tecopa	1	62	37	100	10.36 ± .05
Total	5	243	102	350	10.28 ± .03
<i>nevadensis</i>						
Saratoga Springs and lake	4	155	55	214	10.24 ± .03
<i>calidae</i>						
South Tecopa Hot Springs	5	82	13	100	10.08 ± .04
North Tecopa Hot Springs	1	44	5	50	10.08 ± .05
Total	6	126	18	150	10.08 ± .03
<i>shoshone</i>						
Shoshone Spring S.*	14	47	1	62	9.79 ± .06
Shoshone Spring O.*	10	104	19	133	10.07 ± .04
Total	24	151	20	195	9.98 ± .03
<i>mionectes</i>						
Isaac Ranch	4	44	2	50	9.96 ± .05
Deep Spring	14	57	3	74	9.85 ± .05
Eagle Spring S.	1	6	42	1	50	9.86 ± .06
Eagle Spring O.?	10	37	3	50	9.86 ± .07
Point of Rocks S.	40	62	1	103	9.62 ± .05
Point of Rocks O.	17	81	2	100	9.85 ± .04
Forest Spring	14	110	9	133	9.96 ± .04
Tubb's Spring	33	17	50	10.34 ± .07
Bradford's Spring	10	38	2	50	9.84 ± .07
Big Spring	11	53	3	67	9.88 ± .05
Hidden Spring S.	3	26	3	32	10.00 ± .08
Hidden Spring O.	5	38	7	50	10.04 ± .07
Fairbanks Ranch	3	16	1	20	9.90 ± .10
Fairbanks Spring	6	43	1	50	9.90 ± .05
Total	1	143	680	55	879	9.90 ± .02
<i>pectoralis</i>						
Lovell's Spring	5	87	8	100	10.03 ± .04
Species total	1	187	1,442	258	1,888	10.04 ± 0.1

* S. = Source ; O. = Outlet.

TABLE XVI
PECTORAL FIN-RAY COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Pectoral Rays										No.	$M \pm \sigma_M$	
	11	12	13	14	15	16	17	18					
<i>amargosae</i>													
Death Valley .....	.....	.....	.....	.....	35	195	65	3	298	16.12 ± .03
Amargosa Canyon .....	.....	.....	.....	.....	15	137	45	2	199	16.17 ± .04
Tecopa .....	.....	.....	.....	1	23	120	49	4	197	16.16 ± .05
Total .....	.....	.....	.....	1	73	452	159	9	694	16.15 ± .02
<i>nevadensis</i>													
Saratoga Springs and lake .....	.....	.....	.....	8	79	211	78	2	378	15.97 ± .04
<i>calidae</i>													
South Tecopa Hot Springs .....	.....	.....	1	2	45	124	28	.....	200	15.88 ± .05
North Tecopa Hot Springs .....	.....	.....	.....	.....	10	58	31	.....	99	16.21 ± .06
Total .....	.....	.....	1	2	55	182	59	.....	299	15.99 ± .04
<i>shoshone</i>													
Shoshone Spring S.* .....	.....	.....	.....	5	23	84	14	.....	126	15.85 ± .06
Shoshone Spring O.* .....	.....	.....	.....	.....	42	134	36	2	214	15.99 ± .04
Total .....	.....	.....	.....	5	65	218	50	2	340	15.94 ± .03
<i>mionectes</i>													
Isaac Ranch .....	.....	.....	1	2	31	51	12	1	98	15.75 ± .08	
Deep Spring .....	.....	.....	.....	6	49	81	7	.....	143	15.62 ± .05
Eagle Spring S. ....	.....	.....	.....	.....	25	67	6	.....	98	15.81 ± .05
Eagle Spring O.† .....	.....	1	.....	4	31	49	13	2	100	15.74 ± .09	
Point of Rocks S. ....	.....	.....	1	3	65	112	12	.....	193	15.68 ± .05
Point of Rocks O. ....	.....	.....	1	2	60	119	18	.....	200	15.75 ± .05
Forest Spring .....	.....	.....	.....	4	78	165	18	.....	266	15.73 ± .04
Tubb's Spring	1	.....	.....	3	53	35	6	.....	97	15.45 ± .07
Bradford's Spring .....	.....	.....	1	12	39	11	.....	.....	63	14.95 ± .08
Big Spring .....	.....	.....	.....	8	102	112	11	.....	233	15.54 ± .04
Hidden Spring S. ....	.....	.....	.....	1	26	34	3	.....	64	15.61 ± .08
Hidden Spring O. ....	.....	.....	1	2	29	56	12	.....	100	15.76 ± .07
Fairbanks Ranch .....	.....	.....	.....	1	12	26	.....	.....	39	15.64 ± .09
Fairbanks Spring .....	.....	.....	1	3	30	62	4	.....	100	15.65 ± .07
Total	1	1	6	51	630	980	122	3	1,794	15.65 ± .02			
<i>pectoralis</i>													
Lovell's Spring .....	.....	.....	.....	.....	.....	28	124	48	200	17.10 ± .04
Species total	1	1	7	67	902	2,071	592	64	3,705	15.91 ± .01			

* S. = Source; O. = Outlet.

TABLE XVII

PELVIC FIN-RAY COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Pelvic Rays										No.	<i>M</i>	
	0	1	2	3	4	5	6	7	8	9			
<i>amargosae</i>													
Death Valley	31	1	3	2	3	75	326	17	.....	2	460	5.41
Amargosa Canyon	2	.....	.....	.....	3	19	167	9	.....	.....	200	5.86
Tecopa .....	.....	1	.....	1	6	29	151	11	1	.....	200	5.82
Total	33	2	3	3	12	123	644	37	1	2	860	5.61	
<i>nevadensis</i>													
Saratoga Springs and lake	4	.....	1	.....	8	74	334	7	.....	.....	428	5.74
<i>calidae</i>													
South Tecopa Hot Springs ...	17	.....	.....	.....	4	35	134	10	.....	.....	200	5.33
North Tecopa Hot Springs ...	26	.....	.....	2	7	26	38	1	.....	.....	100	3.99
Total	43	.....	.....	2	11	61	172	11	.....	.....	300	4.88
<i>shoshone</i>													
Shoshone Spring S.*	101	1	2	1	1	7	16	1	.....	.....	130	1.15
Shoshone Spring O.*	37	1	.....	3	4	32	169	12	.....	.....	258	4.98
Total	138	2	2	4	5	39	185	13	.....	.....	388	3.69
<i>mionectes</i>													
Isaac Ranch	3	.....	.....	.....	.....	24	72	1	.....	.....	100	5.59
Deep Spring	13	1	.....	2	22	84	116	.....	.....	.....	238	5.09
Eagle Spring S.	4	.....	1	.....	11	76	103	5	.....	.....	200	5.39
Eagle Spring O. ?	1	.....	.....	.....	.....	21	74	4	.....	.....	100	5.77
Point of Rocks S.	82	.....	.....	3	31	58	32	.....	.....	.....	206	2.99
Point of Rocks O.	5	.....	.....	1	5	26	157	6	.....	.....	200	5.69
Forest Spring .....	.....	.....	1	.....	8	55	200	2	.....	.....	266	5.73
Tubb's Spring .....	.....	.....	.....	.....	.....	9	80	11	.....	.....	100	6.02
Bradford's Spring .....	.....	.....	.....	.....	4	26	55	3	.....	.....	88	5.65
Big Spring	24	3	1	2	5	55	141	3	.....	.....	234	5.01
Hidden Spring S.	1	.....	.....	.....	5	19	39	.....	.....	.....	64	5.45
Hidden Spring O.	2	.....	.....	.....	.....	43	154	1	.....	.....	200	5.73
Fairbanks Ranch .....	.....	.....	.....	.....	.....	9	31	.....	.....	.....	40	5.77
Fairbanks Spring .....	.....	.....	.....	.....	.....	19	81	.....	.....	.....	100	5.81
Total	135	4	3	8	91	524	1,335	36	.....	.....	2,136	5.28
<i>pectoralis</i>													
Lovell's Spring	12	1	.....	3	14	64	104	2	.....	.....	200	5.12
Species total	365	9	9	20	141	885	2,774	106	1	2	4,312	5.21	

* S. = Source ; O. = Outlet.

TABLE XVIII
CAUDAL FIN-RAY COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Caudal Rays											No.	$M \pm \sigma_M$			
	14	15	16	17	18	19	20	21	22							
<i>amargosae</i>																
Death Valley			4	22	58	53	55	8							200	18.79 ± .08
Amargosa Canyon		1	5	20	42	21	10	1							100	18.11 ± .11
Tecopa			9	18	44	19	9	1							100	18.04 ± .11
Total		1	18	60	144	93	74	10							400	18.43 ± .06
<i>nevadensis</i>																
Saratoga Springs and lake		2	36	78	77	16	4								214	17.40 ± .07
<i>calidae</i>																
South Tecopa Hot Springs			24	40	24	12									100	17.24 ± .09
North Tecopa Hot Springs			2	9	26	10	2								49	18.02 ± .12
Total			26	49	50	22	2								149	17.50 ± .08
<i>shoshone</i>																
Shoshone Spring S.*			2	14	34	7	4								61	17.95 ± .11
Shoshone Spring O.*			14	32	53	14	6	1							120	17.74 ± .09
Total			16	46	87	21	10	1							181	17.81 ± .07
<i>mionectes</i>																
Isaac Ranch		1	9	9	26	4	1								50	17.52 ± .14
Deep Spring		2	13	18	30	3	1								67	17.33 ± .12
Eagle Spring S.			4	13	25	7	1								50	17.76 ± .12
Eagle Spring O.†		2	5	16	24	2									50	17.44 ± .13
Point of Rocks S.		2	11	20	43	15	3								94	17.71 ± .11
Point of Rocks O.			9	20	43	19	7								98	17.95 ± .10
Forest Spring			10	25	65	23	8	1							132	17.98 ± .09
Tubb's Spring			3	3	26	6	9								47	18.32 ± .15
Bradford's Spring		4	28	12	3										50	16.16 ± .12
Big Spring	3			8	33	11	11	1							66	18.35 ± .13
Hidden Spring S.		1	4	6	14	3	4								31	17.90 ± .21
Hidden Spring O.			2	7	49	29	13								100	18.44 ± .09
Fairbanks Ranch					1	1									2	
Fairbanks Spring			1	16	24	6	3								50	17.88 ± .12
Total	3	12	100	173	406	129	62	2							887	17.82 ± .04
<i>pectoralis</i>																
Lovell's Spring			10	18	60	9	1								98	17.72 ± .08
Species total	3	15	206	424	824	290	153	13							1,929	17.87 ± .03

* S. = Source; O. = Outlet.

TABLE XIX
LATERAL SERIES SCALE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Lateral Series Scales						No.	$M \pm \sigma_M$
	23	24	25	26	27	28		
<i>amargosae</i>								
Death Valley	22	162	43	3	230	26.12 \pm .04
Amargosa Canyon	20	73	7	.....	100	25.87 \pm .05
Tecopa	7	74	19	.....	100	26.12 \pm .05
Total	49	309	69	3	430	26.06 \pm .03
<i>nevadensis</i>								
Saratoga Springs and lake	24	132	8	.....	164	25.90 \pm .03
<i>calidae</i>								
South Tecopa Hot Springs	1	40	59	.....	.....	100	25.58 \pm .05
North Tecopa Hot Springs	15	24	1	.....	40	25.65 \pm .08
Total	1	55	83	1	.....	140	25.60 \pm .04
<i>shoshone</i>								
Shoshone Spring S.*	7	41	15	.....	.....	63	25.13 \pm .07
Shoshone Spring O.*	1	33	79	3	.....	116	25.72 \pm .05
Total	8	74	94	3	.....	179	25.51 \pm .05
<i>mionectes</i>								
Isaac Ranch	18	32	.....	.....	50	25.64 \pm .07
Deep Spring	5	44	23	.....	.....	72	25.25 \pm .07
Eagle Spring S.	3	33	14	.....	.....	50	25.22 \pm .07
Eagle Spring O. ?	3	34	13	.....	.....	50	25.20 \pm .07
Point of Rocks S.	2	37	54	2	.....	.....	95	24.59 \pm .06
Point of Rocks O.	6	63	31	.....	.....	100	25.25 \pm .06
Forest Spring	2	17	100	14	.....	.....	133	24.95 \pm .05
Tubb's Spring	21	28	1	.....	50	25.60 \pm .07
Bradford's Spring	6	39	4	.....	49	25.96 \pm .06
Big Spring	2	36	29	.....	.....	67	25.40 \pm .07
Hidden Spring S.	7	21	4	.....	.....	32	24.91 \pm .10
Hidden Spring O.	3	37	9	1	.....	50	25.16 \pm .08
Fairbanks Ranch	16	3	.....	.....	19	25.16 \pm .08
Fairbanks Spring	2	31	17	.....	.....	50	25.30 \pm .07
Total	4	85	514	258	6	.....	867	25.20 \pm .02
<i>pectoralis</i>								
Lovell's Spring	2	49	38	1	.....	90	25.42 \pm .06
Species total	4	96	765	914	88	3	1,870	25.53 \pm .02

* S. = Source ; O. = Outlet.

TABLE XX
DORSAL TO PELVIC SCALE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Dorsal to Pelvic Scales							No.	$M \pm \sigma_M$
	7	8	9	10	11	12	13		
<i>amargosae</i>									
Death Valley				40	78	22	5	145	10.94 \pm .06
Amargosa Canyon			2	67	30	1		100	10.30 \pm .05
Tecopa			8	62	29	1		100	10.23 \pm .06
Total			10	169	137	24	5	345	10.55 \pm .04
<i>nevadensis</i>									
Saratoga Springs and lake			33	106	24	1		164	9.96 \pm .05
<i>calidae</i>									
South Tecopa Hot Springs		1	61	30	2			94	9.35 \pm .06
North Tecopa Hot Springs			23	12				35	9.34 \pm .08
Total		1	84	42	2			129	9.35 \pm .05
<i>shoshone</i>									
Shoshone Spring S.*		1	22	1				24	9.00 \pm .06
Shoshone Spring O.*		1	27	20				48	9.39 \pm .08
Total		2	49	21				72	9.26 \pm .06
<i>mionectes</i>									
Isaac Ranch			17	33				50	9.66 \pm .07
Deep Spring	1	5	38	3				47	8.91 \pm .07
Eagle Spring S.		6	37	7				50	9.02 \pm .07
Eagle Spring O. ?			16	31	3			50	9.74 \pm .08
Point of Rocks S.		9	27					36	8.75 \pm .07
Point of Rocks O.		1	35	14				50	9.26 \pm .07
Forest Spring		6	60	30	4			100	9.32 \pm .06
Tubb's Spring		1	28	20	1			50	9.42 \pm .08
Bradford's Spring		4	35	5				44	9.02 \pm .07
Big Spring		4	35	9	1			49	9.14 \pm .08
Hidden Spring S.	1	5	24	2				32	8.84 \pm .10
Hidden Spring O.		3	38	9				50	9.12 \pm .07
Fairbanks Ranch			6	14				20	9.70 \pm .10
Fairbanks Spring		1	29	16	2	2		50	9.50 \pm .11
Total	2	45	425	193	11	2		678	9.25 \pm .02
<i>pectoralis</i>									
Lovell's Spring			14	31	4			49	9.79 \pm .08
Species total	2	48	615	562	178	27	5	1,437	9.67 \pm .02

* S. = Source ; O. = Outlet.

TABLE XXI

DORSAL TO ANAL SCALE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Dorsal to Anal Scales					No.	$M \pm \sigma_M$
	7	8	9	10	11		
<i>amargosae</i>							
Death Valley	2	70	51	27	150	9.69 ± .06
Amargosa Canyon	1	70	29	.....	100	9.28 ± .05
Tecopa	70	28	2	100	9.32 ± .05
Total	3	210	108	29	350	9.47 ± .04
<i>nevadensis</i>							
Saratoga Springs and lake	14	102	45	3	164	9.23 ± .05
<i>calidae</i>							
South Tecopa Hot Springs	17	73	9	1	100	8.94 ± .05
North Tecopa Hot Springs	7	31	2	.....	40	8.87 ± .07
Total	24	104	11	1	140	8.92 ± .04
<i>shoshone</i>							
Shoshone Spring S.*	36	27	.....	.....	63	8.43 ± .06
Shoshone Spring O.*	8	40	2	.....	50	8.88 ± .06
Total	44	67	2	.....	113	8.63 ± .05
<i>mionectes</i>							
Isaac Ranch	3	44	3	.....	50	9.00 ± .05
Deep Spring	1	12	36	1	.....	50	8.74 ± .07
Eagle Spring S.	15	33	2	.....	50	8.74 ± .07
Eagle Spring O.?	1	38	11	.....	50	9.20 ± .06
Point of Rocks S.	25	25	.....	.....	50	8.50 ± .07
Point of Rocks O.	11	24	15	.....	50	9.08 ± .10
Forest Spring	19	98	16	.....	133	8.98 ± .04
Tubb's Spring	3	43	3	1	50	9.04 ± .06
Bradford's Spring	29	21	.....	.....	50	8.42 ± .07
Big Spring	10	37	3	.....	50	8.86 ± .07
Hidden Spring S.	1	20	11	.....	.....	32	8.31 ± .09
Hidden Spring O.	13	35	2	.....	50	8.78 ± .07
Fairbanks Ranch	10	10	.....	.....	20	8.50 ± .11
Fairbanks Spring	7	36	7	.....	50	9.00 ± .07
Total	2	178	491	63	1	735	8.84 ± .02
<i>pectoralis</i>							
Lovell's Spring	5	43	2	.....	50	8.94 ± .05
Species total	2	268	1,017	231	34	1,552	9.02 ± .02

* S. = Source ; O. = Outlet.

TABLE XXII
 PREDORSAL SCALE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Predorsal Scales										No.	$M \pm \sigma_M$
	15	16	17	18	19	20	21	22	23	24		
<i>amargosae</i>												
Death Valley		2	12	34	47	47	32	18	7	1	200	19.67 ± .11
Amargosa Canyon			14	30	26	14	11	4	1		100	18.94 ± .14
Tecopa			9	39	25	17	6	3		1	100	18.86 ± .13
Total		2	35	103	98	78	49	25	8	2	400	19.29 ± .08
<i>nevadensis</i>												
Saratoga Springs and lake		15	48	58	33	9					163	17.83 ± .08
<i>calidae</i>												
South Tecopa Hot Springs		8	35	39	13	3	1				99	17.71 ± .10
North Tecopa Hot Springs		3	12	16	7		1				39	17.79 ± .16
Total		11	47	55	20	3	2				138	17.73 ± .08
<i>shoshone</i>												
Shoshone Spring S.*	4	17	19	11	3						54	16.85 ± .14
Shoshone Spring O.*		3	17	39	34	12	4	1	1		111	18.50 ± .11
Total	4	20	36	50	37	12	4	1	1		165	17.96 ± .11
<i>mionectes</i>												
Isaac Ranch		5	19	20	4	1					49	17.53 ± .12
Deep Spring	1	14	27	23	2						67	17.16 ± .10
Eagle Spring S.	3	9	19	14	3	2					50	17.22 ± .16
Eagle Spring O.?		1	16	21	9	2	1				50	17.96 ± .13
Point of Rocks S.	9	25	33	18	6	1					92	16.89 ± .11
Point of Rocks O.	1	18	31	34	10	6					100	17.52 ± .11
Forest Spring	4	24	59	37	6	1					131	17.15 ± .08
Tubb's Spring		6	14	19	8	3					50	17.76 ± .15
Bradford's Spring		3	8	22	6	4	1				44	18.07 ± .16
Big Spring		6	18	28	12	3					67	17.82 ± .12
Hidden Spring S.	1	4	13	10	3	1					32	17.41 ± .18
Hidden Spring O.		5	16	20	6	2	1				50	17.74 ± .15
Fairbanks Ranch		1	5	7	1						14	17.57 ± .19
Fairbanks Spring	2	6	13	16	8	4	1				50	17.76 ± .18
Total	21	127	291	289	84	30	4				846	17.47 ± .04
<i>pectoralis</i>												
Lovell's Spring		10	19	38	17	4	2				90	17.91 ± .12
Species total	25	185	476	593	289	136	61	26	9	2	1,802	17.99 ± .03

* S. = Source ; O. = Outlet.

TABLE XXIII

CIRCUMFERENCE OF PEDUNCLE SCALE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Circumference of Peduncle Scales								No.	M
	11	12	13	14	15	16	17	18		
<i>amargosae</i>										
Death Valley					3	120	22	5	150	16.19
Amargosa Canyon				3	6	90	1		100	15.89
Tecopa					3	90	4	3	100	16.07
Total				3	12	300	27	8	350	16.07
<i>nevadensis</i>										
Saratoga Springs and lake		2	8	12	14	127			163	15.57
<i>calidae</i>										
South Tecopa										
Hot Springs		1	1	4	14	80			100	15.71
North Tecopa										
Hot Springs				7	9	24			40	15.43
Total		1	1	11	23	104			140	15.63
<i>shoshone</i>										
Shoshone Spring S.* ..		1	9	29	13	10			62	14.35
Shoshone Spring O.* ..			2	6	12	64			84	15.64
Total		1	11	35	25	74			146	15.09
<i>mionectes</i>										
Isaac Ranch				6	8	36			50	15.60
Deep Spring		11	17	26	9	10			73	13.86
Eagle Spring S.		6	13	16	7	8			50	13.96
Eagle Spring O. †			1	10	12	27			50	15.30
Point of Rocks S.	1	34	32	22	4	2			95	13.00
Point of Rocks O.		4	16	22	22	36			100	14.70
Forest Spring		47	33	39	8	6			133	13.19
Tubb's Spring		6	3	15	8	18			50	14.58
Bradford's Spring			4	3	2	8			17	14.82
Big Spring		12	10	16	2	26	1		67	14.34
Hidden Spring S.		13	12	6		1			32	12.87
Hidden Spring O.		2	7	15	11	15			50	14.60
Fairbanks Ranch			1	4	5	9			19	15.16
Fairbanks Spring		3	3	9	8	25	1	1	50	15.12
Total	1	138	152	209	106	227	2	1	836	14.17
<i>pectoralis</i>										
Lovell's Spring			1	15	17	56			89	15.44
Species total	1	142	173	285	197	888	29	9	1,724	14.95

* S. = Source; O. = Outlet.

TABLE XXV
PREORBITAL PORE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Preorbital Pores									No.	M
	0	1	2	3	4	5	6	7	8		
<i>amargosae</i>											
Death Valley	7	2	8	10	26	19	61	12	5	150	4.91
Amargosa Canyon	4	1	6	2	5	13	60	9	.....	100	5.27
Tecopa	3	.....	2	3	7	11	58	14	2	100	5.58
Total	14	3	16	15	38	43	179	35	7	350	5.21
<i>nevadensis</i>											
Saratoga Springs and lake ...	7	2	7	2	10	36	119	23	8	214	5.52
<i>calidae</i>											
South Tecopa Hot Springs ...	13	.....	3	1	2	13	61	5	1	99	4.96
North Tecopa Hot Springs ...	2	1	1	1	2	7	26	.....	.....	40	5.13
Total	15	1	4	2	4	20	87	5	1	139	5.01
<i>shoshone</i>											
Shoshone Spring S.* .....	.....	.....	.....	.....	2	4	54	3	.....	63	5.92
Shoshone Spring O.*	1	.....	.....	.....	3	6	83	8	3	104	5.96
Total	1	.....	.....	.....	5	10	137	11	3	167	5.95
<i>mionectes</i>											
Isaac Ranch	7	.....	2	.....	7	3	27	3	.....	49	4.69
Deep Spring	2	.....	2	.....	5	11	48	2	.....	70	5.44
Eagle Spring S.	1	.....	1	.....	3	7	33	4	1	50	5.66
Eagle Spring O. ?	6	.....	7	.....	4	5	24	3	1	50	4.56
Point of Rocks S.	2	1	2	5	18	22	41	1	1	93	4.98
Point of Rocks O.	2	1	2	1	6	10	69	7	2	100	5.61
Forest Spring .....	.....	1	.....	1	4	9	112	6	.....	133	5.86
Tubb's Spring .....	.....	.....	.....	.....	1	7	38	4	.....	50	5.90
Bradford's Spring	3	.....	1	2	3	6	14	2	.....	31	4.77
Big Spring	5	.....	.....	3	7	9	37	3	.....	64	5.08
Hidden Spring S. ....	.....	.....	1	.....	4	2	13	.....	.....	20	5.30
Hidden Spring O. ....	.....	.....	.....	.....	1	3	41	5	.....	50	6.00
Fairbanks Ranch	9	.....	.....	.....	1	.....	2	1	.....	13	.....
Fairbanks Spring .....	.....	.....	.....	3	4	8	27	2	.....	44	5.48
Total	37	3	18	15	68	102	526	43	5	817	5.34
<i>pectoralis</i>											
Lovell's Spring .....	.....	.....	1	.....	5	5	80	8	1	100	5.91
Species total	74	9	46	34	130	216	1,128	125	25	1,787	5.40

* S. = Source ; O. = Outlet.

TABLE XXVI
PREOPERCLAR PORE COUNTS IN SUBSPECIES OF *Cyprinodon nevadensis*

Subspecies and Locality	Preoperclular Pores											No.	$M \pm \sigma_M$					
	7	8	9	10	11	12	13	14	15	16	17							
<i>amargosae</i>																		
Death Valley					4	72	39	32	3								150	12.72 ± .07
Amargosa Canyon					2	68	21	9									100	12.37 ± .07
Tecopa						64	20	13	3								100	12.55 ± .08
Total					6	204	80	54	6								350	12.57 ± .04
<i>nevadensis</i>																		
Saratoga Springs and lake				1	11	153	29	16	3					1			214	12.29 ± .05
<i>calidae</i>																		
South Tecopa Hot Springs	1			4	1	48	31	12	2					2			100	12.60 ± .10
North Tecopa Hot Springs	1				3	22	10	4									40	12.25 ± .18
Total	1			4	4	70	41	16	2					2			140	12.50 ± .09
<i>shoshone</i>																		
Shoshone Spring S.*				2	2	40	15	4									63	12.27 ± .10
Shoshone Spring O.*				1		63	17	19	3								104	12.64 ± .10
Total				3	2	103	32	23	3								167	12.50 ± .07
<i>mionectes</i>																		
Isaac Ranch						35	11	3									49	12.35 ± .08
Deep Spring				1	2	38	18	12	1								72	12.57 ± .11
Eagle Spring S.		1		1	1	26	15	6									50	12.40 ± .14
Eagle Spring O. ?						24	10	14	1					1			50	12.90 ± .14
Point of Rocks S.				1	2	55	20	18									96	12.54 ± .09
Point of Rocks O.				3	4	50	24	17	2								100	12.54 ± .10
Forest Spring					3	98	21	11									133	12.30 ± .06
Tubb's Spring			1		2	32	8	6									49	12.31 ± .13
Bradford's Spring				1		16	10	5	3								35	12.77 ± .18
Big Spring					1	39	18	8									66	12.50 ± .09
Hidden Spring S.					1	16	5	6									28	12.57 ± .16
Hidden Spring O.					1	35	5	9									50	12.44 ± .11
Fairbanks Ranch						11	4	4						1			20	12.80 ± .24
Fairbanks Spring					1	36	11	1									49	12.24 ± .07
Total		1	1	7	18	511	180	120	7					2			847	12.48 ± .03
<i>pectoralis</i>																		
Lovell's Spring					1	24	18	54	1					2			100	13.36 ± .10
Species total	1	1	1	15	42	1,065	380	283	22					7			1,818	12.53 ± .02

* S. = Source; O. = Outlet.

Cyprinodon diabolis Wales

(Pl. VII)

In 1930 Wales provisionally described this very interesting *Cyprinodon*, which is probably the most unusual species in the genus. The detailed study which I have subsequently made clearly indicates its specific distinctiveness (Tables I, XXVIII-XXXI).

DIAGNOSIS.—This dwarfed species (usually not much larger than 20 mm. in standard length) is exceptional in *Cyprinodon* for the lack of pelvic fins, the convex caudal fin, the absence of scales on the preorbital region, and the lack of vertical cross bars in mature females. The dorsal is very posterior in position, and the caudal peduncle is short, whereas the head and eye are very large, the mouth is wide, and the anal fin as measured along the posterior rays is extremely long (Table XXVIII). In the males the dorsal fin has a golden iridescence, and the anal fin is whitish toward the base. Females lack a spot at the base of the dorsal fin. The usual sexual dimorphism in size of fins is lacking or reversed. The dorsal and caudal fins of the females are as large as, or larger than, those of the males, and there is almost no sexual dimorphism in the size of the pectoral fins.

COMPARISONS.—Most of these characters are completely diagnostic, but some are shared with one or a few other species. Thus, *Cyprinodon laciniatus* Hubbs and Miller (1942: 4-5) and certain races of *C. nevadensis* often lack one or both pelvic fins or have these fins reduced in size and ray number. The absence of preorbital scales is a character also of *C. salinus*, next to be described, and of certain forms of *C. bovinus*, a species of the Río Grande and the Red River drainages, but in *diabolis* this naked region is generally larger. Some specimens of *C. radiosus* (described below) lack the dark spot on the dorsal fin in the young and females.

It is significant that a number of the characters of *diabolis* are juvenile features and that dwarfing is probably also an expression of the retention of juvenile traits. A comparatively large head and eye and a long anal fin are characters seen in the young of *nevadensis*, and in these respects the representatives of that species in Ash Meadows, which are themselves somewhat dwarfed, all approach *diabolis* (Table XIII).

I have examined 195 specimens of *diabolis* (representing 390 counts) for presence or absence of pelvic fins and in this series 1 fish had 1 pelvic ray on the right side of the body. Wales (1930: 65) reported 1 specimen with 1 fin of 6 rays. Thus, pelvic fins are almost never developed.

The dorsal and anal rays average higher than in any other species of the Death Valley system, although the average for dorsal rays in the Owens Valley species, *radiosus*, is almost identical. The pectoral rays are rather numerous. The caudal ray counts are low, perhaps because it is very diffi-

cult to obtain a reliable or complete count in specimens as small as those of *diabolis*. All of the fin-ray counts are enumerated in Table XXIX.

The scales average fewer in the lateral series than in most species of *Cyprinodon*, but are only moderately large elsewhere. Particularly significant is the unexpectedly high count around the body, for in the other representatives of *C. nevadensis* in Ash Meadows, this count is low, averaging 20 to 24 (25 in *pectoralis*), rather than 26 as in *diabolis* (Tables XIX–XXIV, XXX).

C. n. pectoralis is not only similar to *diabolis* in having a comparatively high scale count around the body but also approaches that species in having a larger head and eye, longer anal fin, and more pectoral rays than any other population of *nevadensis* in Ash Meadows. It differs strikingly from *diabolis*, however, in having well-developed pelvic fins, fewer dorsal rays (average 9.5 rather than 11), and in coloration (Tables XIII–XIV, XVI–XVII, XXIV, XXVIII–XXX).

The number of preopercular pores, added together for both sides, is higher in *diabolis* than in *nevadensis*, but is equaled by *salinus* and exceeded by *radiosus* (Table XXXI). Again, *C. n. pectoralis* averages significantly higher (13.36) in number of preopercular pores than does any other population of *nevadensis* studied. The preorbital pores of *diabolis* are only slightly more numerous than in the other species of the Death Valley region (Table XXXI).

The form and color pattern of *diabolis* are shown in Plate VII, and the proportionate measurements are listed in Table XXVIII.

The gill rakers of this species are few, and the counts virtually do not overlap those for *salinus*. The Ash Meadows populations of *nevadensis*, however, have almost as few and those of *radiosus* overlap widely (Table XXXI).

HABITAT.—This species is confined to a single, isolated spring hole in Ash Meadows, Nye County, Nevada, at an elevation of approximately 2300 feet (Map 3). This unique habitat, appropriately named Devil's Hole, is near the base of a low range on the eastern border of Ash Meadows. The spring pool (Pl. XIII, Figs. 1 and 2) in this hole is about 50 feet below the land surface and apparently represents a water-formed cave, the roof of which has collapsed.

The descent into the hole is a sheer drop on all but the western side, where one can scramble down the walls of a narrow rocky crevasse. The clear pool of deep blue water is nearly 65 feet long and 8 to 10 feet wide, and there is no apparent inlet or outlet. The clarity of the water and a barely perceptible current at the eastern end indicate that the water in the hole is constantly being changed.

A rocky ledge at the western end of the pool, approximately 18 feet long, slopes gradually to the east, where its border is marked by a vertical drop into the unknown depths of Devil's Hole. The water over this ledge varies in depth from a few inches to 2 feet, and the eastern half was largely covered with green algae in September, 1942. This is the only vegetation I have seen in Devil's Hole during a number of visits since 1936, and none was noticed prior to 1938. Wales (1930: 61) also noted the absence of plant life. Most of the fish stay on the shallow ledge, and only a few stragglers have been seen over the deep water. No fish were noted in the eastern end of the pool, where scum covered much of the water surface.

The water temperature of this pool has been recorded by several investigators (data summarized in Table XLI), and their readings show that it is remarkably constant seasonally and yearly. The variation of 32.8° C. to 33.9° C. represents records taken during all seasons of the year over a period of 15 years.

VARIATION.—In obtaining the values for the meristic characters of *diabolis*, I studied material covering 8 separate collections made over a period of 11 years, including paratypes collected in March, 1930, by Myers and Wales.

These counts (Tables XXIX–XXX) show little variation, particularly for the number of scales around the peduncle and around the body, and the number of head pores. The caudal rays appear to be equally variable in both *diabolis* and *nevadensis*, but the lower limit of the range of variation in *diabolis* is almost surely extended because of the unreliable caudal counts for small specimens.

The small amount of variation is presumably due in part to isolation and long inbreeding and in part to the nearly constant temperature of the spring in which *diabolis* lives.

RELATIONSHIPS.—In the diagnostic feature of scale structure (Table I) *Cyprinodon diabolis* is aligned with all of the species of the Death Valley system. It is obviously not directly related to either *salinus* of Salt Creek, Death Valley, or to *radiosus* of Owens Valley, but rather to the more widespread species *nevadensis*. It is perhaps significant that the population of *nevadensis* geographically nearest *diabolis*, namely the subspecies *C. n. pectoralis* of Lovell's Spring, is the one most similar to *diabolis* (as is indicated above). *C. n. pectoralis* obviously belongs to the *nevadensis* complex, but may have been derived from the ancestral stock which gave rise to *diabolis*, or the similarities between the 2 may be of independent origin.

The fish inhabiting Devil's Hole very likely have been isolated from the adjacent populations of *nevadensis* in Ash Meadows for a much longer period than have any populations of that species throughout the Amargosa River basin. The greatly dissected lacustrine beds along the eastern side

of Ash Meadows and around Fairbanks Ranch (Pl. XIV, Fig. 1) indicate that a lake once covered the area. The great dissection of these beds, their almost complete obliteration, and the tilting which has taken place since their deposition, all suggest that the lake was older than others of the Death Valley system (Miller, 1946: 43-47, Fig. 1), perhaps middle or early Pleistocene in age.

When the lake existed, presumably *Cyprinodon* in Ash Meadows comprised a single kind. As the waters subsided, a stock became isolated in Devil's Hole and has been effectively cut off from communication with other stocks ever since. Thus, the evolution of *diabolis* is similar to that of *salinus*, in that each species was derived from a *nevadensis*-type of ancestor and each was early isolated from this more widespread form. Both have undergone considerable evolution since their isolation, and if they were presented to a systematist unfamiliar with the group, he would probably place them in separate genera.

Cyprinodon diabolis was recently erroneously listed from California by Shapovalov (1941: 444).

The results of the proportional measurements and of the various counts made on this species are presented in Tables XXVIII-XXXI; the comparison with other western species of *Cyprinodon* is shown in Table I.

Cyprinodon salinus Miller

(Pl. VIII)

This distinctive species of *Cyprinodon* was recently described and figured (Miller, 1943b) during the course of the present study. It lives in Salt Creek, a saline stream about midway on the barren floor of Death Valley, 180 to 250 feet below sea level (Pl. XV). Salt Creek flows through a canyon or narrows for about 2 miles and then dwindles out into the desert sands. A dry wash extends southward about 30 miles to Bad Water, 280 feet below sea level. This is also the sink of the Amargosa River, which in extreme floods enters from the south.

DIAGNOSIS.—A very slender *Cyprinodon*, with the dorsal fin much nearer the caudal base than the tip of the snout, with very small and much crowded scales, and with a prominent ridge on the outer face of the tricuspid teeth. As in *diabolis*, most of the preorbital region is scaleless.

The only information I wish to add to the original description deals with the probable length of time during which *salinus* has evolved. During the existence of Pleistocene Lake Manly, which covered nearly all of the floor of Death Valley, it is assumed that an ancestral form of the *nevadensis* type was rather widespread, but as the lake disappeared part of the stock became isolated in Salt Creek. Blackwelder (1933) tentatively correlated Lake Manly with the Tahoe stage of glaciation in the California Sierra Nevada

and that stage was believed by Blackwelder (1941: 918) to be approximately contemporaneous with the early Wisconsin stage of the last great ice advance in eastern North America. Antevs (in Daly, 1934: 84-86) gave the duration of the Wisconsin as 30,000 years. The duration of postglacial time is generally estimated to be 10,000 to 15,000 years. This means, therefore, that *salinus* and *nevadensis* have probably been isolated some 20,000 years or more.

Cyprinodon salinus is compared with the other western species of this genus in Table I and in Tables XXVIII-XXXI.

Cyprinodon radiosus, new species

(Pl. IX)

TYPES.—The holotype, a mature female 34 mm. long to caudal base, was seined by Robert R. and Ralph G. Miller in the northwestern spring-feeder of Fish Slough, about 10 miles north of Bishop, in Mono County, California, on July 26, 1937; U.M.M.Z. No. 146653. The 378 paratypes include 28 young to adult, U.M.M.Z. No. 133007, 19 to 44 mm. long, taken with the holotype; 123 young to adult, U.M.M.Z. No. 124843, from the same locality, collected by Carl L. Hubbs and family and Robert R. Miller on July 26, 1938; and 69 young to adult, U.M.M.Z. Nos. 131155 and 138317, taken from the same locality as the holotype, by F. B. Sumner and M. C. Sargent, April 24-26, 1939.

DIAGNOSIS.—A *Cyprinodon* closely resembling the lower Colorado River species *C. macularius* but with the structural scale pattern of *C. nevadensis*, *C. diabolis*, and *C. salinus* (the other species of the Death Valley System), from which it differs in having a very anterior dorsal fin, a thickened first dorsal ray, a higher average number of dorsal, anal, and pelvic fin rays, no terminal black band on the caudal fin, a much slenderer head, a longer caudal peduncle, and in certain other details of body proportions, coloration, and squamation (Tables I, XXVIII-XXXI).

DESCRIPTION.—The general shape and markings of *Cyprinodon radiosus* are illustrated in Plate IX, and the proportionate measurements in Table XXVIII. The very anterior position of the dorsal fin is further expressed by using a pair of fine dividers and projecting forward the distance between the caudal base and the origin of the dorsal fin, noting the point reached by the tip of the dividers. In 63 males (22 to 41 mm. long) from different localities, this point falls between the tip of the rostrum to well beyond the lower jaw, usually between the tip of the snout and the tip of the lower jaw. In 70 females (25 to 45 mm. long) from the same localities, the point varies from the anterior border of the eye to beyond the tip of the lower jaw, usually falling rather close to the tip of the snout. The dorsal fin is, therefore, much farther forward than in *Cyprinodon nevadensis* (Miller, 1943a:

12-13), and its position affords a reliable means for distinguishing the 2 species. Since in both *diabolis* and *salinus* this fin is as far back as, or farther back than, it is in *nevadensis*, this character distinguishes the new species from all forms in the Death Valley region. As in *Cyprinodon macularius* (Miller, 1943a: 4, 6), the distance between the posterior margin of the humeral process and the tip of the snout stepped into the predorsal length gives ratios varying from 1.4 to 1.7, average 1.49 for males and 1.58 for females (based on about 50 specimens of each sex, see Table I).

The structural markings of the scales immediately distinguish the new species from *macularius* and align it with the other species of the Death Valley system. The interspaces between circuli possess prominent reticula-

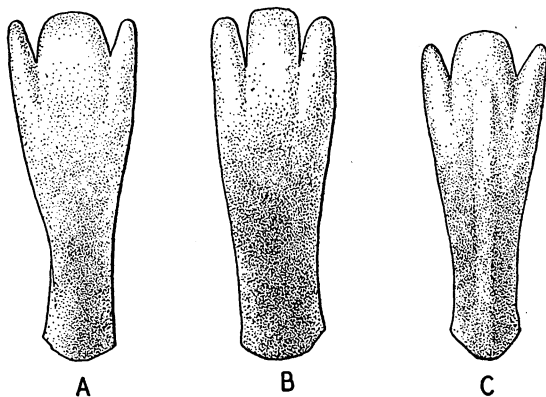


FIG. 2. Mandibular teeth of 3 species of *Cyprinodon*. Drawn by Grace Eager. A. *Cyprinodon macularius*. Outer face of tooth from middle of lower jaw of female, U.M.M.Z. No. 133172, 35 mm. long, from Wise Ranch near Mecca, California. Length, 0.51 mm. B. *Cyprinodon nevadensis*. Outer face of tooth from middle of lower jaw of female, U.M.M.Z. No. 133159, 34 mm. long, from main pool at Saratoga Springs, Death Valley, California. Length, 0.56 mm. C. *Cyprinodon salinus*. Outer face of tooth from middle of lower jaw of female paratype, U.M.M.Z. No. 132941, 32 mm. long, from Salt Creek, Death Valley, California. Length, 0.57 mm.

tions, and upturned projections along the circuli, which characterize the scales of *macularius* (Miller, 1943a: Pl. V and Pl. VII, Fig. 1), are absent. The scales vary in shape from as deep as broad to deeper than broad, and the number of radii varies from 13 to 23 (average, 17.00). In these 2 features the scales of the new species are somewhat intermediate between *nevadensis* and *macularius*. The number of scales is similar to that of most species of *Cyprinodon* (Table XXX). These counts are based on specimens from the known range of the species.

The teeth of the new species are very similar to those of *Cyprinodon macularius* (Fig. 2A). They differ principally in the shape of the central cusp, which, as in *nevadensis*, is truncate rather than spatulate. As in

macularius, the shaft of the tooth is expanded in the distal part and constricted basally; the constriction is perhaps more abrupt and somewhat nearer the base of the tooth in the new species. The outer cusps are rather narrow and pointed, and the median cusp is broad, about 2 to 3 times the width of either lateral cusp. The depth of incision between the cusps is shallow.

The preorbital squamation is like that of most species of *Cyprinodon*. The scales usually extend upward in front of the eye to the level of the middle of the pupil or to the nostrils. The squamation between the pelvic fins is more variable. In about half of the specimens examined, there is only a single, large median scale between the base of each pelvic fin, but the position of this scale is variable, and the character does not afford a reliable specific difference. As pointed out by Myers (1935: 302), the basal scales usually number 2 to 5 in *Cyprinodon*.

Many of the fin rays average higher than in the other species of the Death Valley system, except that in *C. diabolis* the number of dorsal and anal rays is about the same. That species, however, lacks pelvic fins. The fin-ray counts are listed in Table XXIX. It is noteworthy that the rays in the anal fin average fewer than they do for the dorsal fin. This is a reversal of the relationship between these fins in *nevadensis*, *diabolis*, *salinus*, and probably other species of *Cyprinodon*.

The pelvic fins are never absent as they are occasionally in *C. salinus* and frequently in *C. nevadensis*, and the number of rays, 7-7, is the same as in *C. macularius* (Miller, 1943a: 4, 9-11; 1943b: 73). Among the 379 specimens studied for this character, only 5 exhibited abnormalities in these fins. In 2 of these specimens, the left fins had 3 and 4 rays only (whereas the right had 7 rays) and were one-third to one-half the size of their partners. In the other 3 specimens, 1 fin was dwarfed without a reduction in ray number. Forty-two of the 379 fish were less than 21 mm. in standard length, but most of the abnormalities occurred among fish of slightly larger size. The pelvics, however, are somewhat intermediate in size between those of *nevadensis* and *macularius*. In contrast to the latter species, the pelvic fins of the males usually reach only to the vent or slightly beyond and never to the origin of the anal fin. In the females, these fins reach the vent or extend slightly beyond (in the largest individuals), and they fall short of the vent in some of the smaller specimens. When the length of the longer fin is stepped into the predorsal length, intermediate ratios result. Those ratios vary from 4.3 to 5.5 (average, 4.85) in the males, and from 4.6 to 6.2 (average, 5.21) in the females. In *macularius* the average is 4.1 for males and 4.7 for females and in *nevadensis* the ratio for males is only rarely less than 5.4 and for females seldom less than 6.0 (Miller, 1943a: 11). This intermediacy is somewhat influenced by the fact that the predorsal length is slightly less in *radiosus* than in *macularius*.

The preopercular pores are similar in number to those of *macularius*, but average higher in the new species. The preorbital pores average considerably fewer than in any other western species of *Cyprinodon*, but are highly variable (Table XXXI).

The gill rakers are about as numerous as are those of *nevadensis*, varying from 15 to 20, usually 16 to 18 (Table XXXI).

The length of the anal fin of breeding males provides a further character which will usually distinguish *radiosus* from most of the other species of *Cyprinodon* in the West. When the length of this fin was stepped into the standard length, for 45 males from Fish Slough, a swamp near Laws, and Morton's Slough (U.M.M.Z. Nos. 131155 and 65961, and S.N.H.M. No. 4230), the ratios varied from 3.2 to 4.1 (average, 3.7). These ratios broadly overlap those for *C. diabolis*, but are less than those for typical *C. nevadensis* (4.1 to 5.1, average, about 4.5) and only very slightly overlap those for *C. salinus* (Miller, 1943b: 77).

VARIATION.—*Cyprinodon radiosus* is rather variable in certain body proportions. The measurements of anal origin to caudal base, body depth and width, and basal length and length of the dorsal and anal fins, show a considerable range of variation (Table XXVIII). Most of the counts, however, exhibit symmetrical distribution curves.

The material from the 3 localities studied (Fish Slough, swamp near Laws, and Morton's Slough near Independence) seems to represent 2 distinct populations, Fish Slough and Laws contrasting with Morton's Slough. This is to be expected since the first 2 localities are only 7 to 8 miles distant, whereas Morton's Slough is about 40 miles south of Laws.² These 3 populations may represent 2 local races. The most striking meristic difference between them is in the number of dorsal, anal, pectoral, and pelvic fin rays, which average lower in the specimens from Morton's Slough, as expressed by a character index (Table XXVII).

Six proportional measurements were made on 10 specimens of each sex from the Morton's Slough collection. These were: predorsal length, body depth, caudal peduncle length and least depth, pectoral length, and pelvic length. The 10 males of Morton's Slough agree very well in all of these measurements with those measured in the Fish Slough samples. In a comparison of the 10 females from each locality, those at Morton's Slough have a more posterior dorsal fin (predorsal length 541 to 570, average, 555, in contrast to 531 to 553, average, 543), a slightly shorter caudal peduncle (244 to 269, average, 255, rather than 255 to 280, average, 268), and some-

² The old name "Morton's Slough" is not recognized at the present time by local inhabitants and is not indicated on available maps. According to the U. S. Geological Survey, Mount Whitney Quadrangle, there are several sloughs 6 to 12 miles north of Independence, 1 of which may represent this locality.

what shorter pelvic fins (87 to 107, average, 97, in contrast to 101 and 114, average, 107). Otherwise they agree well with the Fish Slough females. No proportional measurements were made for the collections from Laws.

SEXUAL DIMORPHISM AND COLORATION.—*Cyprinodon radiosus* exhibits much less pronounced sexual dimorphism in proportional measurements than do most species of *Cyprinodon* (Table XXVIII). As in nearly all species of the genus, the scales of nuptial males bear prominent ctenii or contact organs. These ciliations are most conspicuous on the sides of the head (below the level of the eye), and, to a lesser extent, along the sides of the body between the dorsal and anal fins. The middle and distal parts of the anal fin of breeding males also bear distinctive tubercles. These features (and the

TABLE XXVII

FREQUENCIES OF THE CHARACTER INDEX FOR FIN-RAY COUNTS IN POPULATIONS OF
Cyprinodon radiosus

The index was derived by summing the counts for the dorsal, anal, pectoral, and pelvic rays. The rays of both pectoral and pelvic fins were counted.

Locality	Character Index											No.	$M \pm \sigma_M$
	61	62	63	64	65	66	67	68	69	70	71		
Fish Slough*	1	3	13	9	17	18	11	2	1	.....	.....	75	65.03 ± .19
Laws	2	1	5	9	8	8	7	8	.....	.....	1	49	65.45 ± .29
Morton's Slough	7	10	17	5	9	2	.....	.....	.....	.....	.....	50	63.10 ± .20

* This sample is based on 2 collections, U.M.M.Z. Nos. 124843 and 133007 (including the holotype, U.M.M.Z. No. 146653).

nuptial coloration, see below) are apparent, however, only during the breeding season, which appears to be unusually short in this species. Adequate collections made in July (1937 and 1938) and August (1915), at a time of year when *C. nevadensis*, *C. macularius*, *C. salinus*, and other species are still breeding, contained no ripe males or females. Of the material examined by me, only the lots collected by Sumner and Sargent between April 24–26, 1939, contained fish in breeding condition. That the season is short and intense is further attested by the remarks of Sumner and Sargent (1940: 47), who were unable to use this species for experimental work in the field because the fish died within a few hours to a day or so after capture, "even when kept in screen cages immersed in the springs from which they had been caught." My father and I have transferred populations of western *Cyprinodon* many times during the spawning season, with exceedingly low mortality (Miller and Miller, 1942).

The features by which the sexes differ are illustrated by Plate IX and Table XXVIII. As usual in *Cyprinodon*, the body, head, and caudal peduncle of the male are deeper, the dorsal is somewhat more anterior in

position, the caudal peduncle is longer, and the fins are larger, particularly the anal.

The markings of the sexes follow the usual dimorphism in this genus. Males possess about 7 or 8 (6-9) vertical bars extending downward from near the mid-line. The lower segments of these bars are often faint and occasionally absent, so that the dorsal parts give the appearance of an interrupted lateral band, similar to that of *Cyprinodon macularius* (Miller, 1943a: Pls. I-II). The area above the mid-line is lighter, with a tendency to form a creamy horizontal band. In both sexes there is often an amber or yellowish bar at the base of the caudal fin. This light bar is set off by a narrow dark band posteriorly and by a broader bar anteriorly (Pl. IX).

The 6 or 7 (5-8) narrower and more prominent crossbars of the females are rather variable in pattern. In some, all of the bars are continuous ventrally, in others they are almost entirely disrupted (as in *macularius*), and intermediate stages of disruption are common. The bars are, however, more often nearly continuous than wholly disrupted. In this respect *radiosus* resembles *nevadensis* more than it does *macularius*. As in the males, there is a light area above the mid-line. This is often separated by a weakly pigmented intervening zone into 2 rather distinct horizontal bands (as somewhat indicated in Pl. IX).

The following color descriptions are taken from the preserved nuptial fish collected by Sumner and Sargent. In the males the dorsal fin is blackened, more intensely near the posterior base, except for a rather wide and very conspicuous milky or amber border (weakly shown in the postnuptial male, Pl. IX). This margin is narrow on the anterior part of the fin, but broadens rapidly posteriorly to cover as much as the outermost third of the longest rays. Along the base of the dorsal in many of the specimens there is a dark, medial spot or a smaller posterior spot, or both spots may be present. (These markings are unusual for males.) The anal fin is also black, particularly on the inner parts of the posterior rays, and bears a narrow to moderately wide milky border in the brightest males. The pectorals and pelvics are dusky to black, with light borders. There is no black terminal band on the caudal fin, but instead, a broad milky or amber edge. The absence of a black border on this fin distinguishes *radiosus* from any other known western *Cyprinodon*. The male fish recently illustrated by me (Miller, 1943a: Pls. I-IV, and Pls. I, III-V herein), which do not show such a black band, are not in nuptial condition. Other males from those localities do possess this band.

In gravid females the anal fin has a broad, milky border posteriorly and the dorsal is similar, but with a narrower border. As in the males the caudal has a light border. The dorsal fin occasionally bears a dark splotch, spot, or bar near the posterior base, but this marking is much less conspicu-

ous than is usual in females (and immature) of *Cyprinodon*. This mark is frequently replaced by a medial, basal dark spot or bar. The pectorals and pelvics are plain or dusky, with lighter margins.

The life colors, as noted in the field for the Fish Slough collection of July 26, 1938 (U.M.M.Z. No. 124843), also distinguish the species. The general color tone of the males is blue, overlying the olive of the upper parts and the light slate of the lower parts. The lateral bars are deep purplish, with some gilt between them posteriorly. The lower parts of the head are silvery blue, and very strong spangles are scattered over the back. The ground color of the fins is dusky amber overlaid with blue. The dorsal and anal are strongly blue with an orange-amber margin, which is rather definite on the dorsal in the brightest males.

The general tone of the females is deep olive, but the lateral blotches shade toward rich brown and the vertical bars toward purplish. The lower parts exhibit strong blue reflections and the same reflections are more or less prominent on the anterior sides, cheeks, and back. The fins are yellowish amber, the dorsal and anal with pale posterior borders. Gilt reflections are rather strong on the posterior parts, on the cheeks, and about the isthmus.

The most distinctive features of coloration are the absence of a terminal black band on the caudal fin of nuptial males and the amber border of the dorsal and anal fins.

RANGE AND HABITAT.—*Cyprinodon radiosus* is restricted to Owens Valley proper. Its natural range was from the vicinity of Lone Pine, Inyo County, north to the source springs feeding Fish Slough, Mono County, about 10 to 12 miles north of Bishop.

The habitat of the species has been described previously by Kennedy (1916: 180), Snyder (1917: 205), and Sumner and Sargent (1940: 46-47). In the early part of the century *C. radiosus* was abundant in the shallow sloughs, irrigation ditches, swamps, and bog pastures along Owens River. According to Kennedy, it was particularly common along the edges of a large swamp which lay in the big bend of Owens River, between Laws and Bishop. The abundance of the species in northern Owens Valley at that time is attested by the fact that mosquitoes were relatively uncommon (Kennedy, 1916: 182; Snyder, 1917: 205). Now that the fish has become very scarce mosquitoes are a great pest in this region.

The northwestern spring source of Fish Slough, located in section 13, T. 5 S., R. 32 E. (U. S. Geological Survey, White Mountain Quadrangle), is the most westerly of several large springs feeding Fish Slough. It is the type locality of *radiosus*. At the source and immediate vicinity the spring area is 8 to 30 feet wide. The water is very clear, up to 3 feet deep, and bubbling springs are dispersed at intervals over a bottom of caked quicksand. No vegetation other than overhanging willows and grass was noted

during several visits, and the shore is extensive meadowland. The current is slight. The water temperature in and near the springs, as recorded by several investigators, is probably rather constant throughout the year; the readings varied from 18.5° to 20.8° C.

The elevation at this locality is about 4225 feet. The main part of Fish Slough is more or less creeklike and infested with large carp and a few native fishes.

DEPLETION.—With the establishment of exotic fishes in Owens Valley and the disappearance or marked reduction of marshy areas due to the tapping of the water supply by the Los Angeles aqueduct, *Cyprinodon radiosus* has rapidly disappeared. In 1934, Hubbs found only a few shallow pools along the river near Laws, and these were fishless. Neither in the river here nor at several other localities where the party collected was *Cyprinodon* secured. At that time, however, the species remained in at least 2 places. Osgood R. Smith, then leader of the United States Bureau of Fisheries Mono-Inyo Survey, wrote (*in litt.*) that *Cyprinodon* was abundant in 1934 in Fish Slough proper in "wide, flat, reedy basins, mostly in water only about three to six inches deep and very warm," and that it was common in a spring or series of springs near Owens River, east of Independence.

In July, 1937, my father and I hurriedly investigated the lower and middle reaches of Fish Slough and found principally carp and bass and a few minnows and suckers, but no *Cyprinodon*. In the upper part of the Slough we discovered *C. radiosus* was rather common in the westernmost spring head (the type locality) and observed a few individuals in the outflow of the most northerly of the spring sources, about 1 mile eastward from the type locality. In that year we found only introduced fishes in the many valley sloughs between Independence and Big Pine.

In July, 1938, the type locality was revisited and in April, 1939, Sumner and Sargent (1940: 46-47) collected there. In both of these years *Cyprinodon* was fairly common to abundant in this spring, although none was observed at any distance below the spring head.

During late August and early September, 1942, our party failed to find a single *Cyprinodon* at the type locality or in near-by springs. The apparent disappearance of *radiosus* from these springs is attributed directly to the presence of introduced largemouth bass, *Micropterus salmoides*. That species was absent from these springs in 1937 and 1938 (and presumably in April, 1939). In contrast to earlier years, there were considerably fewer minnows (*Siphateles* and *Rhinichthys*) and suckers (*Catostomus*) in 1942, a reduction presumably correlated with the invasion of the springs by *M. salmoides*. Considerable local inquiry at Bishop and some investigation of waters between Fish Slough and Big Pine failed to reveal any *Cyprinodon* in 1942.

Cyprinodon radiosus is now rare in Owens Valley, and its depletion is believed to be largely the result of the influx of exotic fishes, particularly largemouth bass and carp. The removal of a major part of the natural water supply of the valley has affected the species in reducing its habitat.

RELATIONSHIPS.—The relationships of *Cyprinodon radiosus* are very interesting. In 1 fundamental character, the structural markings of the scale, the new species is definitely aligned with *Cyprinodon nevadensis* and the other species of the Death Valley system. In several other features, particularly the nature of the teeth, position of the dorsal fin, strength of the first dorsal ray, size of the fins, and slenderness of the head, it very closely approaches *Cyprinodon macularius*. In addition, the new species has developed several peculiar characters, of which the nuptial coloration is perhaps the most distinctive. These lines of relationship are very suggestive. In many ways *radiosus* seems to be less specialized than the other species of *Cyprinodon* inhabiting the Death Valley system. The independent evolution of the new species probably began very early, since it has so few of the features common to the forms of the Amargosa River and Death Valley basins. The ancestral type presumably passed through the waters connecting Owens and Death valleys at a time prior to the evolution of *nevadensis*, an hypothesis supported by geological facts (pages 18–19, and Miller, 1946). The presence of a “fossil” waterfall in the lower course of Pleistocene Owens River, just above Little Lake, is also pertinent to the time of isolation of the new species. Although I have not visited this extinct waterfall, I am told that there is a plunge basin. The ancestral form of *radiosus* passed through this section of the ancient river before the origin of the waterfall. Information on its age would be of value.

As already pointed out, the new species is most easily distinguished from *nevadensis*, *salinus*, and *diabolis* by the very anterior position of the dorsal fin (Table XXVIII). The last 2 species have evolved from the *nevadensis* type, likely approximately coincident with the evolution of *radiosus* in Owens Valley. There is also the possibility, however, that the similarity in scale pattern between these species and *radiosus* is of independent origin.

SYNONYMY.—The Owens Valley *Cyprinodon* has heretofore been recorded only under the specific name *Cyprinodon macularius* (Kennedy, 1916: 179; Snyder, 1917: 202, 205; Evermann and Clark, 1931: 55–56; Dill and Shapovalov, 1939: 317–18; and Sumner and Sargent, 1940: 46). That species, as now defined, is confined to the lower Colorado River basin and adjacent waters.

The interesting paper by Kennedy deals with the habitat and feeding habits of the new species. Snyder's brief account is based almost wholly on information from Kennedy. Dill and Shapovalov reproduced (as Fig. 115) the excellent drawing of the female of *radiosus* made by Kennedy. As I

TABLE XXVIII

PROPORTIONAL MEASUREMENTS OF FOUR SPECIES OF *Cyprinodon* FROM THE DEATH VALLEY SYSTEM
EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH

Character	<i>nevadensis</i>		<i>diabolis</i>		<i>salinus</i>		<i>radiusus</i>	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Standard length	26- 45 (34)	384	14- 28 (19)	34	26- 48 (36)	52	23- 41 (33)	52
Predorsal								
Males	564-636 (603)	110	601-654 (631)	20	561-618 (590)	26	517-550 (533)	26
Females	584-647 (613)	106	617-645 (631)	14	581-615 (599)	26	531-570 (548)	26
Prepelvic								
Males	532-606 (570)	118	.....	.....	530-561 (551)	16	511-561 (537)	16
Females	553-619 (581)	112	.....	.....	550-565 (559)	16	525-567 (545)	16
Anal origin to caudal base								
Males	332-424 (377)	195	329-355 (343)	10	364-380 (374)	16	397-437 (417)	16
Females	313-377 (348)	189	315-332 (325)	10	346-368 (355)	16	371-391 (380)	16
Body, greatest depth								
Males	361-519 (430)	120	309-407 (355)	18	330-398 (365)	26	352-477 (417)	25
Females	336-449 (392)	116	304-353 (329)	12	299-346 (321)	26	340-432 (379)	25
Body, greatest width								
Males	215-301 (252)	135	226-255 (237)	10	215-233 (223)	16	196-252 (224)	16
Females	215-303 (254)	131	220-249 (236)	10	218-237 (229)	16	211-238 (224)	16
Head length	281-359 (316)	354	335-375 (354)	34	285-311 (300)	32	291-325 (305)	32
Head depth								
Males	303-403 (346)	125	307-358 (323)	10	285-346 (325)	26	262-301 (277)	16
Females	276-370 (321)	121	292-338 (313)	10	277-314 (291)	26	249-277 (264)	16
Head width	221-277 (247)	216	231-256 (245)	20	213-234 (222)	32	200-235 (219)	32
Caudal peduncle, length								
Males	230-296 (260)	185	184-219 (200)	10	245-272 (260)	26	271-302 (286)	26
Females	214-269 (241)	179	186-201 (195)	10	234-254 (245)	26	244-280 (262)	26
Caudal peduncle, depth								
Males	177-222 (200)	110	159-177 (165)	10	157-198 (182)	26	178-207 (192)	26
Females	159-202 (179)	106	150-165 (157)	10	149-174 (159)	26	159-185 (171)	26
Interorbital, least bony width	97-134 (114)	215	104-125 (115)	20	100-122 (110)	32	106-120 (112)	32
Preorbital, least width	40- 57 (48)	216	39- 49 (43)	20	41- 57 (49)	32	40- 57 (46)	32
Preorbital margin to preopercular angle	139-191 (162)	364	165-184 (175)	20	146-164 (156)	32	141-164 (154)	32

TABLE XXVIII (Cont.)

Character	<i>nevadensis</i>		<i>diabolis</i>		<i>salinus</i>		<i>radiosus</i>	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Eye margin to preopercular angle								
Males	105-147 (124)	110	98-106 (102)	10	96-125 (113)	16	101-117 (107)	16
Females	93-129 (115)	106	93-113 (101)	10	100-113 (106)	16	95-110 (103)	16
Opercle, greatest length	89-147 (106)	364	104-120 (111)	20	88-107 (97)	32	95-108 (102)	32
Snout length	81-112 (97)	236	95-107 (101)	20	92-109 (100)	32	83-106 (93)	32
Orbit length	66- 94 (78)	364	91-121 (107)	34	67- 81 (74)	32	80- 96 (88)	32
Mouth width	101-133 (117)	252	125-145 (135)	20	106-123 (114)	32	91-111 (102)	32
Upper jaw length	99-135 (114)	364	113-134 (122)	20	100-117 (108)	32	97-116 (107)	32
Mandible length	83-114 (98)	216	95-106 (101)	20	92-104 (97)	32	84-102 (93)	32
Dorsal fin, basal length								
Males	163-227 (196)	110	166-201 (180)	10	182-194 (187)	16	187-250 (217)	16
Females	153-211 (179)	106	173-195 (183)	10	161-177 (171)	16	185-221 (203)	16
Dorsal fin, length								
Males	259-339 (294)	120	232-275 (256)	10	263-297 (279)	16	274-344 (311)	16
Females	228-283 (257)	106	247-274 (262)	10	247-261 (252)	16	276-296 (284)	16
Anal fin, basal length								
Males	95-131 (111)	120	125-148 (133)	10	108-125 (114)	16	113-139 (125)	16
Females	86-121 (103)	106	113-135 (121)	10	101-116 (107)	16	103-121 (113)	16
Anal fin, length								
Males	200-280 (229)	195	251-313 (283)	20	207-259 (229)	16	244-292 (261)	16
Females	166-225 (195)	179	203-241 (217)	14	193-210 (202)	16	203-232 (211)	16
Caudal, length middle rays								
Males	187-237 (212)	110	227-254 (239)	10	188-215 (201)	16	221-256 (234)	16
Females	177-233 (200)	104	238-267 (246)	10	176-201 (191)	16	210-249 (221)	16
Pectoral, length longest ray								
Males	194-251 (223)	180	208-228 (216)	10	181-203 (192)	26	201-234 (216)	25
Females	171-235 (201)	177	200-224 (210)	10	170-195 (178)	26	183-210 (196)	25
Pelvic, length longer fin								
Males	73-120 (95)	193	.....	.....	85-107 (94)	26	104-124 (112)	26
Females	37-101 (85)	175	.....	.....	76- 95 (85)	26	87-114 (103)	26

have previously indicated (Miller, 1943a: 15), this figure is not of *macularius*.

ETYMOLOGY.—The name *radiosus* refers to the high number of dorsal, anal, and pelvic rays in the new species.

TABLE XXIX
FIN-RAY COUNTS IN FOUR SPECIES OF *Cyprinodon* FROM THE DEATH VALLEY SYSTEM

Species	Dorsal Rays						No.	$M \pm \sigma_M$				
	8	9	10	11	12	13						
<i>nevadensis</i>	8	420	1,270	236	6	.....	1,940	9.90 \pm .01			
<i>diabolis</i> .....	.....	.....	14	82	28	1	125	11.13 \pm .05		
<i>salinus</i>	2	75	69	4	.....	.....	150	9.50 \pm .05		
<i>radiosus</i> .....	.....	.....	25	110	40	.....	175	11.09 \pm .05	
Anal Rays												
	8	9	10	11	12							
<i>nevadensis</i>	1	187	1,442	258	.....	1,888	10.04 \pm .01				
<i>diabolis</i> .....	.....	.....	2	92	33	127	11.24 \pm .04			
<i>salinus</i> .....	.....	16	131	3	.....	150	9.91 \pm .03			
<i>radiosus</i> .....	.....	1	105	68	1	175	10.39 \pm .04				
Pectoral Rays												
	11	12	13	14	15	16	17	18				
<i>nevadensis</i>	1	1	7	67	902	2,071	592	64	3,705	15.91 \pm .01		
<i>diabolis</i>	1	43	178	14	236	16.86 \pm .03		
<i>salinus</i>	4	58	195	43	300	15.92 \pm .03		
<i>radiosus</i>	7	127	146	18	2	300	14.60 \pm .04		
Pelvic Rays												
	0	1	2	3	4	5	6	7	8	9		
<i>nevadensis</i>	365	9	9	20	141	885	2,774	106	1	2	4,312	5.21
<i>diabolis</i>	388	1	1	390	0.02
<i>salinus</i>	1	11	26	227	35	300	5.94 \pm .04
<i>radiosus</i>	46	293	11	350	6.90 \pm .02
Caudal Rays												
	13	14	15	16	17	18	19	20	21	22		
<i>nevadensis</i>	3	15	206	424	824	290	153	13	1	1,929	17.87 \pm .03
<i>diabolis</i>	1	7	14	19	27	43	2	2	115	16.83 \pm .13
<i>salinus</i>	4	42	87	14	3	150	16.80 \pm .06
<i>radiosus</i>	37	43	35	3	118	17.03 \pm .08

TABLE XXXI
HEAD-PORE AND GILL-RAKER COUNTS IN FOUR SPECIES OF *Cyprinodon* FROM THE
DEATH VALLEY SYSTEM

Species	Preopercular Pores											No.	$M \pm \sigma_M$	
	7	8	9	10	11	12	13	14	15	16	17			
<i>nevadensis</i> ...	1	1	1	15	42	1,065	380	283	22	7	1	1,818	12.53 ± .02	
<i>diabolis</i> .....	.....	.....	.....	.....	.....	.....	5	66	35	16	1	123	14.53 ± .07
<i>salinus</i> .....	.....	.....	.....	.....	.....	2	4	60	22	9	2	99	14.38 ± .09
<i>radiosus</i> .....	.....	.....	.....	.....	.....	1	8	43	55	36	7	150	14.92 ± .08
Preorbital Pores													No.	$M \pm \sigma_M$
0	1	2	3	4	5	6	7	8	9					
<i>nevadensis</i> ...	74	9	46	34	130	216	1,128	125	25	.....	.....	1,787	5.40
<i>diabolis</i> .....	.....	.....	.....	.....	.....	3	87	25	5	1	.....	121	6.29 ± .06
<i>salinus</i> .....	.....	.....	1	.....	2	14	63	16	4	.....	.....	100	6.02 ± .08
<i>radiosus</i>	31	5	19	7	25	23	26	9	5	.....	.....	150	3.59
Gill Rakers													No.	$M \pm \sigma_M$
14	15	16	17	18	19	20	21	22						
<i>nevadensis</i> ...	1	11	46	93	155	109	61	20	6	.....	.....	502	18.19 ± .06
<i>diabolis</i> .....	.....	2	11	8	1	.....	.....	.....	.....	.....	.....	22	16.36 ± .15
<i>salinus</i> .....	.....	.....	.....	.....	1	12	24	12	1	.....	.....	50	20.00 ± .11
<i>radiosus</i> .....	.....	1	12	28	24	8	1	.....	.....	.....	.....	74	17.39 ± .11

GENUS *EMPETRICHTHYS* GILBERT

Empetrichthys Gilbert, 1893: 233-34. Type, *Empetrichthys merriami* Gilbert.

This remarkable genus of cyprinodont fishes is confined to the Death Valley system. It is represented by the type species, *Empetrichthys merriami*, in Ash Meadows of the Amargosa River drainage, and by *Empetrichthys latos*, described herein, in Pahrump Valley. These localities, both in southern Nye County, Nevada, are isolated by a low alluvial divide. The genus has been recorded erroneously from "Death Valley, California" (Jordan and Evermann, 1896: 667; Jordan, Evermann, and Clark, 1930: 182; and Evermann and Clark, 1931: 56).

The following diagnosis of *Empetrichthys* is based on published accounts and on the results of the present study.

DIAGNOSIS.—A funduline cyprinodont with molar, tuberculate, pharyngeal teeth. Jaw teeth conical, biserial or weakly triserial, a few of the outer teeth enlarged. Upper and lower pharyngeal bones greatly enlarged, the lower pharyngeals completely united. Intestine short, about $1\frac{1}{2}$ times the length of the body, forming a sigmoid curve. Scales cycloid, large, imbricated or nonimbricated, rather irregularly arranged, 29 to 33 in lateral series; those of nuptial males with 1 to 3 ctenii or contact organs. Pre-

maxillaries protractile. Jaws unequal, the lower one projecting. Borders of oviduct swollen, but not forming a distinct pouch about the anal fin (as in *Fundulus*). Dorsal and anal fins placed far back on the body, the anal inserted directly under or slightly behind the dorsal. Dorsal with 9 to 13 rays; anal with 10 to 15. Pectorals set low, but with 2 vertical bases; with 15 to 20 rays. Pelvic fins absent. Caudal fin truncate or rounded, with 16 to 23 principal rays. Preopercular pores usually 14 (13 to 16), pre-orbital pores 8 (7 to 9), and mandibular pores 8 (6 to 8) (Tables XXXIV-XXXVI).

The tubercular-shaped molar teeth and the greatly enlarged upper and lower pharyngeal bones (Gilbert, 1893: Pl. 5) are the most distinctive characters of the genus. The lack of pelvic fins is not diagnostic of *Empetrichthys*, for a related genus, *Crenichthys*, as well as other cyprinodonts (*Orestis*, *Cyprinodon diabolis*, and *Tellia*), has independently lost these fins.

RELATIONSHIPS.—During the course of its classification, this singular genus has been assigned to 3 different families by various authors. In his original description, Gilbert (1893: 233-34) correctly placed *Empetrichthys* in the Cyprinodontidae. Garman (1895: 19, 116) retained *Empetrichthys* in this family, concluding that it is "allied to *Fundulus* through the more compressed species." Jordan and Evermann (1896: 631, 667), following Gill (1894: 115), still put all of the cyprinodonts in 1 family, but used the name Poeciliidae. Later, Jordan (1923: 158), following Eigenmann (1920), regarded *Empetrichthys* and *Orestias* (a superficially similar genus of the High Andes) as the only members of a distinct family, the Orestiidae. Recently, Jordan, Evermann, and Clark (1930: 182) even erected a separate family, the Empetrichthyidae, for the sole reception of *Empetrichthys*. Myers (1931: 10) placed *Empetrichthys* in the subfamily Fundulinae of the family Cyprinodontidae, concluding that *Empetrichthys* ". . . appears to have nothing to do with *Orestias*."

Empetrichthys probably originated from *Fundulus*, as was suggested by Garman. The fossil evidence also supports this view for the Death Valley species, *Fundulus curryi* (Miller, 1945: 316-19, Fig. 1), appears to have been strikingly like *Empetrichthys*.

The nearest living relative of *Empetrichthys* is *Crenichthys* of Railroad Valley (Hubbs, 1932) and the White River basin in eastern Nevada (Hubbs and Miller, 1941). Each of these genera retains primitive features along with specializations. Both probably arose from an ancestral stock which differed from *Fundulus* primarily in the lack of pelvic fins.

HABITAT.—Desert warm springs, frequenting the deeper holes; usually uncommon in shallow spring-fed ditches or marshy areas.

TYPE SPECIMEN.—After my work on this genus was completed I examined the 6 specimens of *Empetrichthys merriami* in the United States

National Museum and found that the type (= holotype) was not so labeled. Jordan and Evermann (1896: 667) incorrectly designated the type as U.S.N.M. No. 46101. This jar contains 3 specimens, 41 to 58 mm. in standard length, none of which is the type; that specimen was figured and so labeled by Gilbert (1893: Pl. 5, Fig. 1). In the jar containing U.S.N.M. No. 46102, however, I found the specimen figured by Gilbert and removed it from the other 2 specimens in this jar. The type may now be correctly designated as U.S.N.M. No. 131151, a large female, 67 mm. in standard length.

Empetrichthys merriami Gilbert

(Pls. X and XI)

This species is present only in Ash Meadows (Map 3) of the Amargosa River drainage, where it is rare. Over the 6-year period (1936-42) during which we collected in this region, only 22 specimens have been taken, although we made special efforts to obtain greater numbers. Myers and Wales collected 3 in 1930. Over the same 6-year period, 3861 specimens of *Cyprinodon nevadensis* and 515 of the cyprinid *Rhinichthys osculus nevadensis* Gilbert were secured in Ash Meadows.

The 22 specimens of *E. merriami* were collected from 5 separated springs in the Meadows, namely Deep Spring, Eagle Spring, Point of Rocks Spring (Kings Spring), Forest Spring, and Hidden Spring (Map 3). According to Shapovalov (1941: 445), the type locality is Kings Spring. The largest number taken from a single spring, 13, came from Deep Spring, where neither *Cyprinodon* nor *Rhinichthys* is particularly common. *E. merriami* prefers the deeper springs, where it dwells near the bottom. A description of the habitat of these springs has been given under the account of *Cyprinodon nevadensis mionectes* (pp. 48-52, 56).

The systematic characters of *merriami* are discussed in detail in connection with the description of the new species, *latos*.

DIAGNOSIS.—A deep-bodied, heavy-set species of *Empetrichthys* with a broadly arched predorsal profile, a large, deep head, a rather narrow mouth, a strong mandible, and 29 or 30 scales in the lateral series. The sides are marked by a rather irregular lateral band (Pls. X and XI). The anal rays usually number 14.

There may be some local differentiation in the populations of the different springs, but the material now available is insufficient to determine whether the observed variations are significant.

Empetrichthys latos, new species

(Pls. X and XI)

To date *Empetrichthys* has been regarded as a monotypic genus. Gilbert (1893: 234) had at his disposal only 6 specimens from Ash Meadows and 1

from Pahrump Valley. It is not surprising that he referred that single specimen to *merriami*. A study of the many specimens of *Empetrichthys* which have been taken in recent years from Pahrump Valley convinces me that this isolated basin contains a species distinct from that of Ash Meadows.

The 3 springs from which we have collected *Empetrichthys* in Pahrump Valley are well isolated although only 7 miles apart, and their remnant populations are regarded as comprising 3 distinct subspecies. Several important characters, shared by all 3, distinguish each of these populations from *merriami*. Subspecific rank is assigned the 3 forms because the differences between them appear to be in the average only.

TYPES.—The holotype of the typical form, *E. latos latos*, is an adult female, 43 mm. long, seized by Robert R. and Frances H. Miller on October 5, 1942, from the main spring pool on Manse Ranch, Pahrump Valley, Nye County, Nevada (U. S. Geological Survey, Las Vegas Quadrangle); U.M.M.Z. No. 141855. The type specimens of each subspecies are designated in the subspecific descriptions.

DIAGNOSIS.—A rather slender species of *Empetrichthys* with a gently sloping to convex predorsal profile, a relatively short and slender head, a comparatively broad mouth, a weak mandible, and usually 31 or 32 scales in the lateral series. The sides are marked by a narrow axial streak (Pls. X and XI), which is faint to obsolescent in *E. l. concavus*. The anal rays usually number 12 or 13.

COMPARISON.—*Empetrichthys latos* differs from *E. merriami*, the only other known species of the genus, principally in mouth structure, body shape, and color pattern (Pls. X and XI). In *merriami* the head constricts abruptly in the preorbital region so that the 2 sides of the snout slope markedly toward the tip of the mandible. As a result of this constriction the mouth is narrower. In *latos* the sides of the head are almost parallel all the way to the tip of the mandible, and the mouth is consequently broader. When the mouth is forced open, as with a pair of forceps, the horizontal gape is definitely evident in *merriami*, but is almost eliminated in *latos*. The bones of the premaxillaries and mandible are much weaker and less firmly connected in *latos*.

In *merriami* the predorsal region is broadly convex. The change in slope of the predorsal profile takes place farther forward so that the head is deeper than it is in *latos*. The body is also thicker in *merriami*. The differences in color pattern between the 2 species are well shown in Plate X. In particular the narrow axial streak of *latos* contrasts with the disrupted lateral band of *merriami*.

The large difference in head depth and opercle length between *merriami* and *latos* can be expressed by a character index in which these measurements, expressed in thousandths of the standard length, are added together (Table XXXII).

TABLE XXXII

CHARACTER INDEX FOR HEAD DEPTH AND OPERCLE LENGTH IN
TWO SPECIES OF *Empetrichthys*

The index was derived by adding together the depth of the head and the length of the opercle, expressed in thousandths of the standard length. The sexes are combined.

Locality and Form	Character Index	
	Range (Ave.)	No.
Pahrump Valley		
<i>E. l. latos</i>	372-426 (391)	21
<i>E. l. pahrump</i>	382-413 (396)	20
<i>E. l. concavus</i>	383-421 (402)	19
Total	372-426 (398)	60
Ash Meadows		
<i>E. merriami</i>	414-449 (431)	13

SUBSPECIES AND ECOLOGY.—The 3 subspecies of *Empetrichthys latos* are discussed in order from south to north. The main spring pool on Manse Ranch was selected as the type locality because the population of *E. latos* is larger there and the natural conditions of that spring appear least likely to be seriously altered by man. *Empetrichthys* is the only fish native to Pahrump Valley. Its comparative abundance there may be largely due to lack of competition.

ETYMOLOGY.—The name *latos*, from *latus* and *os*, refers to the wide mouth of the new species.

Empetrichthys latos latos, new subspecies

(Pl. XI)

TYPES.—The holotype has been designated in the description of the species. There are 143 paratypes, U.M.M.Z. No. 140489, 15 to 48 mm. long, taken with the holotype at Manse Ranch, and 34 paratypes, U.M.M.Z. No. 132915, 10 to 50 mm. long, collected by R. R. Miller and Alex J. Calhoun on July 16, 1938, from the outlet of the main spring pool.

DIAGNOSIS AND COMPARISONS.—A subspecies of *E. latos* characterized by a relatively short distance between anal origin and caudal base. In this character the males of *E. l. latos* show little or no overlap with the males of either *E. l. pahrump* or *E. l. concavus*; in the females the values show only slight overlap. The comparatively short distance between the anal origin and the caudal base appears to be influenced by the more posterior position and the short basal length of the anal fin. The head depth is less in the males, and the width of the preorbital is broader in both sexes than in those 2 subspecies, and the snout is longer than it is in *concavus*. The basal length of the anal fin is shorter, but overlaps the figures for the other 2 subspecies. The caudal fin of *latos* is much shorter than it is in

concauus (Pl. XI). On the average the mouth is broader and the dorsal fin more posterior in position than in either *pahrump* or *concauus* (Table XXXIII). The darker pigmentation of *latos* may be due, in part at least, to the darker habitat.

HABITAT.—The main spring pool at Manse Ranch is about 50 feet wide at the head, 10 feet wide at the outlet, and 60 feet long. It is 1 to 6 feet deep and has a silt bottom. The water is crystal clear and chalky blue in a deep hole near the center of the spring. On October 5, 1942, vegetation noted was thick water cress, *Chara*, green algae, and a fine-leaved *Potamogeton*. The shore is a low bank, bordered by cottonwood (*Populus Fremonti?*) and willow, which well shade the pool. The current is moderate in the pool and swift in the outlet. About 50 yards above is a much smaller spring which flows into the head of the pool just described; it contained no fish life.

The temperature of the main spring, as recorded by several investigators over a period of 26 years, is very constant, about 24° C. (23.3° C. to 24.0° C.).

Mr. Sawday, owner of the ranch at the time of our visit, kindly allowed us to collect specimens.

Empetrichthys latos pahrump, new subspecies

(Pl. XI)

TYPES.—The holotype, an adult female, 35 mm. long, was seined by R. R. and F. H. Miller from the marshy overflow of a spring-fed ditch on Pahrump Ranch, 6 miles northwest of Manse Ranch, in Pahrump Valley, Nye County, Nevada; U.M.M.Z. No. 141856. One hundred and forty-two paratypes, U.M.M.Z. No. 140490, 14 to 36 mm. long, were taken with the holotype.

DIAGNOSIS AND COMPARISONS.—A subspecies of *Empetrichthys latos* closely resembling *E. l. latos*, differing principally in the longer distance between anal origin and caudal base. From *concauus* it is readily separated by the much shorter and more nearly truncate caudal fin (Pl. XI). In the length of the anal and caudal fins *pahrump* is somewhat intermediate between *latos* and *concauus*. It also appears to be intermediate in color pattern, but the paleness is very probably influenced by the clay and silt bottom over which the sample was collected. The head is only very slightly concave.

HABITAT.—The 2 main springs on Pahrump Ranch, which rise about 200 yards east of the principal ranch houses, are used extensively for irrigation. Until recently the northern spring contained native fish life, but it was greatly altered by dredging in 1941, and only a few carp were observed there in 1942. The southern spring still harbored a few fish in 1942, but in October of that year most of the population of *pahrump* was in a marshy area about 200 yards from the source of the southern spring. As shown

by readings over a 26-year period, the temperature of the spring sources is constantly about 25° C. (24.7° C. to 25.0° C.); that of the outlets varies somewhat and is usually less than 25° C.

ETYMOLOGY.—This subspecies is named *pahrump* after the valley in which it is found, and more particularly for Pahrump Ranch, which is the more precise type locality.

Empetrichthys latos concavus, new subspecies

(Pl. XI)

TYPES.—The holotype is an adult female, U.M.M.Z. No. 141857, 39 mm. long. It was collected by R. R. and F. H. Miller on October 5, 1942, in a spring on the Raycraft Ranch, about one-half mile north of Pahrump Ranch, Pahrump Valley, Nye County, Nevada. This spring is named on a map (Pl. VIII) in Waring's report (1920). Twenty-six paratypes, U.M.M.Z. No. 140491, 17 to 40 mm. long, were collected with the holotype.

DIAGNOSIS AND COMPARISONS.—A subspecies of *Empetrichthys latos* most closely resembling *E. l. pahrump*, from which it differs chiefly in the much longer and more nearly rounded caudal fin. The rays along the upper and lower borders of this fin are definitely shorter than they are in either *pahrump* or *latos* (Pl. XI). The profile between snout and occiput is most strongly concave in this subspecies. The anal fin of *concavus* is longer than it is in *pahrump*, especially in the female, and much longer than the anal fin of *latos*. In the males the snout is shorter and the body is deeper than in the 2 other subspecies (Table XXXIII). The cheek is deeper than it is in either *pahrump* or *latos*. The axial streak is generally finer and much less conspicuous than it is in the other 2 subspecies, and in some specimens of *concavus* it is obsolescent.

HABITAT.—*E. latos concavus* was collected on Raycraft Ranch from the spring-fed pond, 5 to 25 feet wide and about 40 feet long, and its outlet ditch, 1 to 4 feet wide. The temperature of the spring on October 5, 1942, was 25.3° C., slightly warmer than were the springs on either Manse or Pahrump ranches. The water in the spring pond and outlet was clear but easily roiled because of a bottom of silt and trash. Vegetation noted in 1942 was water cress, *Typha*, and grass. The current in the spring was slight, but rather swift in the outlet. The depth of water was not over 1½ feet. The shore consisted of low banks, willows, and meadowland. According to Waring (1920: 76) this spring has a flow of about 10 gallons a minute. *Empetrichthys* was not common, perhaps because introduced carp were also present.

ETYMOLOGY.—The new subspecies is named *concavus* in reference to the marked concavity of the top of the head.

TABLE XXXIII (Cont.)

Locality and Form	Interorbital, Least Bony Width		Preorbital, Least Width		Preorbital Margin to Preopercular Angle		Eye Margin to Preopercular Angle			
							Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley										
<i>l. latos</i>	100-118 (107)	20	24- 33 (29)	20	147-167 (155)	20	80- 92 (86)	10	84-110 (94)	10
<i>l. pahrump</i>	103-116 (109)	20	20- 28 (24)	20	144-156 (147)	19	80- 91 (85)	10	76- 97 (88)	10
<i>l. concavus</i>	102-115 (107)	19	19- 28 (24)	19	143-158 (151)	19	78- 90 (84)	9	81- 90 (85)	10
Total	100-118 (108)	59	19- 33 (26)	59	143-167 (151)	58	78- 92 (85)	29	76-110 (89)	30
Ash Meadows										
<i>merriami</i>	98-125 (114)	13	24- 36 (28)	13	130-159 (147)	13	81-101 (87)	8	85- 99 (92)	5
	Greatest Length Opercle,		Snout, Length		Orbit, Length				Mouth, Width	
					Males		Females			
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley										
<i>l. latos</i>	107-128 (117)	20	78- 89 (83)	20	69- 95 (81)	10	70- 89 (76)	10	104-125 (113)	20
<i>l. pahrump</i>	108-124 (118)	20	71- 87 (79)	20	75- 84 (80)	10	69- 83 (77)	10	102-113 (105)	19
<i>l. concavus</i>	115-129 (122)	19	66- 79 (73)	19	77- 93 (86)	9	70- 84 (76)	10	102-114 (106)	19
Total	107-129 (119)	59	66- 89 (78)	59	69- 95 (82)	29	69- 89 (76)	30	102-125 (108)	58
Ash Meadows										
<i>merriami</i>	123-140 (132)	13	73- 88 (80)	13	65-104 (84)	8	61- 91 (74)	5	82-107 (97)	13
	Upper Jaw, Length		Mandible, Length				Dorsal Fin, Basal Length			
			Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley										
<i>l. latos</i>	96-112 (103)	20	95-104 (99)	10	93-110 (101)	10	147-171 (159)	10	136-152 (145)	10
<i>l. pahrump</i>	95-105 (101)	20	94-108 (97)	10	89-102 (95)	10	148-165 (158)	10	127-152 (142)	10
<i>l. concavus</i>	92-106 (100)	19	78- 93 (87)	9	93-103 (98)	10	146-165 (157)	9	132-146 (139)	10
Total	92-112 (101)	59	78-108 (95)	29	89-110 (98)	30	146-171 (158)	29	127-152 (142)	30
Ash Meadows										
<i>merriami</i>	89-107 (98)	13	88-105 (97)	8	93-110 (100)	5	138-173 (150)	8	120-145 (136)	5

TABLE XXXIII (Cont.)

Locality and Form	Dorsal Fin, Length				Anal Fin, Basal Length			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley								
<i>l. latos</i>	230-257 (242)	10	216-247 (227)	10	130-153 (139)	10	112-131 (123)	10
<i>l. pahrump</i>	229-259 (244)	10	203-236 (224)	10	151-167 (158)	10	123-143 (133)	10
<i>l. concavus</i>	241-257 (251)	9	217-233 (227)	10	142-165 (155)	9	127-142 (134)	10
Total	220-259 (245)	29	203-247 (226)	30	130-167 (151)	29	112-143 (130)	30
Ash Meadows								
<i>merriami</i>	208-233 (222)	8	195-218 (209)	5	151-179 (160)	8	124-147 (134)	5
	Anal Fin, Length				Middle Caudal Rays, Length			
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley								
<i>l. latos</i>	214-239 (223)	10	181-210 (199)	10	199-221 (211)	10	194-227 (210)	10
<i>l. pahrump</i>	225-251 (239)	10	195-218 (207)	10	215-228 (221)	10	205-224 (214)	8
<i>l. concavus</i>	236-263 (247)	9	213-226 (221)	10	221-246 (232)	9	220-241 (228)	10
Total	214-263 (236)	29	181-226 (209)	30	199-246 (221)	29	194-241 (218)	28
Ash Meadows								
<i>merriami</i>	216-240 (230)	8	191-213 (204)	5	181-215 (197)	6	179-191 (184)	4
	Pectoral, Length Longest Ray							
	Males		Females		Males		Females	
	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.	Range (Ave.)	No.
Pahrump Valley								
<i>l. latos</i>	165-182 (173)	10	163-187 (171)	10				
<i>l. pahrump</i>	165-178 (170)	10	154-168 (162)	9				
<i>l. concavus</i>	170-186 (179)	9	165-186 (173)	10				
Total	165-186 (174)	29	154-187 (169)	29				
Ash Meadows								
<i>merriami</i>	156-189 (174)	7	153-174 (162)	5				

TABLE XXXIV
FIN-RAY COUNTS IN *Empetrichthys latos* AND *E. merriami*

Locality and Form	Dorsal Rays					No.	$M \pm \sigma_M$			
	9	10	11	12	13					
Pahrump Valley										
<i>l. latos</i>		6	60	44	3	113	11.39 ± .06			
<i>l. pahrump</i>		7	46	19	4	76	11.26 ± .08			
<i>l. concavus</i>		1	18	7		26	11.23 ± .10			
Total		14	124	70	7	215	11.33 ± .04			
Ash Meadows										
<i>merriami</i>	1	4	15	6		26	11.00 ± .14			
	Anal Rays									
	10	11	12	13	14	15				
Pahrump Valley										
<i>l. latos</i>	1	10	61	38	3		113	12.28 ± .07		
<i>l. pahrump</i>		8	37	29	2		76	12.33 ± .08		
<i>l. concavus</i>			5	20	1		26	12.85 ± .09		
Total	1	18	103	87	6		215	12.37 ± .05		
Ash Meadows										
<i>merriami</i>			2	7	15	6	30	13.83 ± .15		
	Pectoral Rays									
	15	16	17	18	19	20				
Pahrump Valley										
<i>l. latos</i>		17	106	70	7	1	201	17.35 ± .05		
<i>l. pahrump</i>	1	32	88	16			137	16.87 ± .05		
<i>l. concavus</i>		28	22	2			52	16.50 ± .08		
Total	1	77	216	88	7	1	390	17.07 ± .04		
Ash Meadows										
<i>merriami</i>	1	10	15	12			38	17.00 ± .13		
	Caudal Rays									
	16	17	18	19	20	21	22	23		
Pahrump Valley										
<i>l. latos</i>		4	24	30	31	9	2		100	19.23 ± .11
<i>l. pahrump</i>	1	1	14	16	25	5	1	1	64	19.36 ± .15
<i>l. concavus</i>		1	5	7	11				24	19.17 ± .18
Total	1	6	43	53	67	14	3	1	188	19.27 ± .08
Ash Meadows										
<i>merriami</i>		1	3	6	7				17	19.12 ± .22

TABLE XXXV
SCALE COUNTS IN *Empetrichthys latos* AND *E. merriami*

Locality and Form	Lateral Series Scales					No.	$M \pm \sigma_M$							
	29	30	31	32	33									
Pahrump Valley														
<i>l. latos</i>		5	45	41	5	96	31.48 \pm .07							
<i>l. pahrump</i>	1	14	41	15	2	73	31.04 \pm .09							
<i>l. concavus</i>		4	13	7		24	31.13 \pm .14							
Total	1	23	99	63	7	193	31.27 \pm .05							
Ash Meadows														
<i>merriami</i>	10	9				19	29.47 \pm .11							
	Dorsal to Anal Scales													
	12	13	14	15	16									
Pahrump Valley														
<i>l. latos</i>	25	30	19	16	3	93	13.38 \pm .12							
<i>l. pahrump</i>	2	18	32	12	1	65	13.88 \pm .10							
<i>l. concavus</i>	1	13	9	2		25	13.48 \pm .14							
Total	28	61	60	30	4	183	13.57 \pm .07							
Ash Meadows														
<i>merriami</i>		7	9	3		19	13.79 \pm .16							
	Predorsal Scales													
	23	24	25	26	27	28	29	30	31					
Pahrump Valley														
<i>l. latos</i>		9	17	29	26	9	1				91	26.13 \pm .12		
<i>l. pahrump</i>	4	9	15	17	12	3	1			1	62	25.69 \pm .19		
<i>l. concavus</i>		3	3	9	5	3		1			24	26.25 \pm .28		
Total	4	21	35	55	43	15	2	1	1		177	25.99 \pm .10		
Ash Meadows														
<i>merriami</i>		2	3	5	6	1		2			19	26.63 \pm .36		
	Circumference of Peduncle Scales													
	16	17	18	19	20	21	22	23	24					
Pahrump Valley														
<i>l. latos</i>	9	14	19	5	37	3	6				93	18.86		
<i>l. pahrump</i>	2		11	7	44		1				65	19.46		
<i>l. concavus</i>			3		18	1	2		1		25	20.12		
Total	11	14	33	12	99	4	9		1		183	19.25		
Ash Meadows														
<i>merriami</i>	1		6	4	7	1					19	19.00		
	Circumference of Body Scales													
	27	28	29	30	31	32	33	34	35	36	37	38		
Pahrump Valley														
<i>l. latos</i>	1	2	8	15	12	13	12	7	8	6	5	4	93	32.47 \pm .28
<i>l. pahrump</i>		1	2	2	4	9	13	12	11	7	1	1	63	33.44 \pm .25
<i>l. concavus</i>			2	5	7	4	3	2		1			24	31.50 \pm .34
Total	1	3	12	22	23	26	28	21	19	14	6	5	180	32.68 \pm .18
Ash Meadows														
<i>merriami</i>			1	2	2	4	4	5	1				19	32.42 \pm .36

TABLE XXXVI
HEAD-PORE COUNTS IN *Empetrichthys latos* AND *E. merriami*

Locality and Form	Preopercular Pores				No.	$M \pm \sigma_M$
	13	14	15	16		
Pahrump Valley						
<i>l. latos</i>	1	86	9	3	99	14.14 ± .05
<i>l. pahrump</i>	6	59	1	1	67	13.95 ± .05
<i>l. concavus</i>	1	25	.....	.....	26	13.96 ± .04
Total	8	170	10	4	192	14.05 ± .03
Ash Meadows						
<i>merriami</i>	1	9	2	.....	12	14.08 ± .14
	Preorbital Pores					
	7	8	9			
Pahrump Valley						
<i>l. latos</i>	5	91	3		99	7.98 ± .03
<i>l. pahrump</i>	1	66	.....		67	7.99 ± .01
<i>l. concavus</i> .....	.....	26	.....		26	8.00
Total	6	183	3		192	7.98 ± .01
Ash Meadows						
<i>merriami</i> .....	.....	13	.....		13	8.00
	Mandibular Pores					
	6	7	8			
Pahrump Valley						
<i>l. latos</i> .....	.....	4	95		99	7.96 ± .02
<i>l. pahrump</i>	2	3	62		67	7.89 ± .04
<i>l. concavus</i> .....	.....	1	25		26	7.96 ± .04
Total	2	8	182		192	7.94 ± .02
Ash Meadows						
<i>merriami</i> .....	.....	1	11		12	7.92 ± .08

EXPERIMENTAL WORK ON *CYPRINODON*

The experimental work on the genus *Cyprinodon* was begun by myself and my father, Ralph G. Miller, in August, 1940, and with my supervision has been carried on by him since that time. During the field work in 1942, I checked the progress of the experiments. The results for the 3-year period ending in the fall of 1943 clearly indicate that we have only scratched the surface of several fields of investigation. At this time, therefore, only the broad outlines and general indications of the work can be briefly presented.

The main purpose of this work is to determine whether differences which have been used to distinguish certain races, subspecies, and species of *Cyprinodon* are genetic or environmental, or both. Thus far no complete answer can be given to this important question, but a preliminary analysis of the data obtained strongly indicates that many of the characters are

wholly or in part genetic. In 1942, the first experiments in interspecific hybridization were begun, and 3 such crosses had been tried through 1943. Experiments of this nature have a definite bearing on systematics and are a contribution to the general problem of the genetics of interspecific hybridization in fishes.

The species of *Cyprinodon* used in these experiments and the source of each stock are: (1) *Cyprinodon macularius*, from the basin of the Salton Sea in southeastern California; (2) *Cyprinodon nevadensis*, from Amargosa River in Death Valley, Saratoga Springs in Death Valley, and the outlet of Shoshone Spring, Inyo County; and (3) *Cyprinodon salinus*, from Salt Creek in Death Valley. All of the stocks are from California.

A brief, popular account of the early experimental work with *Cyprinodon* was published recently (Miller and Miller, 1942).

DESCRIPTIONS OF POOLS

With 1 exception all of the pools in which the experiments described below have been conducted were on Ralph G. Miller's grounds in Los Angeles. One pool was used at the home of Mr. Andrew Schlenk,³ also in Los Angeles, where *Cyprinodon macularius* was first raised successfully.

My father used 8 pools (Pl. XIV, Fig. 2). Six, made of concrete, were sunk into the ground of his back yard; the remaining 2, of galvanized iron (specially treated), were on a second floor open porch at the back of the house. They were numbered 1 to 8 and will be discussed in that order.

Pool 1, one of the largest, was oblong, about 6 feet long, 4 feet wide, and 13 inches deep in the deepest part, with a capacity of about 100 gallons. The sides sloped gradually at the east end to a shallower area or platform. Here, where the water was only a few inches deep over a sandy bottom, spawning, hatching, and growth of young took place.

Pool 2, adjacent to Pool 1, was of much smaller size, about 2½ feet wide and 3 feet long, with a maximum depth of 11 inches. The shallow platform was correspondingly smaller than in Pool 1.

Pool 3, against the back-yard fence, was about the size of Pool 2. It held approximately 40 gallons and received little sunlight in winter.

Pool 4, also against the fence next to Pool 3, contained about 50 gallons. It also received little sunlight in winter.

Pool 5, a galvanized iron tank on the upstairs open porch, was 6 feet long, 4 feet wide, and 15 inches deep. A wooden platform was submerged an inch or so at the most exposed part of the tank.

Pool 6, made of concrete, was almost as large as Pool 1. This pool contained a platform of nearly 6 square feet.

³I am very grateful to Mr. Schlenk for making this pool available for the initial experiment with *Cyprinodon*. The success of this first endeavor led to the detailed work later undertaken.

Pool 7, a galvanized iron tank about 4 feet long and 3 feet wide, was adjacent to Pool 5 on the upstairs porch, and had a wooden platform similar to the one in Pool 5.

Pool 8, made of concrete and almost as large as Pool 2, was situated in a well-exposed part of the yard. Pools 6 and 8 received more sunlight than any of the other pools.

TEMPERATURE

The temperature of the 8 Los Angeles pools varied a certain amount at any given time because of differences in size, exposure, and location. Temperature records were kept during certain periods, particularly when the fish were spawning and the young hatching, and also sporadically during the winter to determine how low the temperature fell at that time. This data is admittedly incomplete and too meager to present in tabular form, but it does serve well to indicate how these variations affected the different pools.

Pools 1 and 2 had very similar temperatures. The temperature in Pool 1 was less extreme in range because this pool was larger than Pool 2. Pools 6 and 8 both had higher maximum temperatures than 1 and 2, but very similar minima. Pools 3 and 4, similarly located, also became warmer than 1 and 2 but not much cooler, except during the winter. Pools 5 and 7, located on the out-of-door porch well above the ground, became much warmer during the day and cooler during the night than any of the pools in the yard. Pool 7 had a more extreme range of variation than Pool 5 because it was the smaller of the 2 pools.

The lowest temperature recorded was 2.0° C. on January 2, 1942, in Pool 4. The highest was 32.2° C. on August 18, 1941 (Pools 6 and 7), and August 20-21, 1941 (Pool 5).

FOOD

The fish raised in Los Angeles were fed "Balto" dog and cat food, a fish product, several times a week during the breeding season. This diet supplemented the rather limited natural food supply. Live brine shrimp (*Artemia*) were also often fed to them. In the winter, or during cold periods, the fish were dormant and no feeding was necessary.

INTERSPECIFIC CROSSES

Three interspecific combinations have been attempted thus far: (1) *Cyprinodon macularius* × *C. salinus*; (2) *C. nevadensis* × *C. salinus*; and (3) *C. macularius* × *C. nevadensis*. In the attempt to cross *macularius* and *salinus*, females of *macularius* were mated with males of *salinus*. No young resulted. In the only other experiment involving *salinus*, 2 *C. n. nevadensis* males were placed in the same pool with 7 Salt Creek females. The matings

were started March 25, 1942. On April 11, 1942, the first hybrid was discovered and 2 more were observed the following day. By May 22, 1942, when the pool was drained, 50 hybrids were found. Second, third, and fourth generation hybrids were born on August 6, 1942, April 18, 1943, and August 26, 1943, respectively. The F_2 and F_3 generations numbered about 50 (as did the F_1), but the F_4 numbered only about 30. Whether males of *macularius* mated with females of *salinus* would give as successful results remains to be determined. Since *salinus* is much more closely related to *nevadensis* than it is to *macularius*, the success of the *nevadensis* × *salinus* cross (and not of the *macularius* × *salinus* combination), may be significant.

The attempts to hybridize *macularius* and *nevadensis* have been rather successful. The following subspecies of *nevadensis* have been used in this combination:

1. *C. n. nevadensis*—males from Saratoga Springs, Death Valley.
2. *C. n. shoshone*—females from the outlet of Shoshone Spring.
3. *C. n. amargosae*—females from the Amargosa River, Death Valley.
4. *C. n. amargosae*—males from the same place (2 experiments).

The first cross (*C. n. nevadensis* × *C. macularius*) was begun on March 26, 1942. The first F_1 offspring were born April 19, 1942. On September 10, 1942, when the experiment was terminated, 98 first generation hybrids were present.

The second cross (*C. n. shoshone* × *C. macularius*) was started on November 5, 1943, too late for spawning to take place. Young were born on June 20, 1944, but these have not been studied.

In the third cross, 12 *amargosae* females, from Death Valley, were mated with 3 *macularius* males on June 6, 1942. On September 10, 1942, when the pool was drained, 2 F_1 hybrids, estimated to be 2 or 3 days old, were present. By October 20, 1942, 4 young were observed, but when the experiment was terminated on March 10, 1943, only 2 hybrids remained.

The fourth cross was started on September 2, 1941, when 1 male of *C. nevadensis amargosae* was placed with 4 females of *C. macularius*. On September 19, 1941, 5 young hybrids were discovered. A dead young hybrid was found on September 22. By September 27, 1941, 2 sizes of young were observed in the pool, although the parents no longer appeared to be spawning. By October 5, 1941, no new young were appearing and not more than 7 were observed at one time. When the pool was drained on November 17, 1941, there were only 3 F_1 hybrids, although the parents were still present. All of the fish were returned to the pool. On March 14, 1942, when the pool was again drained only 2 specimens of *macularius* and 2 hybrids remained.

The second experiment of this cross was begun on June 6, 1942, when 2 males of *amargosae* were put with 8 females of *macularius*. The first generation hybrids were born on June 21, 1942, when 5 were counted. On July 20, 1942, about 10 young were observed at one time, and when the pool was drained on September 9, 1942, 51 young (5 dead) were present. Thirty-four of the smallest hybrids were returned to the pool; the remaining hybrids, as well as the parents, were preserved. About 12 F₂ hybrids were first observed on June 3, 1943, but their size indicated that they were born fully 2 weeks earlier, about May 20, 1943. Eighteen F₂ hybrids were found when the pool was drained on August 16, 1943.

No detailed study of these interspecific hybrids has been made, but preliminary comparisons indicate that their characters are, in general, intermediate between the 2 parents. This is true for fin position, gill-raker number, tooth shape, and scale structure, and probably for other characters not yet checked. The intermediacy is particularly striking for the development of breeding colors. Spawning males of *macularius* from the Salton Sea basin are intense yellow or yellow-orange on the caudal peduncle and caudal fin, whereas on nuptial males of *nevadensis* this color has never been observed. In life, the hybrid males were pale yellow on the proximal half of the caudal fin and on the posterior half of the caudal peduncle, indicating intermediacy in strength and extent of color.

INTRASPECIFIC CROSSES

In the experimental hybridization between different subspecies of *C. nevadensis* 3 combinations have been attempted thus far: (1) *amargosae* × *nevadensis*; (2) *amargosae* × *shoshone*; and (3) *nevadensis* × *shosone*.

In the first cross, begun on October 4, 1940, and finished on August 12, 1943, 4 generations of *amargosae* × *nevadensis* hybrids resulted. No large number of offspring was produced in any of these generations. In the second cross, started July 2, 1941, and terminated on February 23, 1942, 1 generation of about 120 *amargosae* × *shoshone* hybrids was produced. The third combination was begun on July 2, 1941, and terminated in September, 1944. This, by far the most successful experiment, was carried out in Pool 6, one of the largest and most exposed pools. Seven generations of *nevadensis* × *shoshone* hybrids were produced, all of them in great numbers. The date of birth and the approximate number of each generation varied as follows: F₁, July 16, 1941, 300; F₂, April 5, 1942, 350; F₃, August 7, 1942, 100?; F₄, October 2, 1942, 50?; F₅, April 8, 1943, 250; F₆, July 15, 1943, 300; and F₇, April 7, 1944, 200. The production of 3 generations in 1942 exceeds the reproductive capacity of any stock used thus far in these experiments. This prolific capacity may be an expression of hybrid vigor or it may be due also, or solely, to a more favorable environment.

CONSTANCY EXPERIMENTS

To determine whether differences observed between natural populations are maintained when the fish are bred under similar conditions, stocks from 4 sources have been raised for 1 to 6 generations.

1. *Cyprinodon salinus* from Salt Creek, Death Valley. Experiment begun September 11, 1941, and terminated May 22, 1942. Only 1 young resulted, and this specimen is insufficient to determine whether the changed environment altered any of the meristic characters. In nature this species inhabits water having a salinity about three-fourths that of the ocean.

2. *C. n. nevadensis* from Saratoga Springs. Experiment started September 7, 1940, and terminated on April 19, 1944, when only a single fish was in the pool. Five generations were born as follows: F_1 on October 6, 1940; F_2 on June 5, 1941; F_3 on April 23, 1942; F_4 on April 19, 1943; and F_5 on August 19, 1943. It will be noted that in the first year, 1940-41, 2 generations were born; in the second year, 1941-42, only 1 generation; and in the third year, 1942-43, 2 generations. Two generations a year appears to be the normal production for this subspecies. The number of young produced in each generation varied approximately as follows: F_1 , 350; F_2 , 260; F_3 , 150; F_4 , 75; and F_5 , 40. Between August 19, 1943, and April 19, 1944, no young were born, and the stock gradually died out. The figures are not absolutely accurate, but clearly indicate the decreasing vitality of the stock when bred under artificial conditions. A comparison of the meristic characters between the subspecies in nature, 48 P_1 , and the 12 original parents (3 males and 9 females) is given in Table XXXVII. The agreement between the P_1 and F_1 is close. The dorsal rays are more numerous in the F_1 than in the P_1 , and also average slightly but not significantly higher than in the subspecies as a whole in nature. The anal rays of the F_1 have a somewhat greater average than do those of either the P_1 or wild stocks. The much fewer number of caudal rays in the F_1 is perhaps due in part to the below average count for the parents and in part to the small size of the specimens, for, as previously indicated, the caudal rays become fully differentiated at a later stage of development than do the rays of the other fins. The scales around the body are somewhat more numerous in the parents, as well as in the offspring, than in the natural stocks of this subspecies. Though the differences are only slight, it is possible that the higher number of dorsal rays and of body scales in the F_1 may be attributed to the genetic heterogeneity of the stock and to the high number which the P_1 had. Gabriel (1944: 109) demonstrated such inheritance for *Fundulus heteroclitus*. The value for the average number of pelvic rays in the F_1 lies within the range of variation of random samples of this subspecies analyzed over a period of years (Table XLV). Most of the meristic char-

TABLE XXXVII

COMPARISON OF CERTAIN MERISTIC CHARACTERS OF WILD STOCKS, PARENTS,
AND EXPERIMENTALLY RAISED F₁ OFFSPRING OF
Cyprinodon nevadensis nevadensis
The parents were bred and the F₁ raised in Pool 1.

Stock	Dorsal Rays				No.	M ± σ _M						
	9	10	11	12								
Wild stock, total	23	151	39	1	214	10.08 ± .04						
Parents .....	.....	9	3	.....	12	10.25 ± .13				
First generation .....	.....	24	23	1	48	10.52 ± .08					
	Anal Rays											
	9	10	11									
Wild stock, total	4	155	55		214	10.24 ± .03						
Parents .....	.....	9	3		12	10.25 ± .13					
First generation .....	.....	26	22		48	10.46 ± .07					
	Pectoral Rays											
	14	15	16	17	18							
Wild stock, total	8	79	211	78	2	378	15.97 ± .04					
Parents	16	8	24	16.33 ± .10					
First generation	19	74	3	96	15.83 ± .05					
	Pelvic Rays											
	0	1	2	3	4	5	6	7				
Wild stock, total	4	1	8	74	334	7	428	5.74		
Parents	4	18	2	24	5.92		
First generation	1	5	27	62	1	96	5.59		
	Caudal Rays											
	14	15	16	17	18	19	20	21	22			
Wild stock, total	2	36	78	77	16	4	1	214	17.40 ± .07	
Parents	4	6	2	12	16.83 ± .20	
First generation	1	6	22	18	1	48	16.25 ± .11	
	Lateral Scales											
	25		26			27						
Wild stock, total	24		132			8					164	25.90 ± .03
Parents		10			2					12	26.17 ± .11
First generation	1		41			6					48	26.10 ± .05
	Dorsal to Pelvic Scales											
	9	10		11		12						
Wild stock, total	33	106		24		1				164	9.96 ± .05	
Parents	11		1					12	10.08 ± .08	
First generation	7	35		6					48	9.98 ± .07	

TABLE XXXVII (Cont.)

Stock	Dorsal to Anal Scales						No.	$M \pm \sigma_M$		
	8	9	10	11						
Wild stock, total	14	102	45	3			164	9.23 ± .05		
Parents .....	.....	10	2	.....			12	9.17 ± .11
First generation	6	38	4	.....			48	8.96 ± .07	
	Predorsal Scales									
	16	17	18	19	20	21				
Wild stock, total	15	48	58	33	9	.....	163	17.83 ± .08	
Parents .....	.....	2	8	1	.....	1	12	18.17 ± .28
First generation	1	14	19	9	3	.....	46	17.98 ± .14	
	Caudal Peduncle Scales									
	12	13	14	15	16					
Wild stock, total	2	8	12	14	127		163	15.57		
Parents .....	.....	.....	.....	.....	12		12	16.00
First generation .....	.....	.....	2	3	43		48	15.85
	Body Scales									
	21	22	23	24	25	26	27	28		
Wild stock, total	3	5	15	39	27	46	20	8	163	25.09 ± .12
Parents	1	2	4	3	1	1	12	25.33 ± .38
First generation	1	12	13	15	4	3	48	25.37 ± .17

acters studied agree rather closely for the natural stocks, parents, and first generation offspring.

3. *C. n. amargosae*, from Amargosa River, Death Valley. Experiment started June 13, 1941, and terminated March 2, 1942. One generation was born on August 13, 1941, with a maximum number of about 200 fish. The native stream of this subspecies is very saline, but less so than at Salt Creek, the habitat of *C. salinus*. The comparison in certain counts between wild samples of this race, 30 of the F_1 , and the 16 original parents (4 males and 12 females) is given in Table XXXVIII. The values obtained for the P_1 and F_1 generations are very similar except in number of pelvic and caudal rays and predorsal and body scales. Most values for the experimental stocks agree closely with those for the natural samples. An explanation for a low caudal ray count has already been given. The number of pelvic rays of the F_1 is similar to that obtained from the analysis of a sample collected in Amargosa River on June 4, 1939, U.M.M.Z. No. 133177, which gave a value of 5.21 (Table IV). The average number of predorsal and body scale counts of the F_1 is significantly less than the values obtained for any natural sample of this race (Table IV). This may be due in part to the direct effect

TABLE XXXVIII

COMPARISON OF CERTAIN MERISTIC CHARACTERS OF WILD STOCKS,
PARENTS AND EXPERIMENTALLY RAISED F₁ OFFSPRING OF
Cyprinodon nevadensis amargosae
The parents were bred and the F₁ raised in Pool 5.

Stock	Dorsal Rays			No.	M ± σ _M							
	9	10	11									
Wild stock, total*	49	131	20	200	9.85 ± .04							
Parents	3	12	1	16	9.87 ± .12							
First generation	9	17	4	30	9.83 ± .12							
	Anal Rays											
	9	10	11									
Wild stock, total*	2	107	41	150	10.26 ± .04							
Parents	1	13	2	16	10.06 ± .11							
First generation .....	.....	22	8	30	10.27 ± .08						
	Pectoral Rays											
	15	16	17	18								
Wild stock, total*	35	195	65	3	298	16.12 ± .03						
Parents	6	21	4	1	32	16.00 ± .12						
First generation	2	47	11	60	16.15 ± .06						
	Pelvic Rays											
	0	1	2	3	4	5	6	7	8	9		
Wild stock, total*	31	1	3	2	3	75	326	17	2	460	5.41
Parents	1	7	24	32	5.72
First generation	4	3	1	8	44	60	5.28
	Caudal Rays											
	14	15	16	17	18	19	20	21				
Wild stock, total*	4	22	58	53	55	8	200	18.79 ± .08		
Parents	1	3	5	7	16	18.13 ± .23		
First generation	1	2	9	6	10	28	16.79 ± .21		
	Lateral Scales											
	25	26	27	28								
Wild stock, total*	22	162	43	3	230	26.12 ± .04						
Parents	10	6	16	26.37 ± .12						
First generation	2	23	2	27	26.00 ± .07						
	Dorsal to Pelvic Scales											
	9	10	11	12	13							
Wild stock, total*	40	78	22	5	145	10.94 ± .06					
Parents	7	7	2	16	10.69 ± .17					
First generation	2	9	12	3	26	10.62 ± .15					

* For the Death Valley race only.

TABLE XXXVIII (Cont.)

Stock	Dorsal to Anal Scales								No.	$M \pm \sigma_M$			
	8	9	10	11									
Wild stock, total*	2	70	51	27	150	9.69 ± .06							
Parents .....	.....	8	5	3			16	9.69 ± .19					
First generation .....	.....	10	12	5			27	9.81 ± .14					
	Predorsal Scales												
	16	17	18	19	20	21	22	23	24				
Wild stock, total*	2	12	34	47	47	32	18	7	1	200	19.67 ± .11		
Parents .....	.....	.....	2	5	6	2	1	.....	.....			16	19.69 ± .26
First generation .....	.....	.....	4	13	7	.....	.....	.....	.....			24	18.13 ± .14
	Caudal Peduncle Scales												
	15	16	17	18									
Wild stock, total*	3	120	22	5	150	16.19							
Parents .....	.....	14	1	1			16	16.19					
First generation	2	23	1	.....			26	15.96					
	Body Scales												
	24	25	26	27	28	29	30	31	32				
Wild stock, total*	1	3	9	40	72	65	30	8	2	230	28.37 ± .08		
Parents .....	.....	1	2	5	3	3	1	.....	1			16	27.81 ± .42
First generation	1	4	11	6	3	1	.....	.....	.....			26	26.35 ± .22

* For the Death Valley race only.

of the fresh, rather than salt, water in which the F_1 individuals were born.

4. *C. n. shoshone*, from the outlet of Shoshone Spring. Experiment started September 7, 1940, and terminated September 23, 1944. Six generations were produced as follows: F_1 on September 23, 1940; F_2 on May 12, 1941; F_3 on August 15, 1941; F_4 on April 23, 1942; F_5 on April 13, 1943; and F_6 on August 19, 1943. This is one more generation than was attained with the stock of *C. n. nevadensis* over the same period. In contrast to that subspecies, the *shoshone* stock produced 3 (rather than 2) generations in 1940-41. In addition, a seventh generation of *shoshone* was born about April 13, 1944. When the pool was drained on June 19, 1944, 35 young were present, but by July 24, 1944, only 6 fish were present, and by September 23, 1944, when the experiment was terminated, only 4 fish remained. The approximate numbers produced in each generation varied as follows: F_1 , 50; F_2 , 200; F_3 , 50; F_4 , 150; F_5 , 50; F_6 , 20; and F_7 , 35(?). The alternating large and small broods contrast with those of *nevadensis*, but the decreasing productivity is similar to that followed by the stock of *nevadensis*. The meristic characters of 38 of the F_1 generation are com-

TABLE XXXIX

COMPARISON OF CERTAIN MERISTIC CHARACTERS OF WILD STOCKS, PARENTS,
AND EXPERIMENTALLY RAISED F₁ OFFSPRING OF
Cyprinodon nevadensis shoshone

The parents were bred and the F₁ raised in Pool 2.

Stock	Dorsal Rays					No.	M ± σ _M				
	9	10	11								
Wild stock, total*	28	94	12			134	9.88 ± .05				
Parents	8	8				16	9.50 ± .13				
First generation	12	25	1			38	9.71 ± .08				
	Anal Rays										
	9	10	11								
Wild stock, total*	10	104	19			133	10.07 ± .04				
Parents		16				16	10.00				
First generation	3	33	2			38	9.97 ± .06				
	Pectoral Rays										
	14	15	16	17	18						
Wild stock, total*		42	134	36	2	214	15.99 ± .04				
Parents		4	22	6		32	16.06 ± .10				
First generation	1	15	51	9		76	15.89 ± .07				
	Pelvic Rays										
	0	1	2	3	4	5	6	7			
Wild stock, total*	37	1		3	4	32	169	12	258	4.98	
Parents	5			1		4	18	4	32	4.97	
First generation	6					13	54	3	76	5.39	
	Caudal Rays										
	16	17	18	19	20	21					
Wild stock, total*	14	32	53	14	6	1			120	17.74 ± .09	
Parents		3	12	1					16	17.87 ± .12	
First generation	9	8	5						22	16.82 ± .17	
	Lateral Scales										
	24	25	26	27							
Wild stock, total*	1	33	79	3					116	25.72 ± .05	
Parents		9	7						16	25.44 ± .12	
First generation		16	21	1					38	25.61 ± .09	
	Dorsal to Pelvic Scales										
	8	9	10								
Wild stock, total*	1	27	20						48	9.39 ± .08	
Parents	1	14	1						16	9.00 ± .12	
First generation	1	22	13						36	9.33 ± .09	

* For outlet samples only.

TABLE XXXIX (Cont.)

Stock	Dorsal to Anal Scales								No.	$M \pm \sigma_M$		
	8		9		10							
Wild stock, total*	8		40		2				50	8.88 ± .06		
Parents	12		4		.....				16	8.25 ± .11	
First generation	23		15		.....				38	8.39 ± .08	
	Predorsal Scales											
	16	17	18	19	20	21	22	23				
Wild stock, total*	3	17	39	34	12	4	1	1	111	18.50 ± .11		
Parents .....	.....	3	10	3	.....	.....	.....	.....	16	18.00 ± .15
First generation .....	.....	4	12	5	2	.....	.....	.....	23	18.22 ± .17
	Caudal Peduncle Scales											
	13		14		15		16					
Wild stock, total*	2		6		12		64		84	15.64		
Parents .....	.....		3		.....		13		16	15.63
First generation .....	.....		4		2		32		38	15.74	
	Body Scales											
	19	20	21	22	23	24	25	26	27	28		
Wild stock, total*	1	2	4	21	21	20	7	6	2	84	23.25 ± .17
Parents	2	2	6	3	3	16	22.19 ± .31
First generation	1	2	6	5	9	7	6	1	1	38	23.97 ± .29

* For outlet samples only.

pared with those of the 16 original parents (7 males and 9 females) and of the wild population in Table XXXIX. These results are similar to those obtained in the comparison between the F_1 generation and the parents in *nevadensis*, except that the *shoshone* F_1 shows an increase (rather than a decrease) in the number of pelvic rays, and a marked increase over the average value for the parents, and, to a lesser extent, over the natural stocks, in the number of scales around the body. Like first generation *nevadensis*, *shoshone* F_1 specimens appear to have fewer caudal rays, probably because these rays had not become fully differentiated when the samples were preserved. Whereas several counts for the parents average fewer than for natural populations, the F_1 is very nearly average in these characters. With the exception of the number of body scales (excluding from consideration the caudal rays), the F_1 and P_1 generations of *shoshone* agree very closely.

CONCLUSIONS FROM EXPERIMENTAL STUDIES

Several generalizations appear to be warranted from the analysis to date of the experimental material.

In the crosses between distinct species of *Cyprinodon* there is a varying amount of fertility, or, in one cross, an apparent failure in reproductive capacity. No young were produced when *salinus* males were crossed with *macularius* females, but because the cross was attempted only once the evidence is not conclusive. When *nevadensis* males were mated with *salinus* females, several generations of hybrids resulted, but comparatively few fish were produced. Most successful matings took place between *macularius* and *nevadensis*; the success of some of these combinations differed in the reciprocal crossings. For example, when *C. macularius* males were crossed with *C. nevadensis amargosae* females, only moderate success was obtained, but when males of *amargosae* were hybridized with females of *macularius*, very good results were obtained. Some of the variations in productivity probably have been influenced by differences such as size, temperature, and exposure, in the various pools used in the experiment.

One trihybrid cross was attempted. Second generation hybrid males of *C. n. nevadensis* × *C. salinus* were mated with females of *C. macularius* in late March, 1943. On April 20, 1943, the first trihybrids were discovered, and on June 30, 1943, when the pool was drained about 60 of these hybrids were present. On September 27, 1943, 3 F₂ hybrids were discovered when the pool was drained, but they were lost in handling. No other second generation young were born. The first generation was produced in moderate numbers, but there was a greatly lowered fertility among these offspring.

As usual in fish hybrids (Hubbs, 1940: 205-9; Hubbs, Hubbs, and Johnson, 1943), intermediacy in meristic and other characters is indicated by the results of the interspecific hybridization in *Cyprinodon*.

In the hybridization between subspecies of *C. nevadensis*, best results were obtained when the 2 spring forms (*nevadensis* and *shoshone*) were crossed. The 2 other combinations, *amargosae* × *nevadensis* and *amargosae* × *shoshone*, involved 1 parent form (*amargosae*) which develops in nature in saline water. The experimental pools all contained fresh (Los Angeles city) water. Whether this factor may have an important bearing on the poor results when *amargosae* was used as 1 parent or whether *nevadensis* and *shoshone* are more closely related to each other than to *amargosae* and hence cross more readily, is not yet certain. Furthermore, in both of the crosses in which *amargosae* was used, the pools (4 and 7) were not as favorable in size or location as was Pool 6, in which the *nevadensis* × *shoshone* hybrids were raised. The production of 3 generations of *nevadensis* × *shoshone* during the spring, summer, and fall of 1942 may be largely the result of hybrid vigor. Optimum conditions of pool size, temperature, and exposure to sunlight probably influenced this high productivity and may have been the controlling factors. Presumably, both environmental and genetic factors were involved.

TABLE XL
 AVERAGES, WITH STANDARD ERRORS, OF CERTAIN MERISTIC CHARACTERS OF
 EXPERIMENTALLY RAISED STOCKS AND WILD STOCKS OF THREE SUBSPECIES
 OF *Cyprinodon nevadensis*

Based on Tables XXXVII-XXXIX.

Sub-species	Dorsal Rays			Anal Rays		
	Wild Stock	P ₁	F ₁	Wild Stock	P ₁	F ₁
<i>nevadensis</i>	10.08 ± .04	10.25 ± .13	10.52 ± .08	10.24 ± .03	10.25 ± .13	10.46 ± .07
<i>amargosae</i>	9.85 ± .04	9.87 ± .12	9.83 ± .12	10.26 ± .04	10.06 ± .11	10.27 ± .08
<i>shoshone</i>	9.88 ± .05	9.50 ± .13	9.71 ± .08	10.07 ± .04	10.00 ± .00	9.97 ± .06
	Pectoral Rays			Pelvic Rays		
	Wild Stock	P ₁	F ₁	Wild Stock	P ₁	F ₁
<i>nevadensis</i>	15.97 ± .04	16.33 ± .10	15.83 ± .05	5.74	5.92	5.59
<i>amargosae</i>	16.12 ± .03	16.00 ± .12	16.15 ± .06	5.41	5.72	5.28
<i>shoshone</i>	15.99 ± .04	16.06 ± .10	15.89 ± .07	4.98	4.97	5.39
	Caudal Rays			Lateral Scales		
	Wild Stock	P ₁	F ₁	Wild Stock	P ₁	F ₁
<i>nevadensis</i>	17.40 ± .07	16.83 ± .20	16.25 ± .11	25.90 ± .03	26.17 ± .11	26.10 ± .05
<i>amargosae</i>	18.79 ± .08	18.13 ± .23	16.79 ± .21	26.12 ± .04	26.37 ± .12	26.00 ± .07
<i>shoshone</i>	17.74 ± .09	17.87 ± .12	16.82 ± .17	25.72 ± .05	25.44 ± .12	25.61 ± .09
	Dorsal to Pelvic Scales			Dorsal to Anal Scales		
	Wild Stock	P ₁	F ₁	Wild Stock	P ₁	F ₁
<i>nevadensis</i>	9.96 ± .05	10.08 ± .08	9.98 ± .07	9.23 ± .05	9.17 ± .11	8.96 ± .07
<i>amargosae</i>	10.94 ± .06	10.69 ± .17	10.62 ± .15	9.69 ± .06	9.69 ± .19	9.81 ± .14
<i>shoshone</i>	9.39 ± .08	9.00 ± .12	9.33 ± .09	8.88 ± .06	8.25 ± .11	8.39 ± .08
	Predorsal Scales			Caudal Peduncle Scales		
	Wild Stock	P ₁	F ₁	Wild Stock	P ₁	F ₁
<i>nevadensis</i>	17.83 ± .08	18.17 ± .28	17.98 ± .14	15.57	16.00	15.85
<i>amargosae</i>	19.67 ± .11	19.69 ± .26	18.13 ± .14	16.19	16.19	15.96
<i>shoshone</i>	18.50 ± .11	18.00 ± .15	18.22 ± .17	15.64	15.63	15.74
	Body Scales					
	Wild Stock	P ₁	F ₁			
<i>nevadensis</i>	25.09 ± .12	25.33 ± .38	25.37 ± .17			
<i>amargosae</i>	28.37 ± .08	27.81 ± .42	26.35 ± .22			
<i>shoshone</i>	23.25 ± .17	22.19 ± .31	23.97 ± .29			

Pure stocks exhibited a gradual decrease in vitality during the course of the experiments. This phenomenon was expressed by (1) a decrease in the numbers of young born in succeeding generations, and (2) a failure to produce a normal number of generations in succeeding years. The most young

were produced either as a result of the initial matings or during the spring matings of the year in which the experiment was started. If 2 or more generations were born during spring, summer, and fall of 1 year, there were fewer young in each succeeding brood. The running out of these stocks is believed to be the result of inbreeding, with the consequent attainment of lethal homozygotes. The artificial conditions under which the fish were bred presumably also accelerated this decrease in vitality. Although the natural stocks have inbred more or less closely for hundreds and probably thousands of years, they have successfully maintained themselves. A gradual decrease in productivity is a usual phenomenon in the artificial breeding of many wild stocks of animals and plants (Wright, 1922).

Certain meristic characters of some of the first generation pure stocks and their parents and of wild stocks are compared in Table XL. These data indicate, with only few exceptions, that the F_1 generations retain the characters of their respective subspecies in nature. The noteworthy exceptions are in the following counts: (1) Dorsal rays—the average for the F_1 stock of *nevadensis* is significantly higher (t value over 4) than for the wild stock. Although the parents also have a greater average than does the wild stock, the difference is not significant. The difference between the P_1 and the F_1 stocks is also not significant. (2) Dorsal to anal scales—the average for the F_1 of *shoshone* is significantly lower than the value for the wild stocks. The parents have even a lower average, which is also significantly different from the natural stocks. (3) Predorsal scales—the value for the F_1 of *amargosae* has a significantly lower average than does the value for the wild stocks, whereas the parents average almost the same as the natural samples. (4) Body scales—the average for the F_1 generation of *amargosae* is 2 scales fewer than for the natural stocks, whereas the parents do not average significantly lower than do the wild samples. The *shoshone* F_1 have an average value reliably but not significantly lower (t value about 2.0) than the natural samples. The value for the parents is significantly lower (t value nearly 3.0) than it is for the wild stocks. The differences between the natural stocks, parents, and first generation in number of pelvic rays is not so trustworthy because the average number of rays in these fins is much more variable than are average values for other fins. Although the averages obtained for the number of caudal rays are unreliable, the values for the first generation of *nevadensis* and *shoshone* lie in the same direction as do the values of the wild samples of these 2 subspecies. The difference between the averages for the F_1 generation of these 2 forms is greater than it is for the natural stocks. The parents of the *shoshone* F_1 , however, average higher than does the subspecies in nature, whereas the parents of the *nevadensis* F_1 stock average lower. The value for the caudal rays of the *amargosae* F_1 is almost identical with, rather than higher than, the value for first generation

shoshone. This may be due to the fact that the values for the parents of the first generation of *amargosae* and *shoshone* are not significantly different.

In general, the average values for the first generations of the 3 subspecies lie in the same direction as do the values for the natural stocks of these subspecies. When the subspecies in nature do not differ significantly in a particular count, the values for the F₁ stock likewise are not significantly different.

In all of the experiments the young are more or less stunted. Extreme dwarfing took place when a pool was very much overcrowded and fish with disproportionately large heads were produced when the water became foul, as it did on several occasions in Pools 5 and 7. Stunting is a rather common phenomenon among artificially bred wild stocks of fish.

Many more experiments are needed to prove or disprove the results and interpretations obtained thus far, and better controlled conditions are needed. Much experimental material is available and awaiting analysis. Repetition of a number of the experiments attempted is necessary before the results obtained in certain trial crosses can be verified. None of the many interesting stocks of *Cyprinodon nevadensis* in Ash Meadows, Nevada, have been utilized. There remains, therefore, much to be done before a comprehensive experimental analysis of the characters of the many forms can be presented.

CONSIDERATIONS OF GENERAL BIOLOGICAL SIGNIFICANCE

SIZE OF POPULATIONS

The population size of a species or other taxonomic unit has an important bearing upon the rate of evolution of the form. This is particularly true of very small and well-isolated populations, for in such groups the probability of accidental survival of particular genes or gene combinations is greatly increased. In larger populations of more widespread distribution, selection acts to prevent the random survival of nonadaptive characters. The chance fixation of some new mutation or recombination has been termed "drift" by Wright (1940a, 1940b) and the "Sewall Wright effect" by Huxley (1942). In the words of Huxley (1942: 59): "The smaller the size of a natural population and the more perfectly it is isolated the more likely is drift to proceed to its limit. . . ." The determining factor in the chance fixation phenomenon is the size of the minimum effect breeding population. In an extremely small population the Sewall Wright effect may even fix deleterious mutations and thus bring about extinction.

The Sewall Wright effect often explains why island forms show a much greater degree of divergence than do those of the mainland, or why isolated spring or lake fishes often are much more distinct than are the same genera in a continuous river or drainage basin.

In the American desert there are many examples of relatively rapid evolution among the remnant fish populations of isolated springs (Hubbs, 1941; Hubbs and Miller, in press). Presumably, much of this evolution may be attributed to chance fixation, for many of these populations comprise only a few hundred individuals. In addition, high temperature is believed to have also influenced the rate of evolution among these fishes (see "Rate of Speciation and Extent of Differentiation," page 148).

The distinctiveness of *Cyprinodon diabolis* may be largely caused by the Sewall Wright effect, for at times the total breeding population is only about 50 individuals. Any mutation or recombination which arose then, whether it was adaptive or not, would stand a very good chance of survival.

As they are known to be elsewhere, seasonal fluctuations among the fishes of the Death Valley system are marked. Particularly striking changes are illustrated by the species of *Cyprinodon*. For example, in June and July, 1938, the number of individuals of *C. salinus* in Salt Creek, Death Valley, was enormous. The total population was then estimated as amounting to many millions. Yet in the following winter not a fish could be seen. This was due in part to the fact that the fish are inactive in the winter and apparently stay on the bottom or burrow into the mud, as they did in the backyard pools at Los Angeles, but the apparent scarcity of the fish also must have reflected a great reduction which takes place between summer and fall—a decrease correlated with the desiccation of the stream and the prevalence of natural enemies when the fish are trapped in pools disconnected from the creek.

A similar reduction in population takes place in the Saratoga lakes fed by Saratoga Springs, in the southeastern arm of Death Valley. In the spring and early summer individuals of *Cyprinodon nevadensis nevadensis* are swarming, but they are far fewer by late fall. Desiccation of the lake waters is the principal factor responsible for the reduction, but fish-eating birds also deplete the population. The number of fish in the main spring pool at Saratoga Springs does not vary appreciably, for the spring fish, active throughout the year because of the warm temperature (usually 27.8° to 28.3° C.), are not affected by desiccation and have few natural enemies. Their numbers are kept at a maximum by the yearly migration of fish from the lakes into the spring.

In the dwarfed species, *C. diabolis*, of Devil's Hole, Ash Meadows, Nevada, a very close estimate of population is possible because this species is confined to a single, small spring hole, and all of the fish are visible at 1 time. In December, 1938, I estimated that there were only about 50 to 75 fish in this pool—the lowest estimate obtained during 6 visits between 1936 and 1942. In July, 1938, at least 400 fish were present. This species was

observed in late April to early May, 1939, by Sumner and Sargent (1940: 47), who wrote: "The entire existing population of this form can hardly exceed a few hundred individuals."

The populations of *Empetrichthys merriami* in Ash Meadows appear to be even fewer than the minimum numbers of *Cyprinodon diabolis*. As pointed out on page 101, only 22 specimens of *E. merriami* were secured over the 6-year period, 1936-42, despite the fact that special efforts were made to obtain more specimens. The rarity of this species is in striking contrast to the abundance of specimens of *E. latos* of Pahrump Valley to the east, where we collected 426 specimens in 3 years. *E. merriami* undergoes the usual yearly fluctuation in quantity, but *E. latos* has been plentiful at Manse Ranch and fairly common at Pahrump and Raycraft ranches.

Of particular interest is the maintenance of the many isolated stocks of *Cyprinodon* and *Empetrichthys* in the separated spring holes over surprisingly long periods of aridity. Some of the springs contain only a few hundred gallons of water and often less than 1000 fish; yet these springs have, with uninterrupted continuity, maintained their own existence and that of their fish life. Although some of the stocks, such as that of *Cyprinodon diabolis*, occasionally undergo such a decrease in numbers that an unfavorable change in the environment might easily mean extinction, they have nevertheless survived in their greatly restricted habitats for thousands of years.

ISOLATION

In deserts, perhaps more than anywhere else, isolation is a potent factor in the evolution of plants and animals. This is particularly true of fish life, since aquatic habitats in arid regions are few and far between, and fishes are inseparably bound to the available waters. It is also generally true of terrestrial animals, as attested, for example, by the great number of known geographic races of desert mammals. In the words of the late naturalist, Joseph Grinnell (1924: 228):

The production of deserts, conditioned by aridity induced by circumstances in the geological and climatological history of the Western Hemisphere, has resulted in many more subspecific, specific, generic, and possibly even family types coming into being than would have been the case had conditions of aridity not arisen; and these new divergencies will have influence in world evolution in that they are supplying a much wider range of materials for further selection—for preservation and improvement of, perhaps, new adaptive structures in the history of life.

In the Death Valley region, which includes the Salt Creek and Amargosa River drainage basins, are several distinct but closely related forms of cyprinodonts. It is estimated that Salt Creek has been isolated from the Amargosa basin for at least 20,000 years (page 87). The distinctiveness of *Cyprinodon salinus*, the species confined to Salt Creek, strongly suggests

such a long period of isolation. Similarly, *Cyprinodon diabolis* of Devil's Hole, Ash Meadows, has probably been separated for as long a time from its nearest relative, *C. nevadensis*, in the Amargosa River drainage. It too is a very well-defined species. The close relationships between the subspecies and races of *Cyprinodon nevadensis* in the basin of Amargosa River indicate recency of isolation. Blackwelder (in Wales, 1930: 61) wrote (*in litt.*): "It would not require a large climatic change to connect the various Amargosa springs in an integrated river system. There was such a river in late Pleistocene time,—twenty thousand years ago, more or less. There may have been such a river a few centuries ago." In winters of heavy rainfall in the headwater area, Amargosa River still pours its flood waters on the great Death Valley salt flat, which marks the remnant of Pleistocene Lake Manly, but I have found no evidence of intermingling between the fish populations of the Amargosa basin during such floods (see discussion of *Cyprinodon nevadensis amargosae*, pp. 30-33).

The duration of time since Pahrump Valley and Ash Meadows have been separated cannot be reliably estimated because there have been no detailed studies of the past hydrography of these regions. The isolation has been of sufficient duration to allow the differentiation of a species of *Empetrichthys* in each basin. In Pahrump Valley, the evolution of 3 subspecies of *E. latos* suggests that the lake which formerly covered the valley floor was of Pleistocene age, and the physiographic evidence supports this view.

Isolation has obviously played a powerful role in the differentiation of desert fishes. Those drainage basins known to have been separated for the greatest length of time usually contain the largest number of endemic forms. It can, therefore, be laid down as a general rule that, for desert fishes, there is a positive correlation between duration of isolation and extent of differentiation (see Hubbs and Miller, *in press*). For the fish life in arid regions, geographical isolation is probably the most important isolating mechanism, but ecological isolation (and presumably other such mechanisms—see Dobzhansky, 1941: 257) is also effective. Thus, although flood waters often connect the isolated drainages, most of the fish populations seek refuge in deep holes or otherwise avoid the swift current. Consequently, they are not shifted about by recurring floods and hence tend to remain isolated even during such environmental disturbances.

RELATION OF CHARACTERS TO ENVIRONMENT

A close correlation between the environment and the characters that differentiate the lower systematic categories has been repeatedly demonstrated in studies of the systematics of fishes. These relationships have been discussed recently by Hubbs (1940: 198-205).

In the present work, temperature and salinity have been particularly

open for study, especially in species of the genus *Cyprinodon*. The following discussion is confined to an analysis of the environmental correlations shown by the characters of *C. salinus*, *C. nevadensis*, and *C. diabolis*, the 3 species of *Cyprinodon* inhabiting the Death Valley region.

Temperature

The temperature of each of the springs studied in the Amargosa basin, from Death Valley to Ash Meadows, is remarkably constant (Table XLI). The temperatures vary from 22.1° to 42.5° C. The highest temperature at which fish were found was 40.0° C. This reading was made with a standardized instrument near the source of South Tecopa Hot Spring, which is inhabited by *Cyprinodon nevadensis calidae*. To my knowledge this is the second highest recorded temperature in which fish have been taken. Jordan and Richardson (1907: 321) reported a temperature of 120° F.

TABLE XLI
TEMPERATURE VARIATION IN CERTAIN WARM SPRINGS OF THE AMARGOSA RIVER BASIN,
CALIFORNIA AND NEVADA

Locality	° C.	Dates (No. of Readings)
	Range (Ave.*)	
Saratoga Springs	27.0-29.7 (27.8-28.3)	1915-1942 (10)
South Tecopa Hot Springs		
Source	41.3-42.2 (41.7)	1915; 1942 (3)
Outlet	36.1-37.2 (36.7) †	1942 (2)
North Tecopa Hot Springs		
Source	42.1-42.8	1915; 1942 (3)
Outlet	32.0	1942 (1)
Shoshone Spring	33.5	1891 (1)
Source	33.3-34.0 (33.5)	1942 (2)
Outlet	27.8-33.7 (30.0-30.5)	1930-1942 (6)
Deep Spring	27.2-27.5	1939; 1942 (2)
Eagle Spring	27.6	1942 (1)
Point of Rocks Spring		
Source	31.1-31.8 (31.4)	1930-1942 (3)
Outlet	27.9	1942 (1)
Forest Spring	26.0-26.7 (26.4)	1939; 1942 (2)
Tubb's Spring	23.8-24.1 (23.9)	1939 (3)
Bradford's Spring	22.2	1930 (1)
Big Spring	30.7-31.1 (30.9)	1942 (2)
Lovell's Spring	32.5-33.0 (33.0)	1939 (3)
Hidden Spring	28.0	1942 (1)
Fairbanks Ranch	22.1	1942 (1)
Fairbanks Spring	26.6	1942 (1)
Devil's Hole	32.8-33.9 (33.0)	1930-1947 (8)

* This "average" is the usual temperature or range and does not represent the average of readings.

† This is the temperature at which fish were most abundant.

(48.9° C.) for the hot spring in northeastern Lower California that is inhabited by *Lucania browni* (= *Cyprinodon macularius*). The temperature of this spring was taken by Godfrey Sykes, the well-known engineer and authority on the dynamics of the lower Colorado River, and I have been assured (*in litt.*) of its accuracy by both Mr. Sykes and Dr. D. T. MacDougal, who was in charge of the Carnegie Institution expedition engaged in studying the region. Although I do not doubt the accuracy of the reading it is questionable whether the fish were actually swimming in water of that temperature. Kniffen (1932:213) reported a temperature range of 112° to

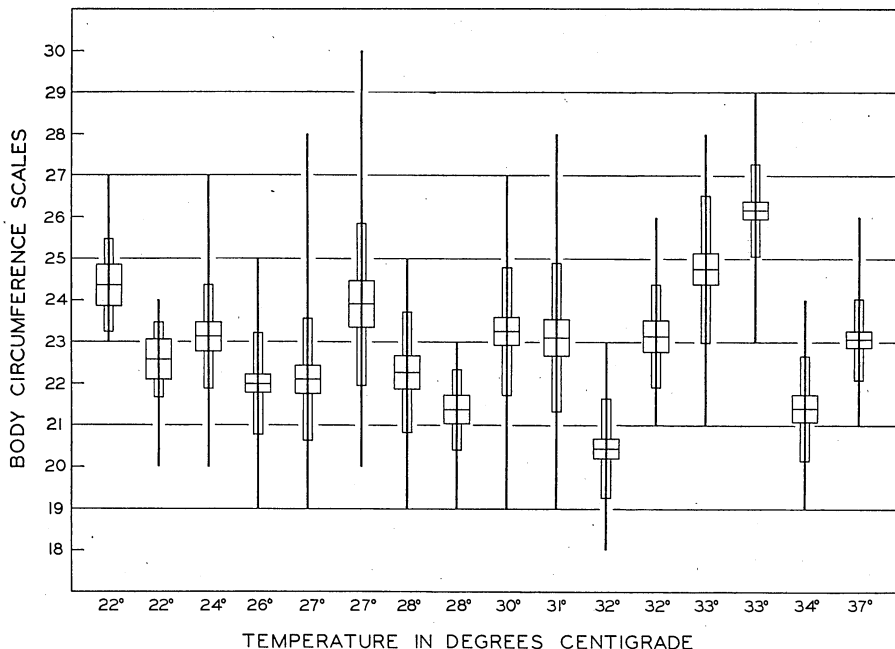


FIG. 3. Correlation of body circumference scales with temperature in 2 species of *Cyprinodon* inhabiting the Amargosa River basin, California and Nevada. Data based on Table XLII.

120° F. (44.5° to 48.9° C.) for a hot spring that may be the same as the one inhabited by this *Cyprinodon*.

There is evidence that desert fishes have become highly adapted to extreme temperatures. Physiological modifications in the respiratory metabolism of warm- and cool-spring populations of *Cyprinodon* and *Crenichthys* are discussed in the section on "Rate of Speciation and Extent of Differentiation" (pp. 148-49).

The correlation between temperature and certain meristic characters between and within the Amargosa springs is discussed below.

VARIABILITY OF CHARACTERS AT DIFFERENT TEMPERATURES.—In the 11 fin-ray and scale counts made for populations of *Cyprinodon* in the Amargosa basin, the mean values of any given character fluctuate from spring to spring. When all of the forms are considered together, there is no positive correlation between the characters studied and temperature. This is particularly well demonstrated by the number of scales around the body (Table XLII and Fig. 3). For example, *C. nevadensis calidae* of South Tecopa Hot Spring, which is most abundant in water having a temperature of about 36° or 37° C., averages 23.2 in number of body scales, whereas the race

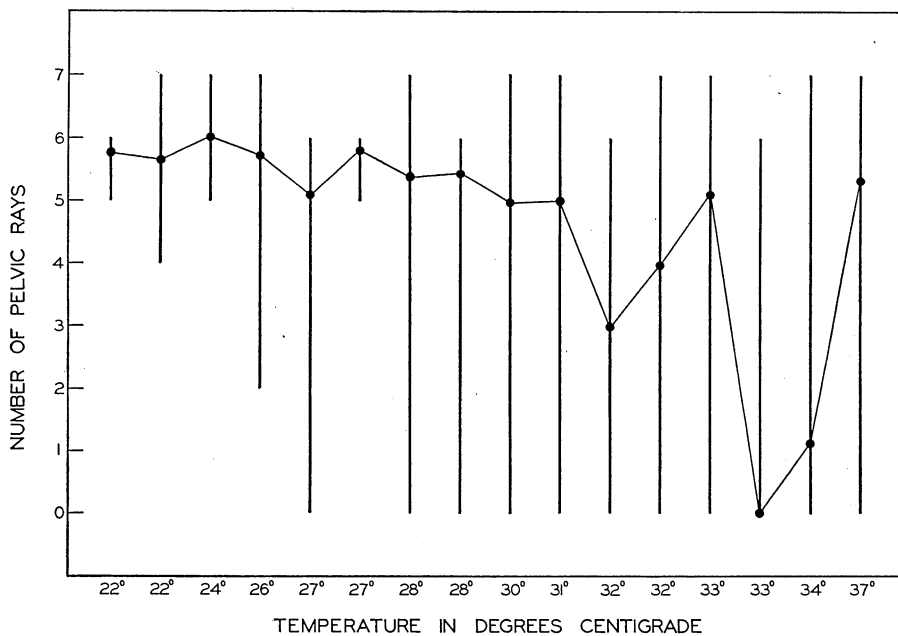


Fig. 4. Correlation of number of pelvic fin rays with temperature in 2 species of *Cyprinodon* inhabiting the Amargosa River basin, California and Nevada. Based on Tables XVII and XXIX. Localities arranged as in Table XLII.

of *C. n. mionectes* living in Tubb's Spring, at a temperature of approximately 24° C., averages 23.1 for the same character. If temperature affected the number of body scales among all forms of *C. nevadensis* in the same way, then the Tubb's Spring fish should have a much greater number than does *C. n. calidae*. The lack of correlation between meristic characters and temperature is also evident in the analysis of pelvic rays (Fig. 4). *C. diabolis* of Devil's Hole, living in water of about 33° C., only very rarely develops pelvic fins, but *C. n. pectoralis* of Lovell's Spring, which also inhabits water nearly constantly 33° C., has pelvic fins as well developed as do some populations inhabiting much cooler temperatures. Again, *C. n. calidae*, com-

TABLE XLII

CORRELATION OF BODY CIRCUMFERENCE SCALES WITH TEMPERATURE IN TWO SPECIES OF *Cyprinodon* INHABITING THE AMARGOSA RIVER BASIN, CALIFORNIA AND NEVADA

Locality	Temperature, ° C.	Body Scales												No.	$M \pm \sigma_M$	
		18	19	20	21	22	23	24	25	26	27	28	29			30
1. Fairbanks Ranch	22	.....	.....	.....	.....	.....	4	10	2	3	1	.....	.....	.....	20	24.35 ± .25
2. Bradford's Spring	22	.....	.....	1	.....	4	8	1	.....	.....	.....	.....	.....	.....	14	22.57 ± .24
3. Tubb's Spring	24	.....	.....	1	2	12	16	14	2	1	1	.....	.....	.....	49	23.12 ± .18
4. Forest Spring	26	.....	2	11	32	48	23	15	2	.....	.....	.....	.....	.....	133	21.99 ± .11
5. Deep Spring	27	.....	2	9	10	26	16	8	1	.....	.....	1	.....	.....	73	22.09 ± .17
6. Fairbanks Spring	27	.....	.....	1	.....	11	12	12	8	.....	2	2	1	1	50	23.90 ± .28
7. Eagle Spring	28	.....	2	4	7	16	11	7	3	.....	.....	.....	.....	.....	50	22.26 ± .20
8. Hidden Spring	28	.....	1	5	10	13	3	.....	.....	.....	.....	.....	.....	.....	32	21.37 ± .17
9. Shoshone Spring, Outlet	30	.....	1	2	4	21	21	20	7	6	2	.....	.....	.....	84	23.25 ± .17
10. Big Spring	31	.....	1	4	8	11	15	15	7	4	1	1	.....	.....	67	23.10 ± .22
11. Point of Rocks Spring	32	4	19	21	29	16	2	.....	.....	.....	.....	.....	.....	.....	91	20.44 ± .12
12. North Tecopa Hot Spring	32	.....	.....	.....	2	13	10	10	3	2	.....	.....	.....	.....	40	23.13 ± .19
13. Lovell's Spring	33	.....	.....	.....	2	8	14	16	17	15	12	5	.....	.....	89	24.75 ± .19
14. Devil's Hole*	33	.....	.....	.....	.....	.....	2	4	19	40	27	10	1	.....	103	26.17 ± .11
15. Shoshone Spring, Source	34	.....	3	12	20	15	8	4	.....	.....	.....	.....	.....	.....	62	21.40 ± .16
16. South Tecopa Hot Spring	37	.....	.....	.....	2	30	35	27	5	1	.....	.....	.....	.....	100	23.06 ± .10
Total		4	31	71	128	244	200	163	76	72	46	19	2	1	1057	22.97 ± .06

* *Cyprinodon diabolis*. All other populations are *Cyprinodon nevadensis*.

monly in water of 37° C., has even better developed pelvic fins than has *C. n. pectoralis*.

A comparison in certain counts between the main Point of Rocks Spring race of *C. n. mionectes* and *C. n. pectoralis*, which inhabit water usually having a temperature of 31.4° and 33.0° C., respectively, very clearly indicates the lack of a clear-cut correlation between certain characters and temperature, as shown by the average values in Table XLIII (based on Tables XV-XVII, XIX-XXIV).

If temperature alone were responsible for the number of fin rays and scales, the counts for these characters should be nearly alike or lower in *pectoralis* than in the race of *mionectes* from Point of Rocks Spring. This

TABLE XLIII
CORRELATION BETWEEN CERTAIN MERISTIC CHARACTERS AND TEMPERATURE IN
TWO WARM-SPRING SAMPLES OF *Cyprinodon nevadensis*
Based on Tables XV-XVII and XIX-XXIV

Character	Subspecies and Locality	
	<i>C. n. pectoralis</i> Lovell's Spring (33.0° C.)	<i>C. n. mionectes</i> Point of Rocks Spring (31.4° C.)
Anal rays	10.03 ± .04	9.62 ± .05
Pectoral rays	17.10 ± .04	15.68 ± .05
Pelvic rays	5.12	2.99
Lateral scales	25.42 ± .06	24.59 ± .06
Dorsal to pelvic scales	9.79 ± .08	8.75 ± .07
Dorsal to anal scales	8.94 ± .05	8.50 ± .07
Predorsal scales	17.91 ± .12	16.89 ± .11
Caudal peduncle scales	15.44	13.00
Body scales	24.75 ± .19	20.44 ± .12

example most strikingly illustrates the lack of correlation between temperature and meristic characters, but there are other good examples that are not discussed here for lack of space and time.

Although no definite correlation between temperature and meristic characters can be demonstrated when comparing distinct populations within 1 area or between 2 regions, a general correlation of this nature is evident. Thus, the average value of most of the counts for all populations of *C. nevadensis* in the Ash Meadows region is lower than it is for the subspecies of the lower Amargosa basin (Tables XIV-XXIV). This reduction in meristic characters is presumably correlated roughly with the generally warmer temperatures of the springs in Ash Meadows.

Within the limits of a single spring and its outlet, there seems to be a very definite correlation between temperature and certain meristic characters. This correlation is particularly well illustrated by the number of scales around the body (Table XLIV and Fig. 5). In the samples from the

spring outlets, which are always cooler than the source springs, the body scales are significantly greater in number than they are in the fish from the springs. Apparently, in each complex of spring source and outlet there is a distinct genetic stock, the members of which respond to differences in temperature in the same way. It will be noted that although the spring sources may have identical or nearly identical temperatures, the average number of body scales is usually not the same. Thus, the sample from Hidden Spring, whose waters appear to have nearly the same temperature as those of Eagle or of Deep Spring, differs significantly in average number of body scales

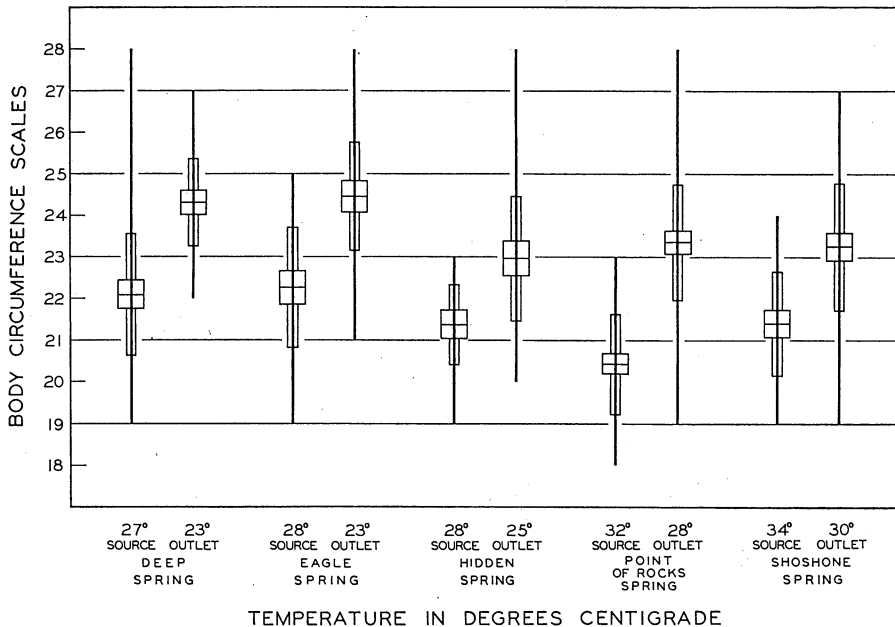


FIG. 5. Correlation of body circumference scales in *Cyprinodon nevadensis* with the temperatures of spring sources and outlets in the Amargosa River basin. Based on Table XLIV.

from the samples from either of those springs. Likewise, in the sample from the main Point of Rocks Spring, the average number is significantly lower than it is for the source sample from Shoshone Spring, despite the fact that Shoshone Spring is 2° C. warmer than Point of Rocks Spring. The Deep Spring and Eagle Spring stocks do not differ significantly in the average number of body scales. This, perhaps, results because the fish of these 2 springs, which are only 1 mile apart, are very closely related.

STABILITY OF CHARACTERS AT UNIFORM TEMPERATURES.—Within single springs, populations of *Cyprinodon* are rather remarkably similar in meristic characters in successive generations. To what extent the uniformity of the

TABLE XLIV

CORRELATION OF BODY CIRCUMFERENCE SCALES IN *Cyprinodon nevadensis* WITH THE TEMPERATURES OF SPRING SOURCES AND OUTLETS IN THE AMARGOSA RIVER BASIN

Locality and Temperature	Body Scales											No.	$M \pm \sigma_M$
	18	19	20	21	22	23	24	25	26	27	28		
Ash Meadows, Nev.													
Deep Spring													
Source 27° C. ....	.....	2	9	10	26	16	8	1	.....	.....	1	73	22.09 ± .17
Outlet 23° C.* .....	.....	.....	.....	.....	2	7	22	11	6	1	.....	49	24.31 ± .15
Eagle Spring													
Source 23° C. ....	.....	2	4	7	16	11	7	3	.....	.....	.....	50	22.26 ± .20
Outlet 23° C.* .....	.....	.....	.....	1	1	8	18	13	5	3	1	50	24.46 ± .19
Hidden Spring													
Source 28° C. ....	.....	1	5	10	13	3	.....	.....	.....	.....	.....	32	21.37 ± .17
Outlet 25° C.† .....	.....	.....	2	3	16	13	12	1	1	1	1	50	22.96 ± .21
Point of Rocks Spring													
Source 32° C.	4	19	21	29	16	2	.....	.....	.....	.....	.....	91	20.44 ± .12
Outlet 28° C. ....	.....	1	1	4	20	30	26	13	3	1	1	100	23.35 ± .14
Shoshone, Calif.													
Shoshone Spring													
Source 34° C. ....	.....	3	12	20	15	8	4	.....	.....	.....	.....	62	21.40 ± .16
Outlet 30° C. ....	.....	1	2	4	21	21	20	7	6	2	.....	84	23.25 ± .17

* In these instances it is very likely, but not absolutely certain, that the cooler samples were taken in the outlets of Deep and Eagle springs. The Deep Spring outlet is discussed under Isaac Ranch in the systematic section, page 48.

† Assumed temperature, 250 yards below source.

environment influences these characters is not known, but it is presumably an important factor. The examples best suited to illustrate constancy of characters are those involving springs from which samples have been collected over a period of years. Three springs of the Amargosa basin have been sampled periodically, and certain meristic characters of their fish populations are analyzed in Tables XLV-L.

A study of each of these tables demonstrates that the fish from Saratoga Springs do not maintain their characters as consistently as do the fish from the 2 springs in Ash Meadows. The average values differ significantly in the Saratoga Springs samples in the following periodic counts, selected to show maximum differences: (1) anal rays—1930, $10.03 \pm .03$, 1942, $10.32 \pm .07$, t value about 3; (2) caudal rays—1937, $17.08 \pm .12$, 1939, $17.58 \pm .12$, t value nearly 3; and (3) dorsal to pelvic scales—1939, $10.24 \pm .08$, 1942, $9.74 \pm .09$, t value over 4. None of the values for the characters of the races of *C. n. mionectes* from Point of Rocks and Forest springs differs significantly between any 2 years. The greater variability in the samples of *C. n. nevadensis* is believed to be due to the fact that this subspecies does not spawn in the nearly constant temperature of its spring habitat but rather in the spring-fed lakes. Young born early in the spring or during a cooler season than normal would presumably develop a greater number of meristic parts than would those born during summer or during a warm spring season. The remarkable constancy of fin-ray and scale counts in the Point of Rocks and Forest spring samples may be influenced to a considerable extent by the uniform temperature of these springs (Table XLI).

The consistency in average values between 2 samples of *C. n. shoshone* from the source of Shoshone Spring, collected in 1936 and 1942, has already been discussed (page 43). Experimental evidence that reduced counts in meristic characters result from high temperature has been given recently for *Fundulus heteroclitus* by Gabriel (1944: 109-18).

STABILITY OF CHARACTERS UNDER VARYING TEMPERATURES.—A third relationship between characters and environment indicates the interplay of at least 2 influences, namely (1) genetic and (2) temperature-controlled factors. In the comparison of races of *Cyprinodon nevadensis amargosae*, given in Table IV, the uniformity in certain fin-ray and scale counts, within periodic samples of a single race, is very striking. This consistency is maintained despite the fact that the temperature during development must be rather variable in the stream inhabited by these populations. Thus, there is no significant difference between the average number of dorsal and caudal fin rays and the dorsal to pelvic, dorsal to anal, predorsal, and body circumference scales in these samples. There is, however, a pronounced variation in the average number of pelvic rays between the June, 1939, sample and the other 2 samples of the Death Valley race. An explanation for this variation

TABLE XLV

COMPARISON OF FIN-RAY COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis nevadensis* FROM SARATOGA SPRINGS, DEATH VALLEY, CALIFORNIA
For location of springs and discussion of population see pages 25-28.

Year	Dorsal Rays					No.	$M \pm \sigma_M$			
	8	9	10	11	12					
1929 .....	.....	2	8	3	1	14	10.21 ± .21		
1930*	2	32	134	31	1	200	9.98 ± .04			
1937 .....	.....	7	34	9	.....	50	10.04 ± .08	
1939 .....	.....	9	35	6	.....	50	9.94 ± .08	
1942 .....	.....	2	40	8	.....	50	10.12 ± .06	
1942† .....	.....	3	34	13	.....	50	10.20 ± .07	
Anal Rays										
	9		10		11					
1929	1		10		3		14	10.14 ± .14		
1930*	21		151		28		200	10.03 ± .03		
1937	1		40		9		50	10.16 ± .06		
1939	2		40		8		50	10.12 ± .06		
1942 .....	.....		34		16		50	10.32 ± .07	
1942† .....	.....		31		19		50	10.38 ± .07	
Pectoral Rays										
	13	14	15	16	17	18				
1929 .....	.....	.....	13	12	3	.....	28	15.64 ± .13
1930*	1	7	70	91	31	.....	200	15.72 ± .06	
1937 .....	.....	1	12	26	11	.....	50	15.94 ± .10
1939 .....	.....	2	13	60	23	2	100	16.10 ± .07	
1942 .....	.....	4	20	60	16	.....	100	15.88 ± .07
1942† .....	.....	1	21	53	25	.....	100	16.02 ± .07
Pelvic Rays										
	0	1	2	3	4	5	6	7		
1929	1	3	24	28	5.68 ± .21
1930*	13	2	3	13	88	261	20	400	5.52 ± .06
1937	2	1	4	28	64	1	100	5.49 ± .10
1939	3	19	74	4	100	5.79 ± .06
1942	1	1	13	84	1	100	5.80 ± .07
1942†	11	88	1	100	5.90 ± .03
Caudal Rays										
	15	16	17	18	19	20	21	22		
1929	1	3	5	4	1	14	17.07 ± .28
1937	1	12	21	14	2	50	17.08 ± .12
1939	3	24	15	7	1	50	17.58 ± .12
1942	7	17	21	4	1	50	17.50 ± .13
1942†	11	11	23	2	2	1	50	17.54 ± .17

* Data from Wales (1930: 64), subtracting 1 from his dorsal and anal ray counts.

† The second 1942 collection is from the lake; all of the others are from the main spring pool.

TABLE XLVI

COMPARISON OF SCALE COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis nevadensis* FROM SARATOGA SPRINGS, DEATH VALLEY, CALIFORNIA
For location of springs and discussion of population see pages 25-28.

Year	Lateral Series Scales				No.	$M \pm \sigma_M$				
	25	26	27							
1929	5	9	.....		14	25.64 ± .13			
1939	3	43	4		50	26.02 ± .05				
1942	9	40	1		50	25.84 ± .06				
1942*	7	40	3		50	25.92 ± .06				
	Dorsal to Pelvic Scales									
	9	10	11	12						
1929	7	6	1	.....	14	9.57 ± .17			
1939	3	33	13	1	50	10.24 ± .08				
1942	18	27	5	.....	50	9.74 ± .09			
1942*	5	40	5	.....	50	10.00 ± .06			
	Dorsal to Anal Scales									
	8	9	10	11						
1929	2	10	2	.....	14	9.00 ± .14			
1939	2	28	19	1	50	9.38 ± .08				
1942	6	35	8	1	50	9.08 ± .08				
1942*	4	29	16	1	50	9.28 ± .09				
	Predorsal Scales									
	16	17	18	19	20					
1929	3	5	4	1	13	17.23 ± .25			
1939	4	14	17	11	4	50	17.94 ± .15			
1942	5	18	14	10	3	50	17.76 ± .15			
1942*	3	11	23	11	2	50	17.96 ± .13			
	Circumference of Peduncle Scales									
	12	13	14	15	16					
1929	1	3	2	4	3	13	14.38			
1939	2	1	2	45	50	15.80			
1942	1	3	8	4	34	50	15.34			
1942*	1	4	45	50	15.88			
	Circumference of Body Scales									
	21	22	23	24	25	26	27	28		
1929	1	1	2	5	3	1	13	23.85 ± .36
1939	2	5	8	10	16	6	3	50	25.26 ± .21
1942	2	2	5	13	7	15	3	3	50	24.86 ± .23
1942*	3	13	7	14	11	2	50	25.46 ± .19

* The second 1942 collection is from the lake; all of the others are from the main spring pool.

TABLE XLVII

COMPARISON OF FIN-RAY COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis mionectes* FROM THE MAIN POOL AT POINT OF ROCKS SPRING, ASH MEADOWS, NEVADA

For location of spring and discussion of population see Map 3 and pages 50-51.

Year	Dorsal Rays					No.	$M \pm \sigma_M$			
	8	9	10	11						
1930*	4	72	119	5		200	9.62 \pm .04			
1939 .....	.....	25	27	1		53	9.55 \pm .07		
1942	1	22	25	2		50	9.56 \pm .09			
	Anal Rays									
	8	9	10	11						
1930*	4	79	116	1		200	9.57 \pm .04			
1939 .....	.....	19	33	1		53	9.66 \pm .07		
1942 .....	.....	21	29	.....		50	9.58 \pm .07	
	Pectoral Rays									
	13	14	15	16	17					
1930*	1	9	90	88	12	200	15.50 \pm .05			
1939 .....	.....	.....	37	50	6	93	15.67 \pm .06	
1942	1	3	28	62	6	100	15.69 \pm .07			
	Pelvic Rays									
	0	1	2	3	4	5	6	7		
1930*	128	2	4	18	64	123	61	400	3.25
1939	37	19	39	11	106	3.18
1942	89	1	4	21	42	42	1	200	2.83
	Caudal Rays									
	15	16	17	18	19	20				
1939	1	8	9	21	4	1	44	17.50 \pm .16		
1942	1	3	11	22	11	2	50	17.90 \pm .14		

* The 1930 data are from Wales (1930: 64). As mentioned previously, his counts of the dorsal and anal rays are 1 higher than mine. Therefore, 1 was subtracted from his data for these 2 counts.

TABLE XLVIII

COMPARISON OF SCALE COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis mionectes* FROM THE MAIN POOL AT POINT OF ROCKS SPRING, ASH MEADOWS, NEVADA

For location of spring and discussion of population see Map 3 and pages 50-51.

Year	Lateral Series Scales						No.	$M \pm \sigma_M$
	23	24	25	26				
1939 .....	.....	17	28	.....			45	24.62 ± .07
1942	2	20	26	2			50	24.56 ± .09
	Predorsal Scales							
	15	16	17	18	19	20		
1939	5	13	15	6	3	1	43	16.81 ± .18
1942	4	12	18	12	3	.....	49	16.96 ± .15
	Circumference of Peduncle Scales							
	11	12	13	14	15	16		
1939 .....	.....	16	16	10	2	1	45	13.02 ± .15
1942	1	18	16	12	2	1	50	12.98 ± .14
	Circumference of Body Scales							
	18	19	20	21	22	23		
1939	2	8	10	12	7	2	41	20.49 ± .20
1942	2	11	11	17	9	.....	50	20.40 ± .16

has been given on pages 30-36. Presumably, high temperature was the dominant factor in causing the lower average for pelvic rays in the April, 1939, collection. Aside from this observed variation, the average values for the 3 samples of this race are remarkably alike.

The values obtained for certain meristic characters in 2 samples of *Cyprinodon salinus* also demonstrate that these counts have outstanding uniformity (Table LI). This species inhabits Salt Creek, a stream which varies considerably in temperature during the spawning period. With 1 exception the average values of each character for the 2 samples are not significantly different. The average number of lateral scales for the 1938 collection, $29.34 \pm .19$, and for the 1942 collection, $28.44 \pm .16$, differs significantly (t value 3.6). It is very likely, however, that part of this difference is due to an error in counting, because the enumeration of lateral scales in specimens of *C. salinus* is difficult, owing to the crowded arrangement (Fig. 1).

TABLE XLIX

COMPARISON OF FIN-RAY COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis mionectes* FROM FOREST SPRING, ASH MEADOWS, NEVADA

For location of spring and discussion of population see Map 3 and pages 52-53.

Year	Dorsal Rays				No.	$M \pm \sigma_M$			
	9	10	11	12					
1937	3	29	.....	1	33	$9.97 \pm .07$			
1939	6	41	3	.....	50	$9.94 \pm .06$			
1942	9	33	8	.....	50	$9.98 \pm .08$			
	Anal Rays								
	9	10	11						
1937 .....	.....	31	2		33	$10.06 \pm .04$			
1939	4	45	1		50	$9.94 \pm .04$			
1942	10	34	6		50	$9.92 \pm .08$			
	Pectoral Rays								
	11	12	13	14	15	16	17		
1937 .....	.....	.....	.....	1	17	42	6	66	$15.80 \pm .07$
1939 .....	.....	.....	.....	1	38	56	5	100	$15.65 \pm .06$
1942	1*	.....	.....	2	23	67	7	100	$15.75 \pm .08$
	Pelvic Rays								
	2	3	4	5	6	7			
1937	1	.....	4	10	51	.....		66	5.67
1939 .....	.....	.....	2	26	72	.....		100	5.70
1942 .....	.....	.....	2	19	77	2		100	5.79
	Caudal Rays								
	16	17	18	19	20	21			
1937	2	8	14	6	2	.....		32	$17.94 \pm .17$
1939	3	6	26	11	3	1		50	$18.16 \pm .14$
1942	5	11	25	6	3	.....		50	$17.82 \pm .14$

* The left fin of this fish had 15 pectoral rays.

TABLE L

COMPARISON OF SCALE COUNTS IN PERIODIC SAMPLES OF *Cyprinodon nevadensis mionectes* FROM FOREST SPRING, ASH MEADOWS, NEVADA
For location of spring and discussion of population see Map 3 and pages 52-53.

Year	Lateral Series Scales				No.	$M \pm \sigma_x$		
	23	24	25	26				
1937 .....	.....	4	25	4	33	25.00 \pm .09	
1939	1	5	37	7	50	25.00 \pm .08		
1942	1	8	38	3	50	24.86 \pm .07		
	Dorsal to Pelvic Scales							
	8	9	10	11				
1937 .....	.....	.....	.....	.....	.....	.....
1939	5	27	17	1	50	9.28 \pm .09		
1942	1	33	13	3	50	9.36 \pm .09		
	Dorsal to Anal Scales							
	8	9	10					
1937	5	22	6	33	9.03 \pm .10			
1939	4	42	4	50	9.00 \pm .06			
1942	10	34	6	50	8.92 \pm .08			
	Predorsal Scales							
	15	16	17	18	19	20		
1937	1	5	13	12	31	
1939	1	9	23	13	4	50	
1942	2	10	23	12	2	1	50	
	Circumference of Peduncle Scales							
	12	13	14	15	16			
1937	8	8	10	4	3	33	13.57	
1939	14	14	17	2	3	50	13.32	
1942	25	11	12	2	50	12.82	
	Circumference of Body Scales							
	19	20	21	22	23	24	25	
1937	1	3	7	11	6	4	1	33
1939	4	13	24	7	2	50
1942	1	4	12	13	10	9	1	50

TABLE LI

VARIATION IN CERTAIN MERISTIC CHARACTERS IN TWO SAMPLES OF *Cyprinodon salinus*
FROM SALT CREEK, DEATH VALLEY, CALIFORNIA

Character	Range	Ave.	No.
Dorsal rays			
July 18, 1938	8-11	9.44	50
Sept. 29, 1942	8-11	9.54	50
Anal rays			
July 18, 1938	9-11	9.98	50
Sept. 29, 1942	9-11	9.84	50
Pectoral rays			
July 18, 1938	15-17	15.83	100
Sept. 29, 1942	15-17	16.20	100
Pelvic rays			
July 18, 1938	4-7	6.00	50
Sept. 29, 1942	4-7	5.96	100
Caudal rays			
July 18, 1938	15-19	16.80	50
Sept. 29, 1942	15-19	16.84	50
Lateral scales			
July 18, 1938	27-34	29.34	50
Sept. 29, 1942	27-31	28.44	50
Dorsal to pelvic scales			
July 18, 1938	12-16	14.00	50
Sept. 29, 1942	12-16	13.92	50
Dorsal to anal scales			
July 18, 1938	10-14	12.08	50
Sept. 29, 1942	10-14	12.08	50
Predorsal scales			
July 18, 1938	23-28	26.00	50
Sept. 29, 1942	22-30	25.66	50
Circumference of peduncle scales			
July 18, 1938	17-22	19.64	50
Sept. 29, 1942	18-22	19.88	50
Circumference of body scales			
July 18, 1938	33-46	39.58	50
Sept. 29, 1942	35-45	39.14	50
Preopercular pores			
July 18, 1938	12-17	14.54	50
Sept. 29, 1942	12-16	14.22	49
Preorbital pores			
July 18, 1938	2-8	6.04	50
Sept. 29, 1942	4-8	6.00	50

Salinity

It has been rather generally established in systematic studies of fishes that meristic characters tend to increase in number with increasing salinity (Hubbs, 1926a). The present study substantiates this generalization, at least for certain scale counts, particularly the number around the body, for, in *C. salinus*, which inhabits the very saline Salt Creek in Death Valley, the body circumference scales are very much smaller than in any other species studied. In the Death Valley race of *C. nevadensis amargosae*, which inhabits the less saline waters of Amargosa River, the count for body scales is greater than it is in any other form of *C. nevadensis*. In the spring-fed lakes at Saratoga Springs, where *C. nevadensis nevadensis* spawns, the waters are only moderately salty, and the average number of scales around the body is lower than it is at either of the preceding localities (Table LII).

TABLE LII
CORRELATION BETWEEN BODY CIRCUMFERENCE SCALES AND SALINITY IN
TWO SPECIES OF *Cyprinodon*

Species and Locality	Number of Scales Around Body			Salinity*
	Range	No.	$M \pm \sigma_M$	
<i>salinus</i> Salt Creek	33-46	100	39.36 \pm .24	Very high
<i>nevadensis</i> Amargosa River	23-32	480	27.44 \pm .07	High to moderate
Saratoga Springs and lake	21-28	163	25.09 \pm .12	Moderate

* See Table LIII.

What effect other chemical and physical conditions in the various springs and creeks may have in modifying the characters of the fishes is not known. Presumably, the fish life has become highly adapted to the great variety of chemical conditions in these water holes (Table LIII), and it is assumed that the conditions in each spring and creek in some way influence the development of the remnant populations.

Stability of Experimentally Raised Pure Stocks

In an attempt to determine whether the characters used to differentiate races and subspecies of *Cyprinodon nevadensis* in the Death Valley region have a genetic basis, stocks of *C. n. nevadensis*, *C. n. amargosae*, and *C. n. shoshone* were raised in out-of-door pools for 1 to 6 generations over the 3-year period, 1940-43. Time has permitted the analysis of only the first generation fish. The average values for the meristic characters of the F_1 are, with 1 or 2 notable exceptions, very similar to those obtained for re-

TABLE LIII
 ANALYSES OF CERTAIN WATER SAMPLES FROM THE DEATH VALLEY REGION
 Made in 1932 by the Rubidoux Laboratory of the U. S. Department of Agriculture, Riverside, California.

Location	pH	Conduct- ance K × 10 ⁵ @ 25° C.	Total Solids p.p.m.	Boron p.p.m.	Percentage Composition							
					Ca	Mg	Na	K	HCO ₃	SO ₄	Cl	NO ₃
Salt Creek	8.6	3,368	23,594	38.8	1.5	7.8	87.6	3.3	3.4	20.3	76.2	.....
Saratoga Springs, main pool	8.2	465	3,041	9.96	3.7	6.7	87.7	1.8	15.0	43.7	41.0	0.3
Saratoga Springs, lake	8.8	780	5,394	18.8	2.5	6.7	88.4	2.4	15.6	44.3	40.0	0.1
Amargosa River at Tecopa ...	.....	675	.....	19.9	1.0	1.9	94.7	2.4	33.8	31.9	34.2	0.1
South Tecopa Hot Springs ...	.....	331	.....	7.78	1.0	1.1	95.0	2.9	35.7	31.2	33.1	.....
North Tecopa Hot Springs ...	.....	350	.....	8.38	0.9	1.7	95.6	1.7	33.6	31.1	35.2	.....
Shoshone Spring .....	.....	147	.....	4.19	13.3	16.4	66.4	4.0	41.1	32.3	26.3	0.3
Point of Rocks Spring .....	.....	69.7	.....	0.41	33.6	27.5	38.9	.....	70.1	20.6	8.8	0.4
Forest Spring .....	.....	77.6	.....	0.63	25.7	22.7	51.6	.....	63.2	26.8	10.0	.....
Big Spring .....	.....	71.5	.....	0.41	32.4	28.6	38.9	.....	69.3	21.2	9.5	.....
Fairbanks Spring .....	.....	68.8	.....	0.39	32.1	27.1	40.8	.....	69.7	20.8	9.4	.....

peated samples of the wild stocks of these subspecies (see Tables XXXVII-XL). The outstanding exceptions are in the lower number of predorsal and body scales in the F_1 stock of *C. n. amargosae* as compared with natural samples. Because the Death Valley race of this subspecies inhabits water of high salinity, and the experimental offspring were born in fresh water, it is suspected that a causal relation may exist between the decrease in the number of these scales and the decrease in salinity. The average values of these counts, with their standard errors, are as follows: (1) predorsal scales—natural stocks, $19.67 \pm .11$ (200 specimens); parents, $19.69 \pm .26$ (16 specimens); and F_1 , $18.13 \pm .14$ (24 specimens). (2) Body circumference scales—natural stocks, $28.37 \pm .08$ (200 specimens); parents, $27.81 \pm .42$ (16 specimens); and F_1 , $26.35 \pm .22$ (26 specimens). These figures demonstrate that whereas the values for the parents and natural stocks are very close, those for the F_1 generation are very significantly lower.

The role of temperature is believed to be unimportant because, in all probability, temperatures were lower during the period when experimentally produced F_1 were born than they were in Death Valley when the fish represented in the wild samples passed through the critical stage of development. As has been demonstrated recently for *Fundulus heteroclitus* (Gabriel, 1944: 110), cooler temperatures are correlated with a greater number of segments. Table XLIV and Figure 5 clearly demonstrate that the body scales of *Cyprinodon nevadensis* within single springs show a very definite increase in number with a decrease in temperature. Further experiments are needed to substantiate or disprove the tentative interpretation that this decrease in number of predorsal and body scales may be directly due, in part at least, to a decrease in salinity.

It is evident from the studies on the species of *Cyprinodon* inhabiting the Death Valley region that there is a general relationship between meristic characters and environment. When all of the warm-spring populations are considered as a unit, a rough correlation with temperature is demonstrated. Thus, an increase in temperature is generally associated with a decrease in number of scales and fin rays. This correlation is more obvious within a single spring and outlet, where analysis demonstrates that the meristic characters decrease very markedly with an increase in temperature. It is also evident that there is a definite decrease in number of scales, particularly around the body, with decreasing salinity.

Within a given spring or creek, the meristic characters are remarkably constant over a period of years. In most of the localities, the temperature is also very uniform yearly and seasonally. Consequently, it is not known to what extent constant temperature may influence the development of meristic characters. In 2 creek habitats, however, where the temperature

is known to fluctuate greatly, the characters nevertheless maintain their uniformity over a period of time. Thus, a genetic effect is indicated.

That the characters of the wild stocks are very probably influenced by both environment and heredity is strongly supported by the general stability of experimentally raised pure stocks. With only 1 or 2 noteworthy exceptions, the F_1 generation of the 3 subspecies studied retained the characters of the respective forms as present in nature. It remains to be seen how these characters vary in succeeding generations.

RATE OF SPECIATION AND EXTENT OF DIFFERENTIATION

There is evidence to indicate that at least 4 important factors are involved in the rate at which evolution takes place in desert fishes and the amount of differentiation undergone by them: (1) population size, (2) number of generations each year, (3) ecological conditions, and (4) duration of isolation.

Population size has a definite effect on the rate of speciation. Some of the spring populations of *Cyprinodon*, including the single stock of *C. diabolis*, number only a few hundred individuals. In such small units new characters, whether adaptive or not, are presumed to have a greater chance to survive than in very large populations. The size of the population has no doubt played an important role in the evolution of many of these spring forms, as already suggested (pp. 126-27).

The number of generations produced each year also has an important bearing on the rate of speciation. In the warm-spring populations of *Cyprinodon* there is good evidence that spawning takes place during nearly every month of the year. The limits of the breeding period for the stream stocks, such as *Cyprinodon nevadensis amargosae*, are approximately from April to October, but in the spring forms, such as *C. n. shoshone*, ripe fish and newborn young have been taken during midwinter. Whereas in the stream populations 2 or perhaps 3 generations are produced between spring and fall, it may be surmised that 3 or even 4 times that number are produced each year among warm-spring stocks of *Cyprinodon*. It is known from our experimental studies that *Cyprinodon nevadensis* may reach maturity and produce young when only 2 months old. As the experimental young are born and develop in much cooler water than do the warm-spring stocks, it seems safe to assume that in nature such forms as *C. nevadensis shoshone* are capable of breeding when only 1 month or 6 weeks old. This production of numerous generations each year may greatly accelerate the time rate of evolution of these warm-spring populations.

Ecological conditions in the desert springs are also probable factors in the rate and extent of speciation. Such waters are extremely varied in both physical and chemical makeup. The effects of these conditions upon the

fishes have, however, received little attention. The most extensive studies of the physiological adjustment of fishes to desert warm springs are those of Sumner and Sargent (1940) and Sumner and Lanham (1942). These authors carried out field studies on the respiratory metabolism of desert fish of the genera *Cyprinodon* and *Crenichthys*. Their work has shown, for example, that the physiology of such fish may be highly modified. Thus, cool-spring individuals of *Crenichthys baileyi* when transferred to a warm spring inhabited by another race of the same species are speedily killed by the higher temperature. Such studies when continued and expanded will no doubt have an important bearing on the interpretation of speciation in desert fishes.

There is considerable evidence that some desert fishes have been adapted to warm springs and that high temperature plays an important role in hastening the rate of speciation (Hubbs, 1941). Certain marked trends in characters are evident among warm-spring fish: (1) there is a general reduction in number of meristic segments; (2) the dorsal fin is often more posterior; (3) the head and eye, and, in general, the anterior parts of the body, are enlarged; (4) the fins are more expansive; (5) the size is often smaller, and other modifications have been observed (Hubbs and Kuhne, 1937: 12-16, 20). Similar results are demonstrated by our more recent and more extensive studies (Hubbs and Miller, in press). The greater differences between warm- and cool-spring or creek fish probably involves both the rate of change and the amount of change. These factors are difficult to separate.

The salt content appears to have a direct effect on meristic characters (p. 145) and very likely also has some parallel genetic effect. Thus, the very high number of scales in the Salt Creek form, *Cyprinodon salinus*, is probably due not alone to the direct effect of the high salinity, but also to a genetic factor indirectly correlated with the environment. This assumption, however, remains to be clearly proved by experiment.

SUMMARY

The Death Valley system forms a complex of now isolated basins lying in the arid desert region of eastern California and southwestern Nevada, in the southern part of the Great Basin. Physiographic evidence indicates that most of these basins were hydrographically connected during the latter part of Pleistocene time. It is highly plausible that the system was also connected in some way, during the Pleistocene, with the basin of Lake Lahontan to the north. Perhaps as early as late Pliocene time the large inflow of water into the system led to a discharge through a river-lake series of connecting troughs into what is now the lower Colorado River basin. By stream capture, the old drainage system is also believed to have once been joined with what is now Las Vegas Wash, a tributary of the Colorado River.

Studies of both the Recent and the fossil fish fauna of the ancient system substantiate these views on the former hydrography of the region. The relict populations now inhabiting the disrupted basins testify to the former continuity of the system. Relationships between the Death Valley fishes and those of the surrounding drainages demand the postulated waterways, or similar ones. Recent and fossil members of the genus *Cyprinodon* are represented in the Death Valley system, but are unknown elsewhere from the Great Basin. This genus, however, is widespread in the lower Colorado River drainage basin, and the species of the Death Valley system were obviously derived from an ancestral form in the Colorado basin. The minnow *Siphateles*, present in Mohave and Owens rivers both as a Recent and as a fossil member, is unknown in either living or fossil form from the Colorado River system. The genus is abundant in the Lahontan basin and in drainages to the north and west. Its presence in the Death Valley system very strongly suggests that a waterway once united the drainages of the Lahontan and Death Valley basins. Thus, there is agreement between the physiographic information and the data on the distribution, origin, and relationships of the living and fossil fish fauna of the Death Valley system.

The cyprinodont fish fauna of the system comprises 2 living genera, *Cyprinodon* and *Empetrichthys*, and fossil representatives of the genus *Fundulus*, treated by Miller (1945). Four species of *Cyprinodon*—*nevadensis*, *diabolis*, *salinus*, and *radiosus*—are recognized, the last 1 described as new. Differentiation in *Cyprinodon nevadensis* has led to the recognition of 6 subspecies, all of them new except the typical form. Most of these subspecies show at least racial differentiation, particularly *C. n. mionectes*, which inhabits the numerous isolated springs in Ash Meadows, Nevada. Most of the forms of *Cyprinodon* are spring inhabitants, although 1 subspecies, *C. nevadensis amargosae*, is confined to the lower Amargosa River near and in Death Valley. The springs inhabited by these fishes vary in temperature from 20° to 40° C., usually not much above 34° C. Two species of *Empetrichthys*, *merriami* and *latos*, are recognized, each of which inhabits an isolated, adjoining region. *E. latos* of Pahrump Valley is described as new, and the 3 isolated springs in which this species occurs contain forms distinct enough to warrant subspecific recognition. Although the fauna is limited in number of species it is highly endemic and rich in material for evolutionary studies. Some of the local subspecies have very small ranges, which may be closely approximated. Some of the forms have an extremely small population, with effective breeding sizes as low as 50. One full species, *Cyprinodon diabolis*, is confined to a single small spring in which its total numbers fluctuate from about 50 to 400.

Experimental work on certain species of *Cyprinodon* was initiated in Los Angeles in 1940. In these experiments fish from the natural popula-

tions were reared in out-of-door pools under conditions of water and temperature unlike those in their native habitats. The pools were roughly similar in size and exposure, and all contained city water. Despite the greatly altered environment, F_1 generations of pure stocks have essentially the same meristic characters as do the natural populations. One or 2 exceptions, however, indicate that altered environment, as well as heredity, is a factor determining the number of parts. The viability of the pure stocks was greatly reduced after the first generations were born in 1940. This common phenomenon is expressed by a decrease in number of successive generations and in the lower number of fish produced in succeeding broods. Experimental hybridization between species of *Cyprinodon* has generally resulted in lowered fertility, particularly in certain reciprocal crosses. The characters of the hybrids, as studied thus far, have proved to be generally intermediate between the 2 parents—a phenomenon now definitely established as the rule for interspecific hybrids in fishes.

Speciation has apparently been rather rapid among the relict fishes of the Death Valley system. Differentiation probably has been largely initiated by geographical isolation, but ecological and perhaps other types of isolation have also been operative. It may be generally stated for desert fishes that the longer the period of isolation of populations the greater the amount of their differentiation. Some local forms remain isolated from each other despite the floods that often connect the isolated springs or separated drainages, because such floods are generally ineffectual in mixing the fishes or extending the range of a species. Population size, number of generations each year, and high temperature have apparently played an important role in the evolution of the fish fauna. Small breeding populations appear to have led to speciation through the chance fixation of "drift" or the "Sewall Wright effect." In the warm springs, where breeding is nearly continuous throughout the year, the production of numerous generations may greatly accelerate the time rate of evolution in these populations.

An increase in temperature generally is associated with a decrease in number of meristic segments. The correlation is only rough and irregular within a species as a whole. Within single races of *Cyprinodon nevadensis*, however, a very definite negative correlation between temperature and fin-ray or scale counts is demonstrated. Warm-spring fish have enlarged anterior parts (head, eye, etc.), a reduced number of meristic segments, a more posterior dorsal fin, and deeper bodies than do those of cool waters. An increase in salinity seems to have had about the same speciation effect as a decrease in temperature. Fishes inhabiting waters of high salinity have a greater number of scales than do those of the same or different species or subspecies in less salty water. A direct, environmental influence is indicated, but it is thought that the observed differences are due in part to

genetic adaptations that parallel those due to the direct effect of the surroundings.

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ROBERT R. MILLER

PLATE I

Cyprinodon nevadensis nevadensis Eigenmann and Eigenmann.

FIG. 1. Adult male, U.M.M.Z. No. 133159, 43 mm. long, from main pool at Saratoga Springs in Death Valley, San Bernardino County, California.

FIG. 2. Adult female, 41 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE I

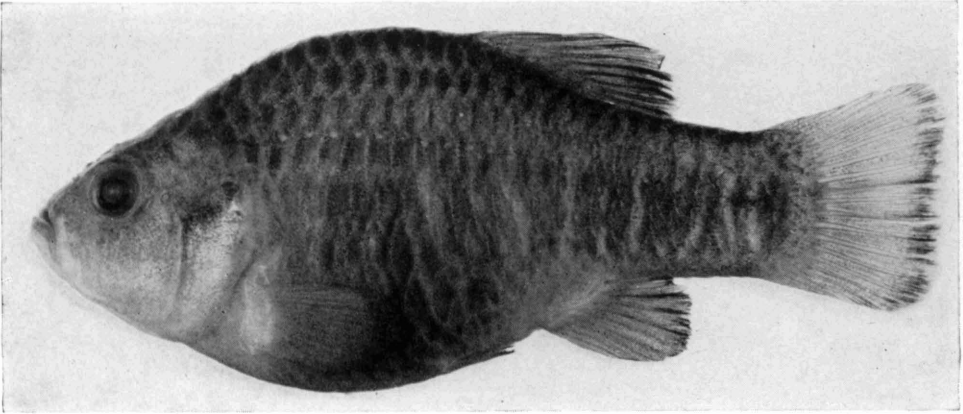


FIG. 1

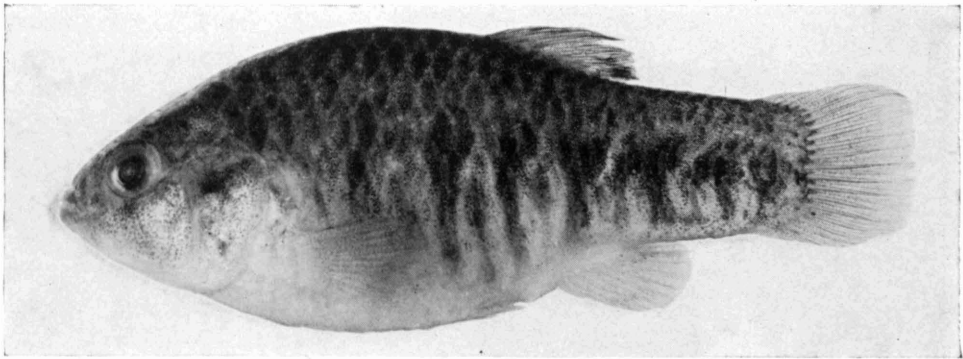


FIG. 2

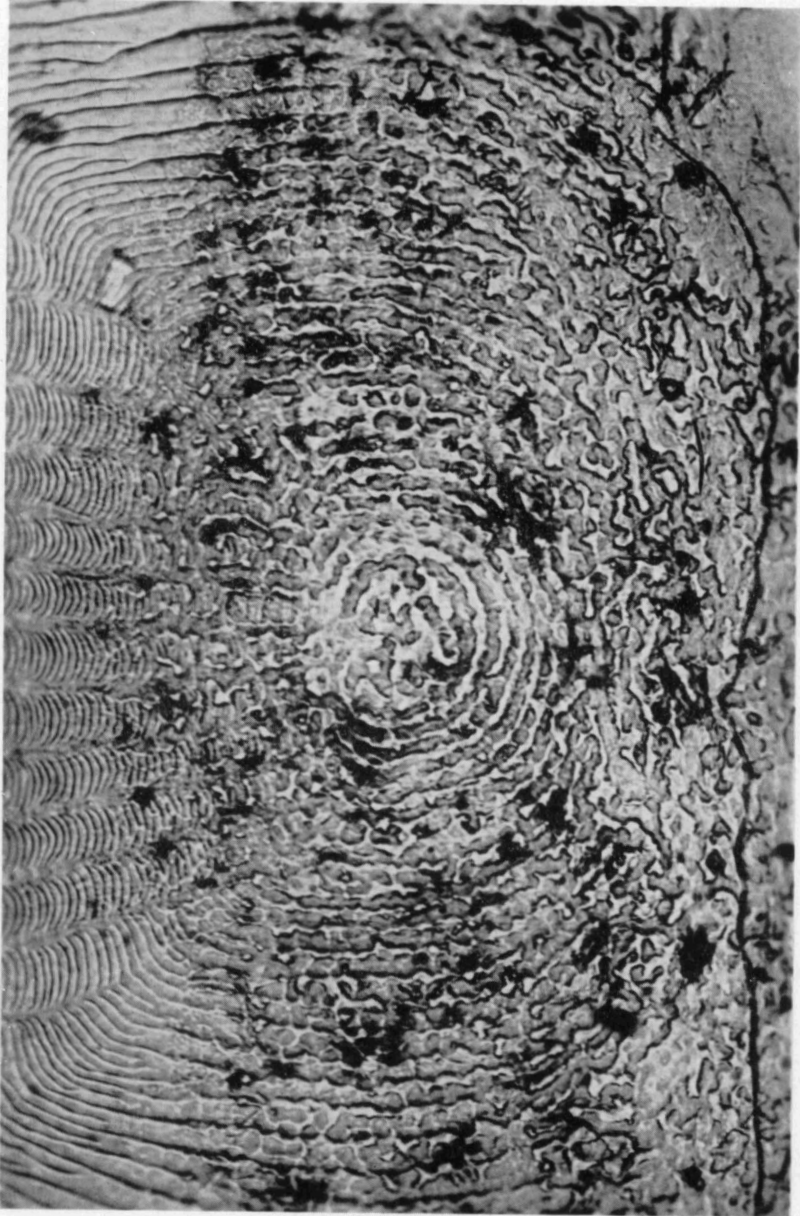
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PLATE II

Enlarged scale center of *C. n. nevadensis*. × 90.

Photographed by William C. Beckman.

PLATE II



ROBERT R. MILLER

PLATE III

Cyprinodon nevadensis amargosae, new subspecies

FIG. 1. Adult male, U.M.M.Z. No. 132939, 38 mm. long, from Amargosa River in Death Valley, San Bernardino County, California.

FIG. 2. Adult female, 39 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE III

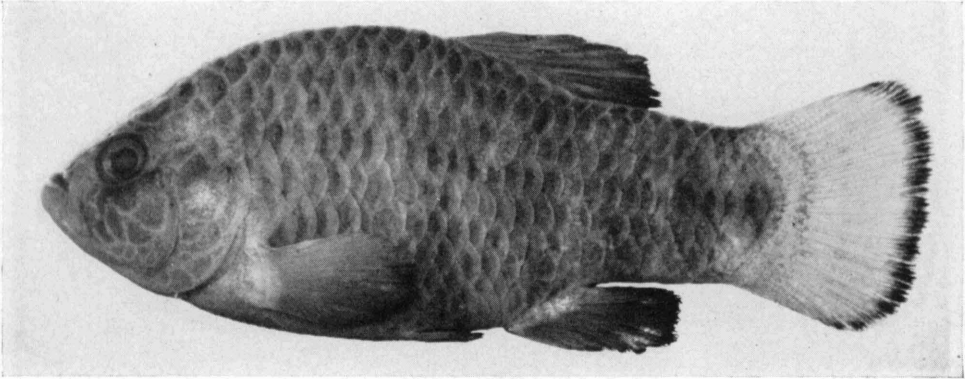


FIG. 1

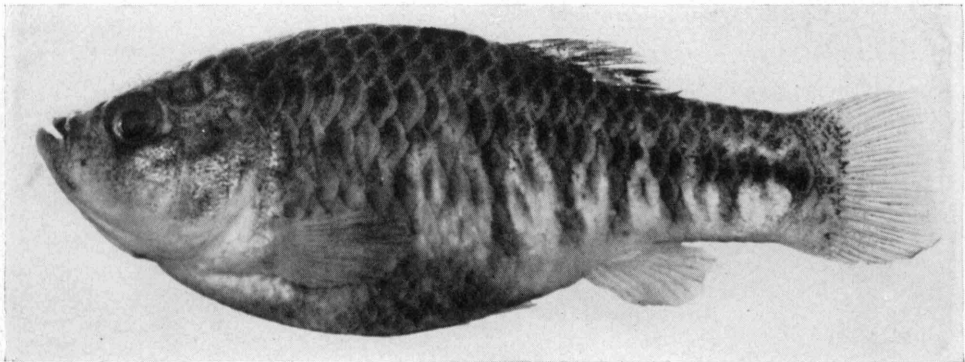


FIG. 2

PLATE IV

Cyprinodon nevadensis shoshone, new subspecies.

FIG. 1. Adult male paratype, U.M.M.Z. No. 132936, 42 mm. long, from outlet of Shoshone Spring, Inyo County, California.

FIG. 2. Adult female paratype, 38 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE IV

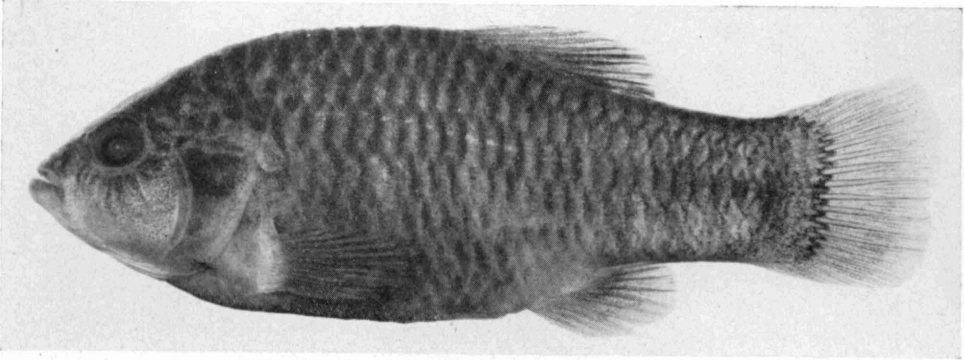


FIG. 1

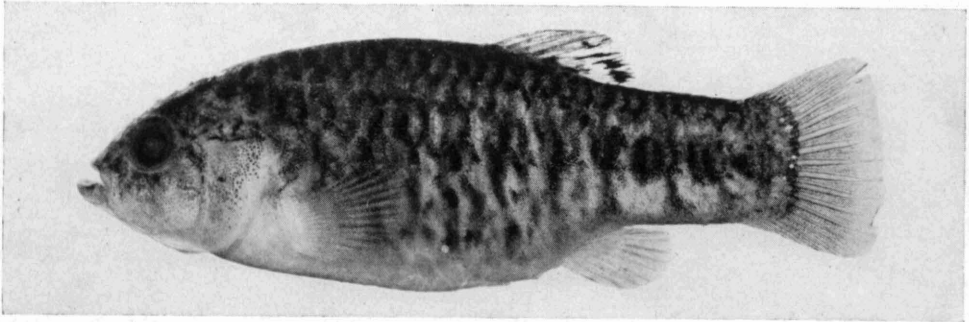


FIG. 2

PLATE V

Cyprinodon nevadensis mionectes, new subspecies.

FIG. 1. Adult male, U.M.M.Z. 132902, 38 mm. long, from Forest Spring, Ash Meadows, Nye County, Nevada.

FIG. 2. Adult female, 35 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE V

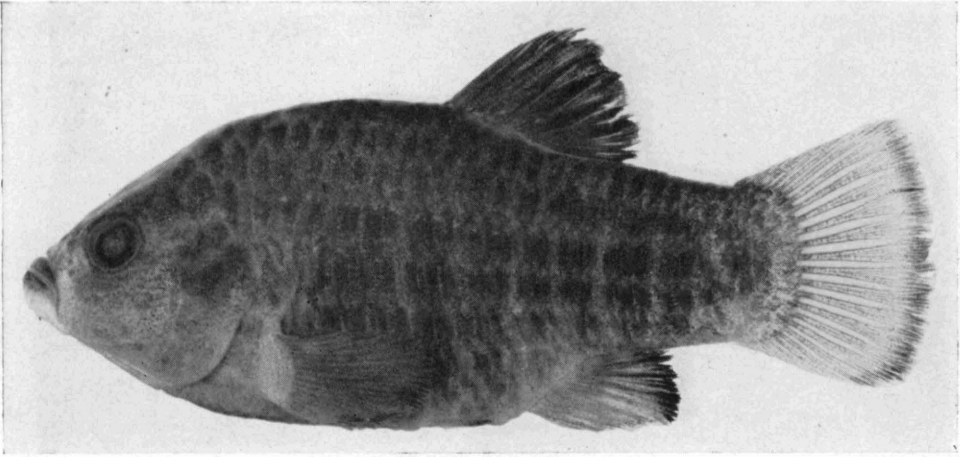


FIG. 1

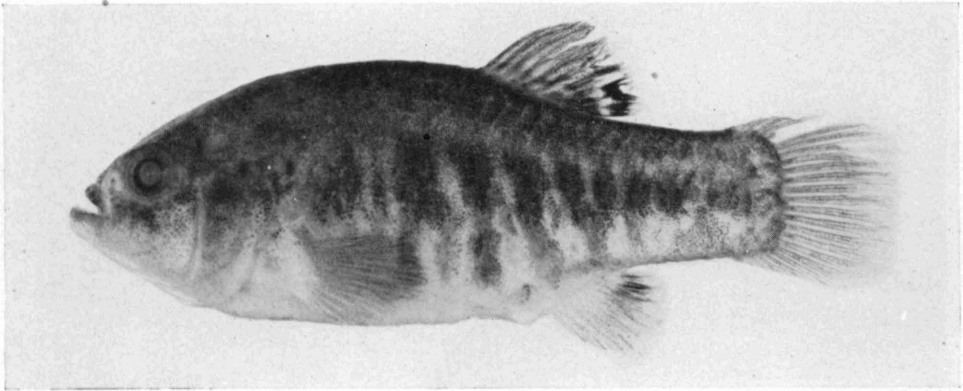


FIG. 2

PLATE VI

Cyprinodon nevadensis pectoralis, new subspecies.

FIG. 1. Adult male paratype, U.M.M.Z. No. 132908, 32 mm. long, from Lovell's Spring, Ash Meadows, Nye County, Nevada.

FIG. 2. Adult female paratype, 29 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE VI

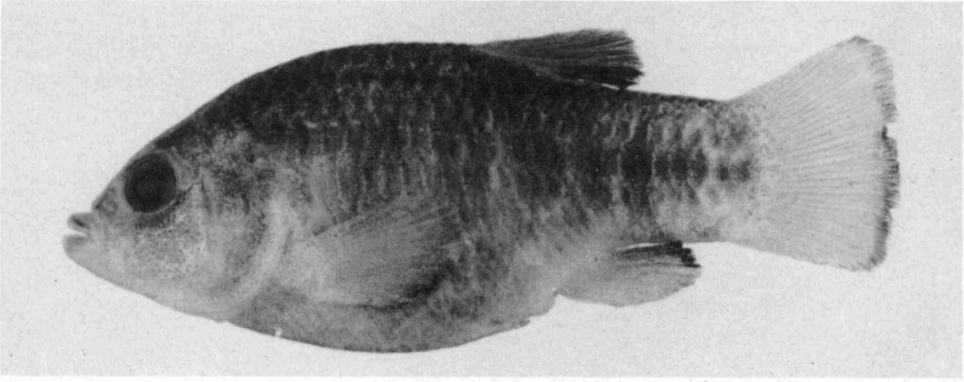


FIG. 1

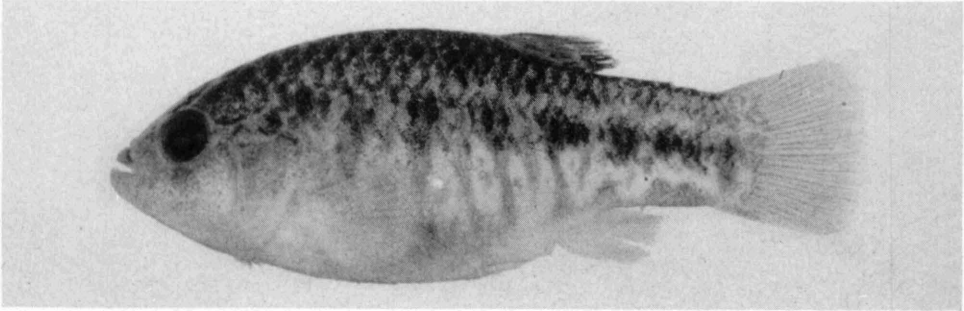


FIG. 2

PLATE VII

Cyprinodon diabolis Wales.

FIG. 1. Adult male, U.M.M.Z. No. 134803, 18 mm. long, from Devil's Hole, Ash Meadows, Nye County, Nevada.

FIG. 2. Adult female, 18 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE VII

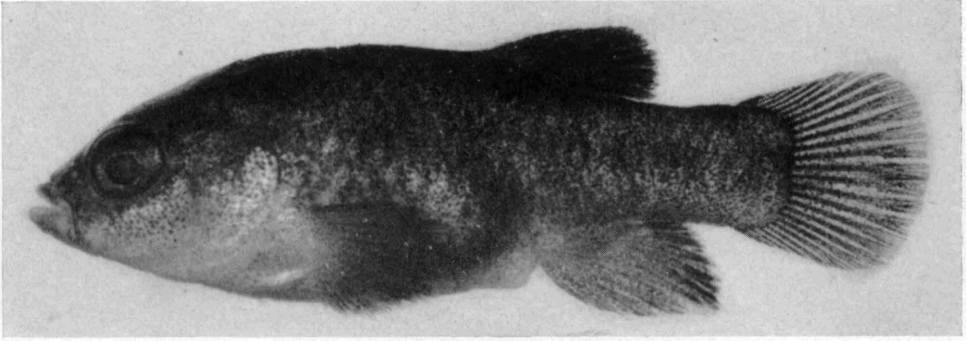


FIG. 1

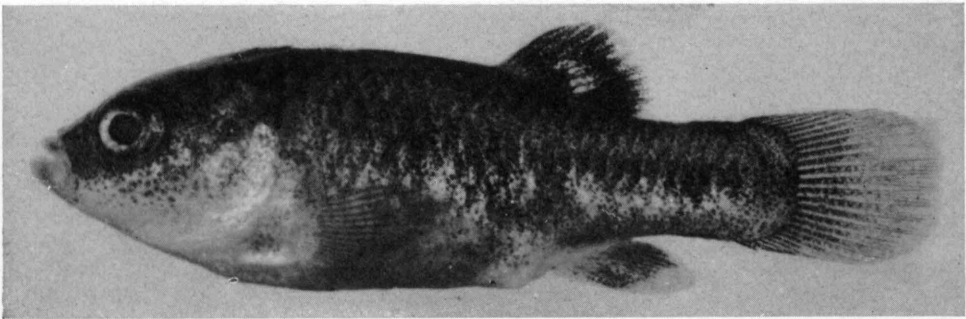


FIG. 2

PLATE VIII

Cyprinodon salinus Miller.

FIG. 1. Adult male holotype, U.M.M.Z. No. 132940, 42 mm. long, from Salt Creek, Death Valley, Inyo County, California.

FIG. 2. Adult female paratype, U.M.M.Z. No. 132941, 40 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE VIII

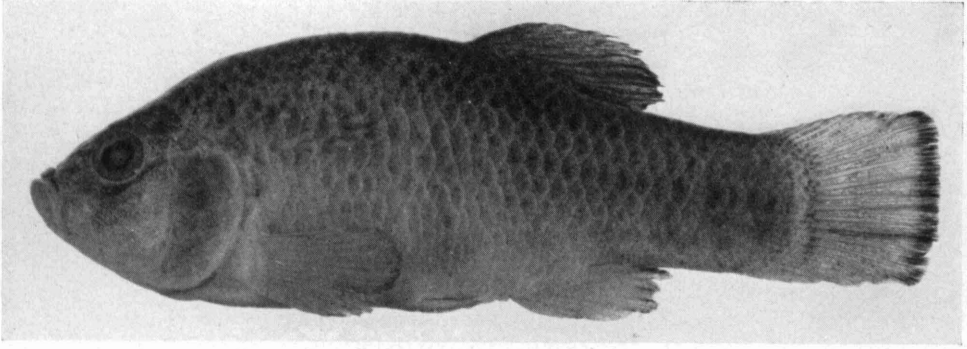


FIG. 1

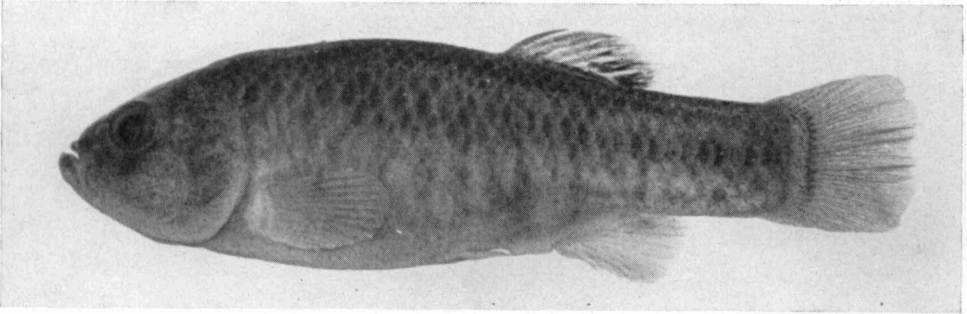


FIG. 2

PLATE IX

Cyprinodon radiosus, new species.

FIG. 1. Adult male paratype, U.M.M.Z. No. 124843, 35 mm. long, from the northwestern spring head of Fish Slough, Owens River drainage basin, Mono County, California. locality.

FIG. 2. Adult female holotype, U.M.M.Z. No. 146653, 34 mm. long, from same locality.

Photographed by Clarence Flaten.

PLATE IX

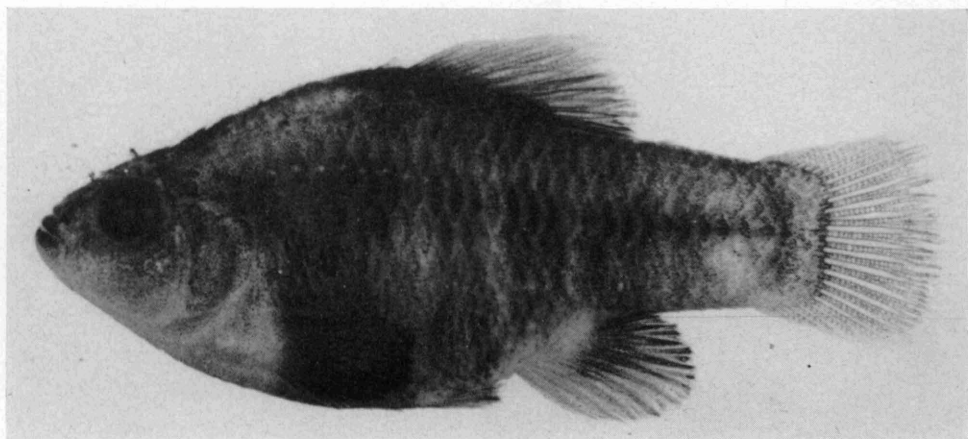


FIG. 1

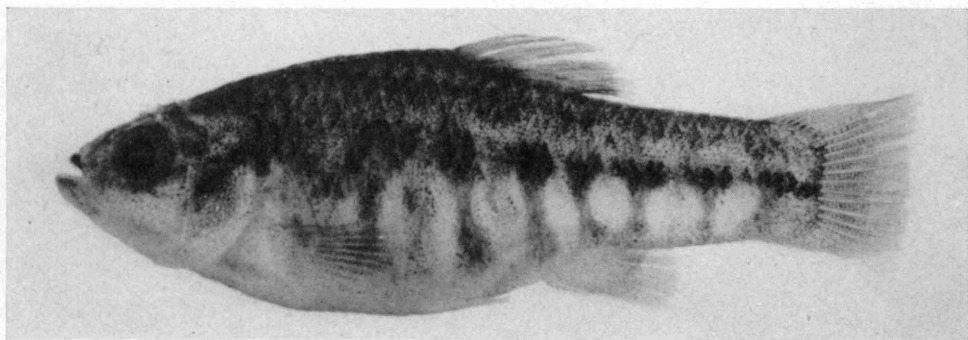


FIG. 2

PLATE X

Two species of *Empetrichthys*.

FIG. 1. *E. merriami* Gilbert. Immature male, U.M.M.Z. No. 140467, 20 mm. long, from Eagle Spring, Ash Meadows, Nye County, Nevada.

FIG. 2. *E. latos*, new species. Immature male paratype, U.M.M.Z. No. 140489, 20 mm. long, from main spring pool on Manse Ranch, Pahrump Valley, Nye County, Nevada.

Drawn by Grace Eager.

PLATE X

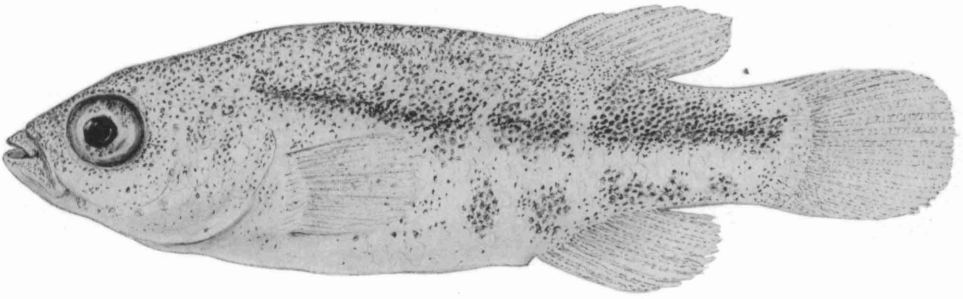


FIG. 1



FIG. 2

PLATE XI

Four forms of *Empetrichthys*.

Top to bottom:

E. merriami Gilbert. Adult male, U.M.M.Z. No. 140467, 34 mm. long, from Eagle Spring, Ash Meadows, Nye County, Nevada.

E. latos concavus, new subspecies. Adult male paratype, U.M.M.Z. No. 140491, 34 mm. long, from spring on Raycraft Ranch, Pahrump Valley, Nye County, Nevada.

E. latos pahrump, new subspecies. Adult male paratype, U.M.M.Z. No. 140490, 32 mm. long, from spring-fed ditch on Pahrump Ranch, Pahrump Valley, Nye County, Nevada.

E. latos latos, new subspecies. Adult male paratype, U.M.M.Z. No. 140489, 34 mm. long, from main spring pool in Manse Ranch, Pahrump Valley, Nye County, Nevada.

Photographed by F. W. Ouradnik.

PLATE XI

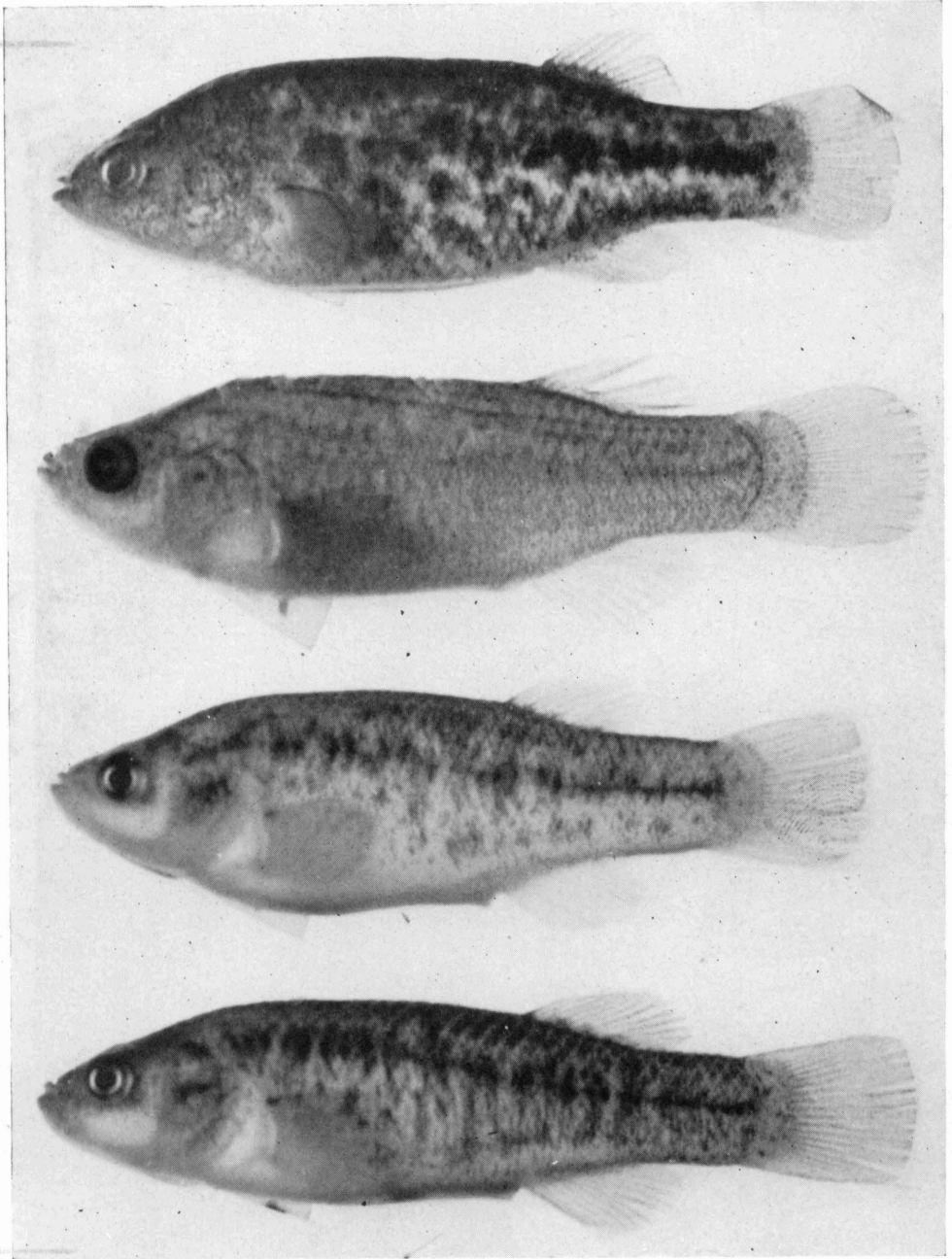


PLATE XII

FIG. 1. North Tecopa Hot Spring (right) and South Tecopa Hot Spring, looking west. Photographed September 26, 1942.

FIG. 2. Big Spring, Ash Meadows, Nye County, Nevada, looking north. In the left foreground is the outlet ditch. Photographed September 27, 1942.

PLATE XII

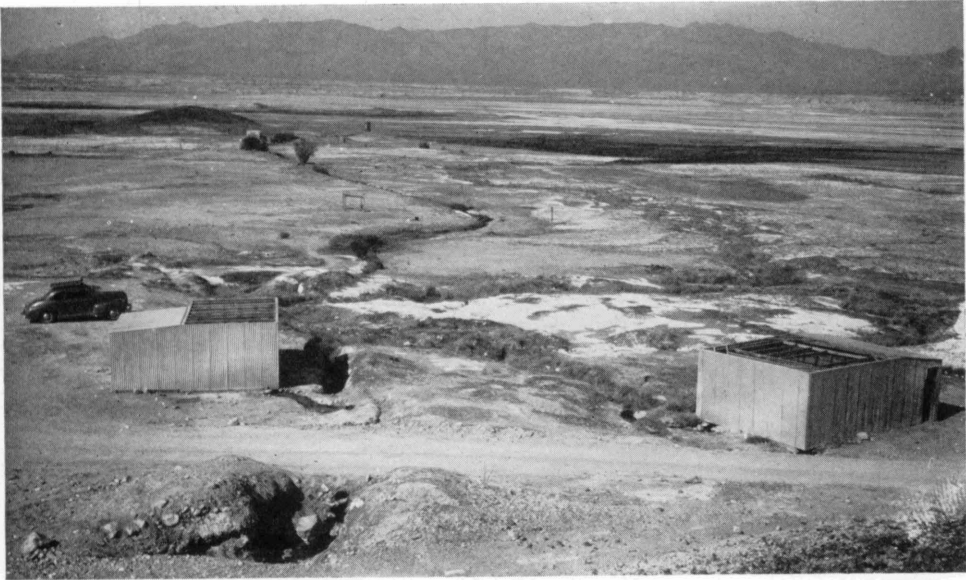


FIG. 1



FIG. 2

PLATE XIII

FIG. 1. Devil's Hole, Ash Meadows, Nye County, Nevada. Close-up view of spring hole, showing the shallow platform in the foreground which comprises the habitat over which 90 per cent of the population of *Cyprinodon diabolis* occurs. Photographed June 5, 1937.

FIG. 2. Devil's Hole, Ash Meadows, Nye County, Nevada. View vertically downward from rim, about 50 feet above. The shallow platform (Fig. 1) lies near the lower end of the pool. Photographed June 5, 1937.

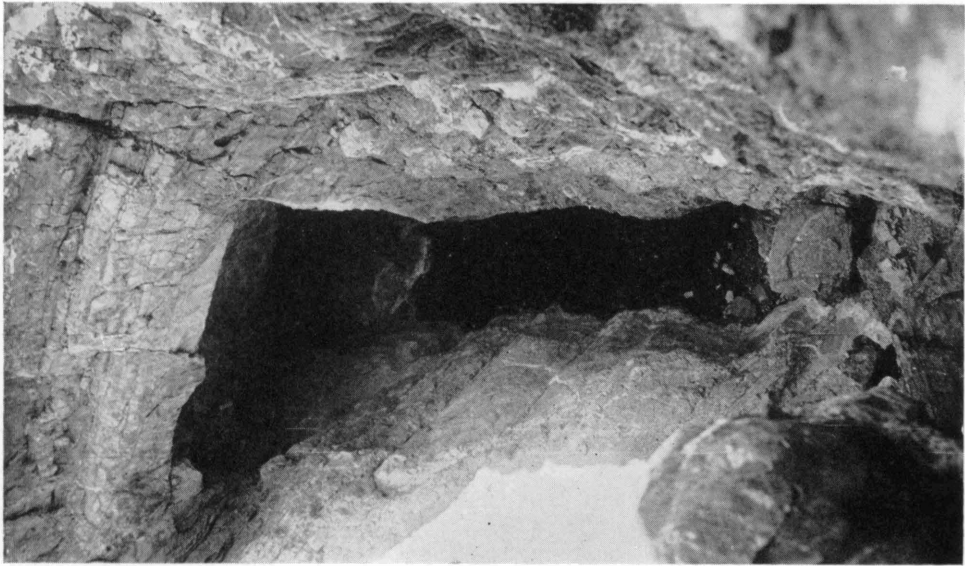


FIG. 2



FIG. 1

PLATE XIV

FIG. 1. Fairbanks Spring, Ash Meadows, Nye County, Nevada, looking northeast. In the left center is the spring head from which the outlet ditch leads eastward. In the background are dissected lake beds. Photographed September 27, 1942.

FIG. 2. Concrete pools in Los Angeles used for experimental studies of *Cyprinodon*. At the bottom is most of Pool 6; directly behind is Pool 8; Pool 1 is at the left; Pool 2 is in the center distance; and Pool 4 is in the upper left-hand corner of the picture. Photographed October 1, 1942.

PLATE XIV



FIG. 1



FIG. 2

PLATE XV

Salt Creek, Death Valley, Inyo County, California.

FIG. 1. The headwater area on Mesquite Flat, looking northeast. Photographed in January, 1938.

FIG. 2. A typical pool in the clumps of salt grass near the head of the canyon just south of Mesquite Flat, looking northwest. Photographed June 25, 1938.

PLATE XV



FIG. 1

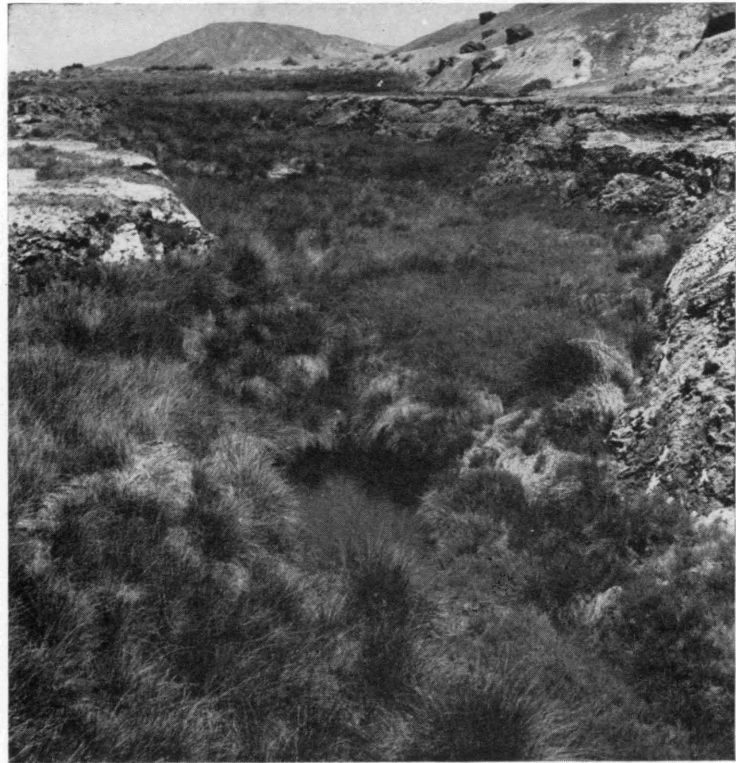
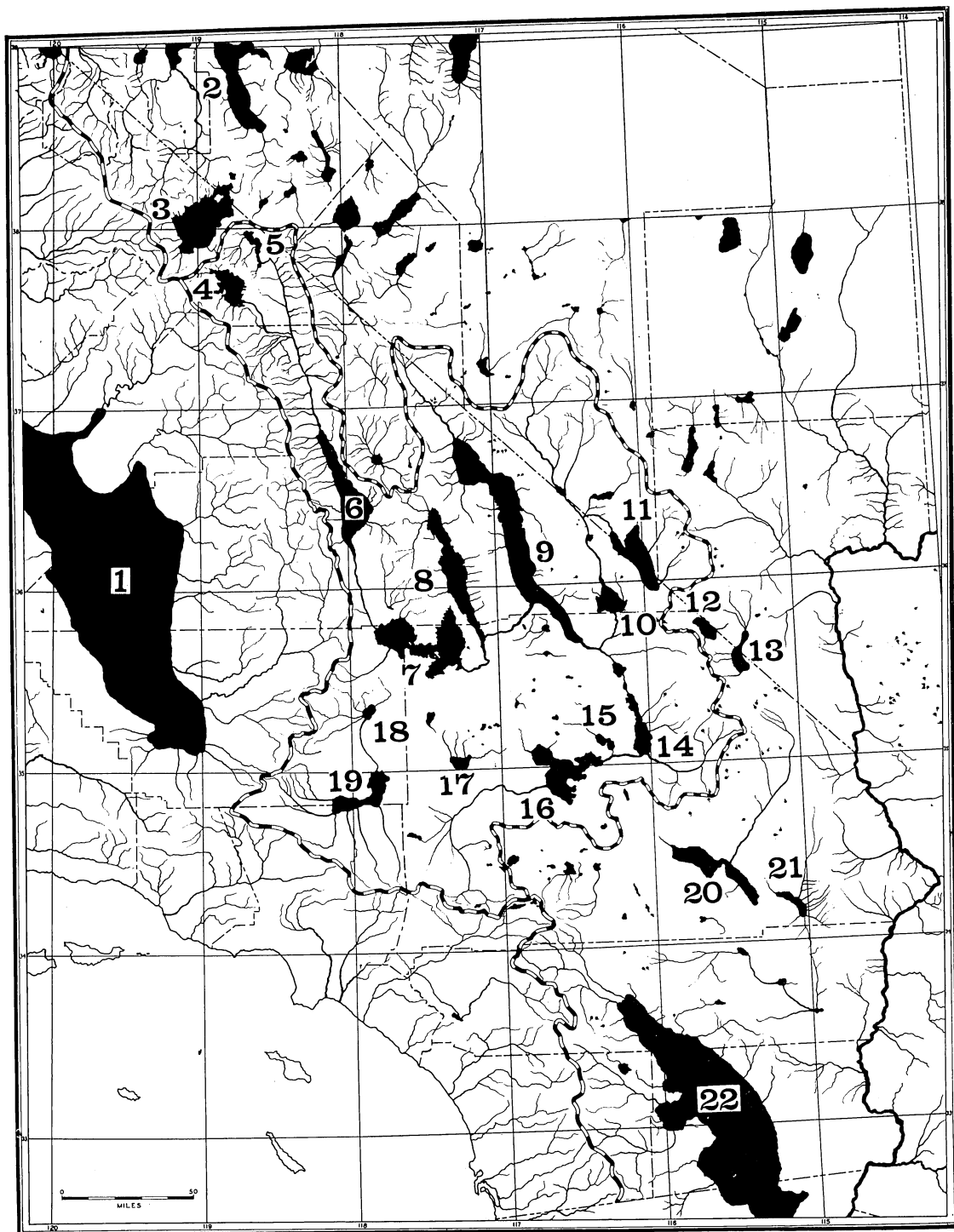


FIG. 2

MAP 1

<i>Pleistocene Lake</i>	<i>Authorities</i>
1. Lake Tulare	Blake, 1857 (last map at end of geological report)
2. Walker Lake arm of Lake Lahontan	Russell, 1885 Russell, 1889
3. Lake Mono	Mayo, 1934; Jenkins, 1938; original observations
4. Lake Long Valley	Original observations, 1938, 1942; Miller, 1946
5. Lake Adobe	Gale, 1914; Jenkins, 1938
6. Lake Owens	Gale, 1914
7. Lake Searles	Gale, 1914
8. Lake Panamint	Gale, 1914
9. Lake Manly	Blackwelder, 1933
10. Lake Tecopa	Noble, 1931; Thompson, 1929, Pl. VIII; Blackwelder, 1936; Jenkins, 1938; original observations
11. Lake Pahrump	Waring, 1920; original observations (see text)
12. Lake Mesquite	Jenkins, 1938
13. Lake Ivanpah	Waring, 1920; Jenkins, 1938
14. Lake Mohave	Thompson, 1921, 1929; Bode, 1935
15. Little Lake Mohave	Thompson, 1921, 1929; Jenkins, 1938; original observations
16. Lake Manix	Buwalda, 1914; Blackwelder and Ellsworth, 1936; Jenkins, 1938; original observations
17. Lake Harper	Jenkins, 1938
18. Lake Kane	Thompson, 1929, Pl. VIII.
19. Lake Thompson	Thompson, 1929; Jenkins, 1938; Miller, 1946
20. Lake Amboy	Thompson, 1929; Jenkins, 1938
21. Lake Ward	Thompson, 1929; Jenkins, 1938
22. Lake LeConte	Bailey, 1902; Blake, 1907; U. S. G. S. Salton Sink Quad- rangle; Mexican part after Sykes, 1937, modified by Rogers, 1939; Hubbs and Miller, in press.



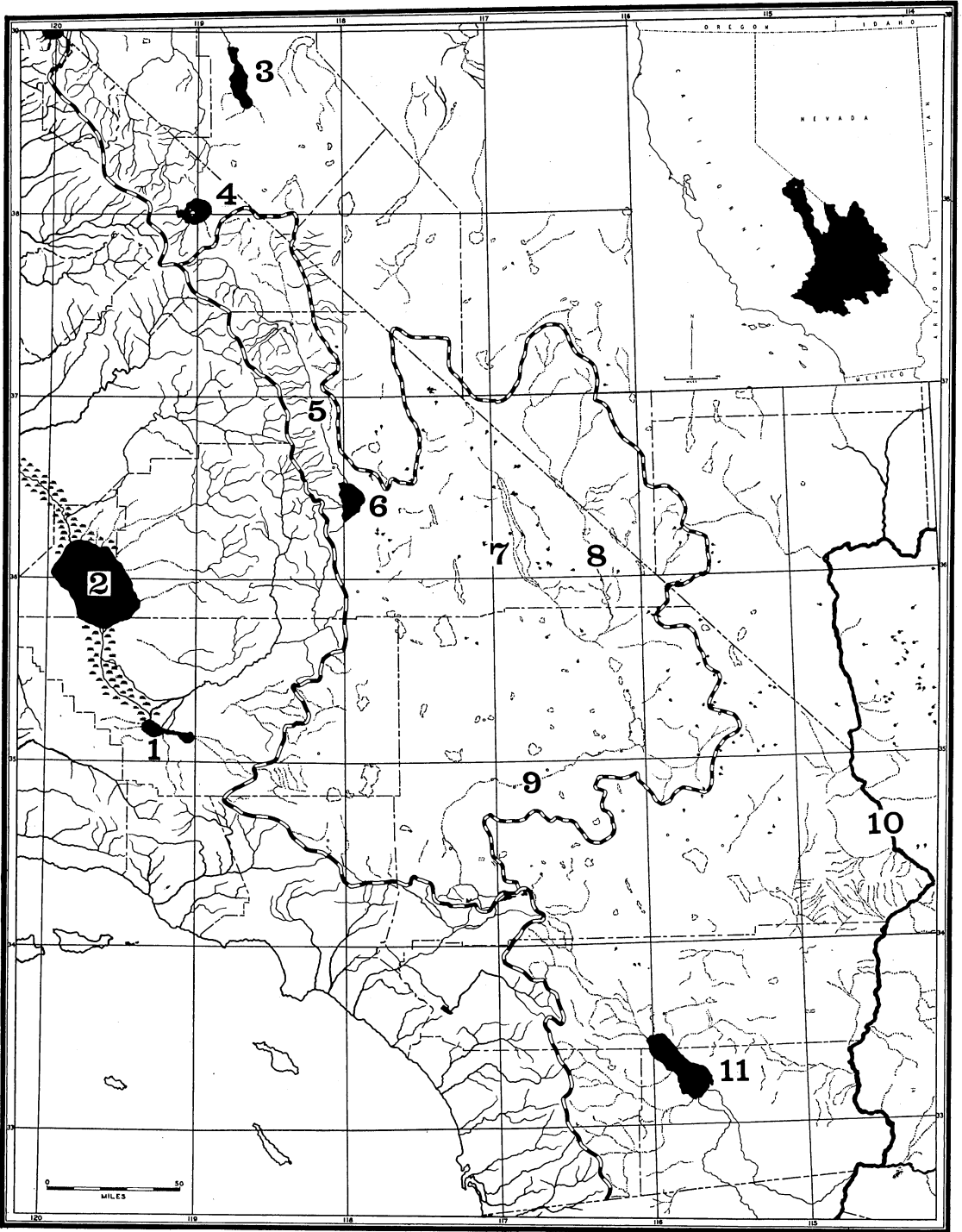
MAP 1. Maximum extent of the Pleistocene waters of the southern Great Basin and adjacent areas. The wider boundary line marks the separation between coastal and interior or Colorado River drainages. The narrower line indicates the outline of the Death Valley stem (see Map 2, inset).

ROBERT R. MILLER

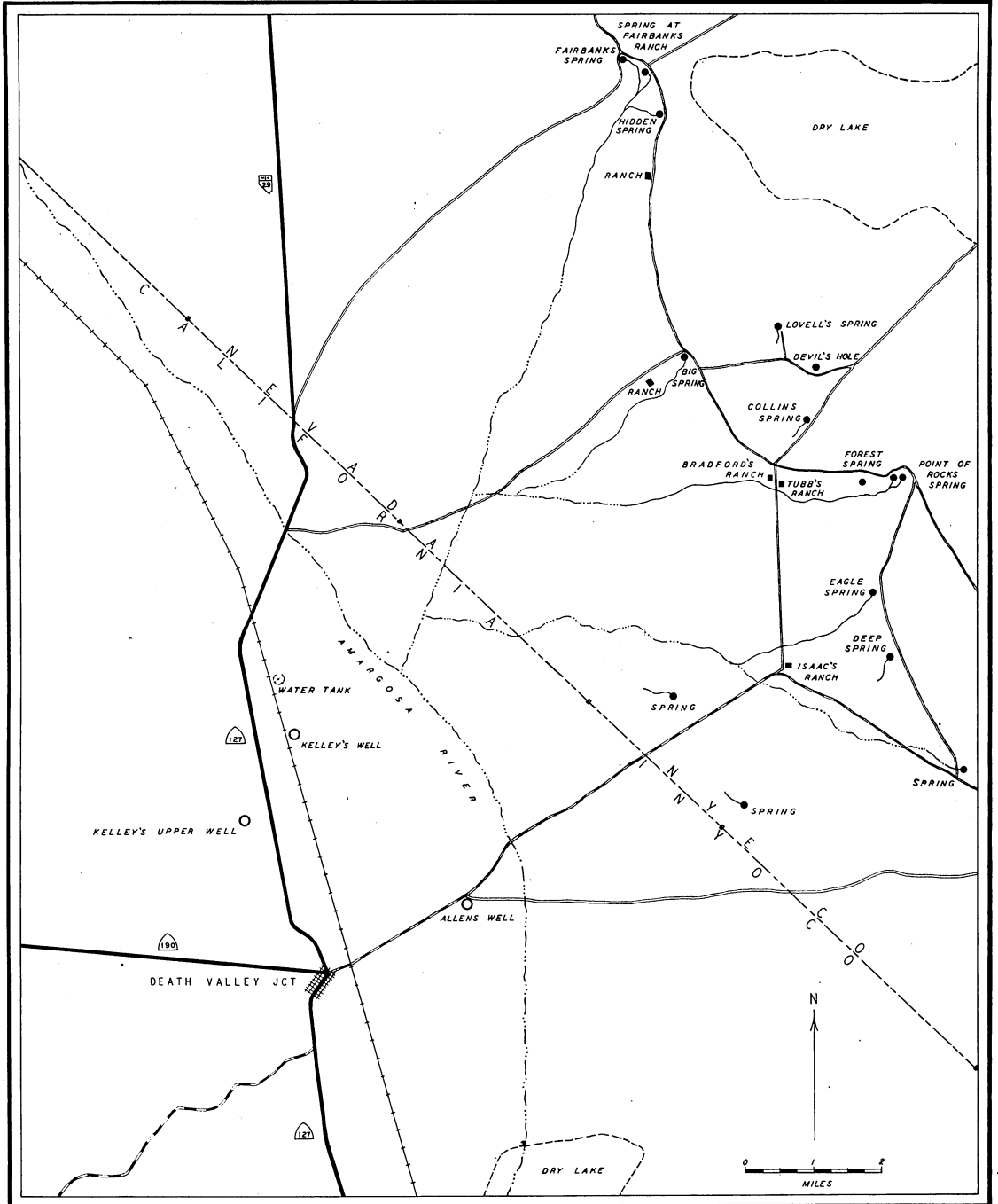
MAP 2

1. Kern and Buena Vista lakes
2. Tulare Lake
3. Walker Lake
4. Mono Lake
5. Owens River
6. Owens Lake
7. Death Valley
8. Amargosa River
9. Mohave River
10. Colorado River
11. Salton Sea

Kern, Buena Vista, and Tulare lakes are mapped as they existed in 1876. These lakes are now dry basins.



MAP 2. Recent hydrography of the southern Great Basin and adjacent areas. The wider boundary line marks the separation between coastal and interior or Colorado River drainages. For comparison with the Pleistocene waters see Map 1. Inset map: Death Valley system and enclosed basins.



MAP 3. Ash Meadows and vicinity. Area between $36^{\circ} 15'$ and $36^{\circ} 30'$ Lat., and $116^{\circ} 15'$ and $116^{\circ} 30'$ Long., modified after and enlarged from U. S. Geological Survey, Furnace Creek Quadrangle, California and Nevada.

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