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SYSTEMATICS AND VARIATION OF A NEW CYPRINODONTID FISH, *CYPRINODON FONTINALIS*, FROM CHIHUAHUA, MEXICO

Michael Leonard Smith and Robert Rush Miller

Abstract.—*Cyprinodon fontinalis,* new species, is described from a cluster of springs in the endorheic Guzmán Basin of northwestern Mexico. It differs from other pupfishes in head form, coloration, and meristic characters. Populations in five springs are variously distinct in coloration and meristic characters.

The Chihuahuan Desert of southwestern United States and northern Mexico is traversed by a few major tributaries of the Rio Grande system (Miller, 1978:fig. 1); however, the larger part of its area is divided into endorheic basins which are commonly occupied only by intermittent streams or isolated springs (Tamayo and West, 1964). During pluvial times, many now enclosed basins of the Chihuahuan Desert had outlets or contained lakes, as shown by abandoned shoreline bars and lacustrine sediments (Reeves, 1969). This formerly complex hydrographic system also left biological remnants: aquatic and semiaquatic organisms in isolated desert springs. Only recently, four new species of *Cyprinodon* were described from the Chihuahuan Desert in Mexico (Miller, 1976).

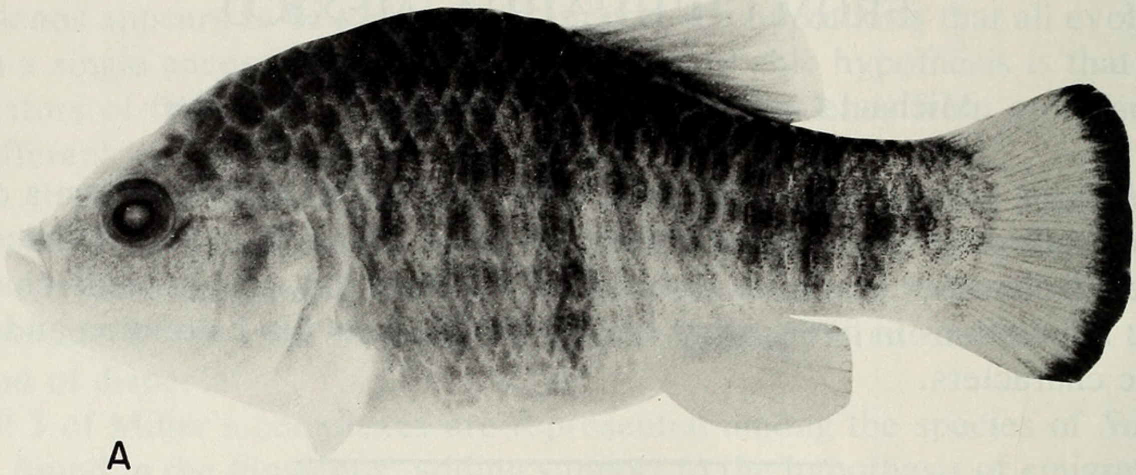
An additional relict pupfish of this genus is here described from a complex of isolated springs in the Bolsón de los Muertos, Chihuahua, Mexico, and variation among its five populations is examined. The new species is based on material in The University of Michigan Museum of Zoology (UMMZ), Field Museum of Natural History (FMNH), and United States National Museum (USNM).

Cyprinodon fontinalis, new species

Fig. 1

Holotype.—UMMZ 204189, male 45.5 mm SL: Mexico, State of Chihuahua, Ojo de Carbonera, about 36 airline km west of Villa Ahumada (106°51′W, 30°35′N), collected by R. R. Miller, E. Marsh and M. L. Smith, 28 May 1978.

Paratopotypes.—UMMZ 203022, 613 specimens (11.0–49.7 mm SL) including 20 cleared and stained individuals collected with the holotype; USNM 220601, 15 specimens including juveniles and adult males and females, 20.2–43.0 mm SL, ex UMMZ 203022; FMNH 83893, 15 specimens



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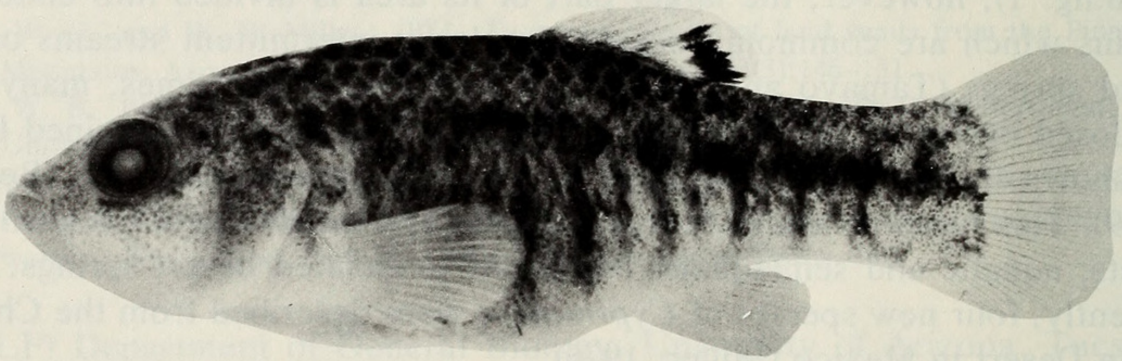

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Fig. 1. *Cyprinodon fontinalis* n. sp. **A.** ♂ UMMZ 204189, holotype, 45.5 mm SL. **B.** ♀ UMMZ 203022, 30.7 mm SL. Mexico, State of Chihuahua, Ojo de Carbonera.

including juveniles and adult males and females, 22.1–14.0 mm SL, ex UMMZ 203022; UMMZ 204190, 36 specimens (8.8–44.2 mm SL) from the same locality as the holotype, collected by M. L. Smith and B. Chernoff, 1 June 1979.

Paratypes.—UMMZ 204191, 28 specimens (18.7–36.4 mm SL), Ojo del Apache, about 3 km SW of Ojo de Carbonera, 31 May 1979; UMMZ 204192, 105 specimens (15.3–40.7 mm SL), Ojo El Medio, about 0.5 km N of Ojo de Carbonera, 2 June 1979; UMMZ 204193, 53 specimens (12.1–39.2 mm SL), Ojo de las Varas, about 1 km N of Ojo de Carbonera, 2 June 1979; UMMZ 204194, 68 specimens (15.7–39.6 mm SL), Ojo Solo, about 3 km N of Ojo de Carbonera, 2 June 1979.

Table 1.—Morphometrics in thousandths of standard length of *Cyprinodon fontinalis*, based on UMMZ 203022, 204189, 204191, 204192, 204193, and 204194; holotype included with males.

	30 Males			30 Females	
	Holotype	Range	$\bar{x}$	Range	$\bar{x}$
Standard length, mm	45.5	22.4–48.8	32.8	25.9–44.6	33.6
Predorsal length	626	559–638	593	506–632	597
Prepelvic length	611	513–614	577	527–635	587
Anal origin to caudal base	360	339–497	381	298–371	347
Body depth	468	335–477	411	295–424	369
Body width	248	179–258	218	189–487	239
Head length	345	303–355	333	285–350	323
Head depth	413	290–413	345	261–405	316
Head width	231	195–258	221	189–257	226
Caudal-peduncle length	237	206–269	244	218–341	247
Caudal-peduncle depth	198	176–227	196	149–251	177
Interorbital width	119	94–127	106	93–119	107
Preorbital width	55	35–62	49	36–54	47
Postorbital width	149	137–166	154	125–165	149
Snout length	108	43–113	95	75–115	92
Eye diameter	86	55–94	82	66–99	82
Mouth width	90	71–121	93	80–113	95
Mandible length	83	73–106	89	72–141	88
Dorsal fin, depressed length	303	254–348	298	213–267	247
Anal fin, depressed length	231	201–281	246	176–218	201
Caudal-fin length	202	185–247	214	160–223	189
Pectoral-fin length	204	184–245	221	175–230	205
Pelvic-fin length	90	79–104	89	26–108	77

Diagnosis.—The new species is a *Cyprinodon* of typical body form (short and deep) which is distinguished from other members of the genus by the following characters. Breast and abdomen fully scaled. Scapular scale not notably enlarged in comparison to surrounding scales; cleithral process moderately developed. First dorsal-fin ray slender and flexible; outer half of dorsal fin of males yellow or cream-colored, basal half dusky; a pronounced ocellus present in the dorsal and sometimes anal fin of females. First anal-fin ray of mature females thicker than the rays which follow. Caudal fin short, 16–23% SL, ending in a jet-black band in males which is much wider than pupil. Pelvic fins small, barely reaching or falling short of anus, most often six-rayed. Mouth upturned; mandible heavy and robust, projecting beyond tip of snout. Branchiostegals 6.

Description.—Aspects of morphology and pigmentation are apparent in Fig. 1; morphometric data are given in Table 1. Methods of counting and measuring follow those described by Miller (1948). The last two closely approximated rays of both dorsal and anal fins are counted as one ray. Characters which show significant differences between populations are

Table 2.—Frequency distributions of cephalic sensory-pore counts in *Cyprinodon fontinalis*. Pores were counted on both sides of the head of each specimen.

	Mandibular pores					Preopercular pores				
	0,0	0,1	0,2	1,2	2,2	5,6	6,6	6,7	7,7	7,8
Ojo del Apache	3			3	14		9	7	2	2
Ojo de Carbonera	12	2	4	2	10	2	19	6	2	1
Ojo El Medio	15				5	1	13	4	1	1
Ojo de las Varas	5	1	3	1	10		11	7	2	
Ojo Solo	1		2		17		2	2	14	2
Total	36	3	9	6	56	3	54	26	21	6

treated by locality (Table 2); otherwise the data from all populations are combined. In the meristic data below, the count for the holotype is indicated by an asterisk.

Body deep and compressed. Median fins set back on body, dorsal-fin origin slightly behind pelvic insertion, closer to caudal base than to tip of snout. Predorsal length equals 51–64% SL.

First dorsal-fin ray slender and short, 51–79% as long as fourth ray. Dorsal-fin rays 9(1 count), 10*(54), 11(5). Anal-fin rays 9(2), 10(46), 11*(12). Pectoral-fin rays 12–14(1), 14–15(6), 14–16(2), 15–15*(31), 15–16(5), 16–16(14), 17–18(1). Pelvic-fin rays 0–0(1), 1–4(1), 3–4(1), 3–5(1), 5–5(6), 5–6(7), 6–6*(52), 6–7(1), 7–7(3). Caudal-fin rays 14(1), 15*(6), 16(29), 17(18), 18(4), 19(2).

Scapular scales about the same size as adjacent scales, the underlying cleithral process broad, but not much expanded posteriorly. Scales in lateral series 23(8), 24*(36), 25(15), 26(1). Body-circumference scale rows 23(1), 24(1), 25(5), 26(9), 27*(10), 28(20), 29(4), 30(10). Caudal-peduncle scale rows 14(5), 15(2), 16*(52), 18(1). Predorsal scales irregular, the diagonal rows numbering 14(5), 15(13), 16*(23), 17(15), 18(4). Total gill rakers on right anterior arch, including all rudiments, 16(3), 17*(14), 18(21), 19(16), 20(6). Total vertebrae (including hypural plate as 1), taken from radiographs, 25*(11), 26(46), 27(3). Precaudal vertebrae 11(4), 12*(53), 13(4). Caudal vertebrae 13*(10), 14(47), 15(4). Branchiostegal rays, from alizarin preparations, 6–6(20).

Sensory pores of acoustico-lateralis system on lacrimal 0–0(63), 0–1(2), 0–2(11), 1–1(1), 1–2(2), 2–2*(20), 2–4(4), 2–6(1), 3–3(1), 3–4(1), 4–4(3). Other sensory pore counts are given in Table 2.

Pelvic fin aberrations.—Pelvic fins are irregular in the 1979 collection from Ojo de Carbonera (UMMZ 204191). Aberrations occur in 33% of the 36 specimens. Although the pelvic girdle is always present, either or both fins may be absent, fin-rays may be imbedded in the skin of the abdomen, size and fin-ray counts may be reduced, or the fins may be connected to each other by a membrane. In other collections, aberrations occur in 5% of the specimens.

Sexual dimorphism.—The fins of males, particularly the dorsal and anal fins, are generally longer than those of females. With increasing size, males become very compressed and deep-bodied, developing a high predorsal crest (Fig. 1). In breeding males, contact organs develop on the head, the sides of the body between the dorsal and anal fins, and on the first six anal-fin rays. Breeding tubercles are not as well-developed in *C. fontinalis* as they are in many other *Cyprinodon.*

The first anal-fin ray of males is slender and flexible. In females, it is thickened and bow-shaped, with a wide interradial space between it and the second ray.

Color patterns as described in the next section also distinguish the sexes.

Coloration.—In life, adults are light gray-green on the back and sides; the breast, periproct and lower half of the head are silvery, sometimes with a yellow cast. The sides are crossed by 5 to 13 prominent gray-blue vertical bars which extend low onto the sides but are not continuous ventrally; the interspaces, silvery to milky white, are wider than the bars. Occasionally (particularly in females), the bars are expanded mid-way on the sides to form a lateral series of blotches which give the impression of a broken lateral stripe. The predorsal region may be bright iridescent purple-blue, particularly in males.

In adult males, the caudal fin ends in a jet-black marginal band wider than the pupil; the rest of the fin is hyaline. The margin and interradial membranes of the dorsal fin are yellow-orange or cream-colored; the rays and base of the fin are dusky. Anal-fin rays are cream-colored or yellow-orange with hyaline interradial membranes; the fin may end in a very fine black margin. Paired fins are yellowish, with a fine black edge.

In adult females, fins are mostly clear, but with a yellowish cast near the base of paired fins. The dorsal fin bears a black ocellus, the size of the eye or larger, in its posterior half. The ocellus is usually preceded by a contrasting spot of white. An ocellus occurs consistently in the anal fin of females from Ojo del Apache; it occurs rarely as a spot or faint ocellus in females from Carbonera, El Medio and Las Varas. The anal ocellus is consistently absent in females from Ojo Solo.

Juveniles (our specimens 8.8 to 18.3 mm SL) are mostly gray-green but the background color is lighter than in adults. The back is mottled by a series of dark blotches on both sides of the upper back; these blotches and the prominent vertical bars make the juveniles difficult to see against the coarse sand and fine gravel where they were collected. A faint ocellus may be present in the dorsal fin of immature males.

In ethyl alcohol, white, blue and gray-green colors disappear. The upper part of the body becomes leaden gray, the lower part yellowish or buff.

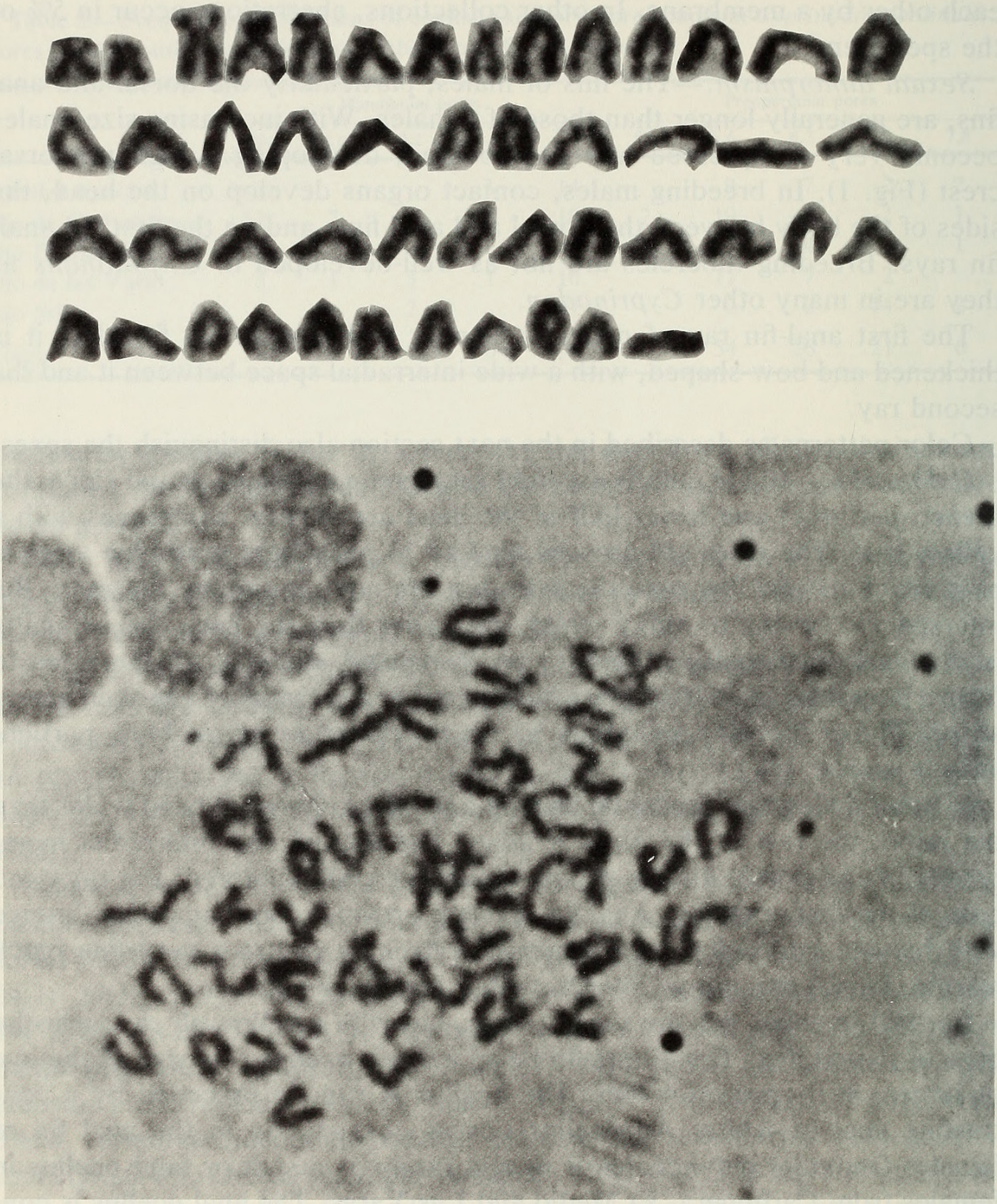

Fig. 2. Somatic chromosomes at metaphase of *Cyprinodon fontinalis*; female from the type locality.

Vertical bars remain prominent as do the black fin margins of males and ocelli of females. Males retain the characteristic dusky color in the lower half of the dorsal fin. The dorsal spots of juveniles quickly disappear in preservative.

Comparisons.—The cleithral process of *C. fontinalis* is only moderately

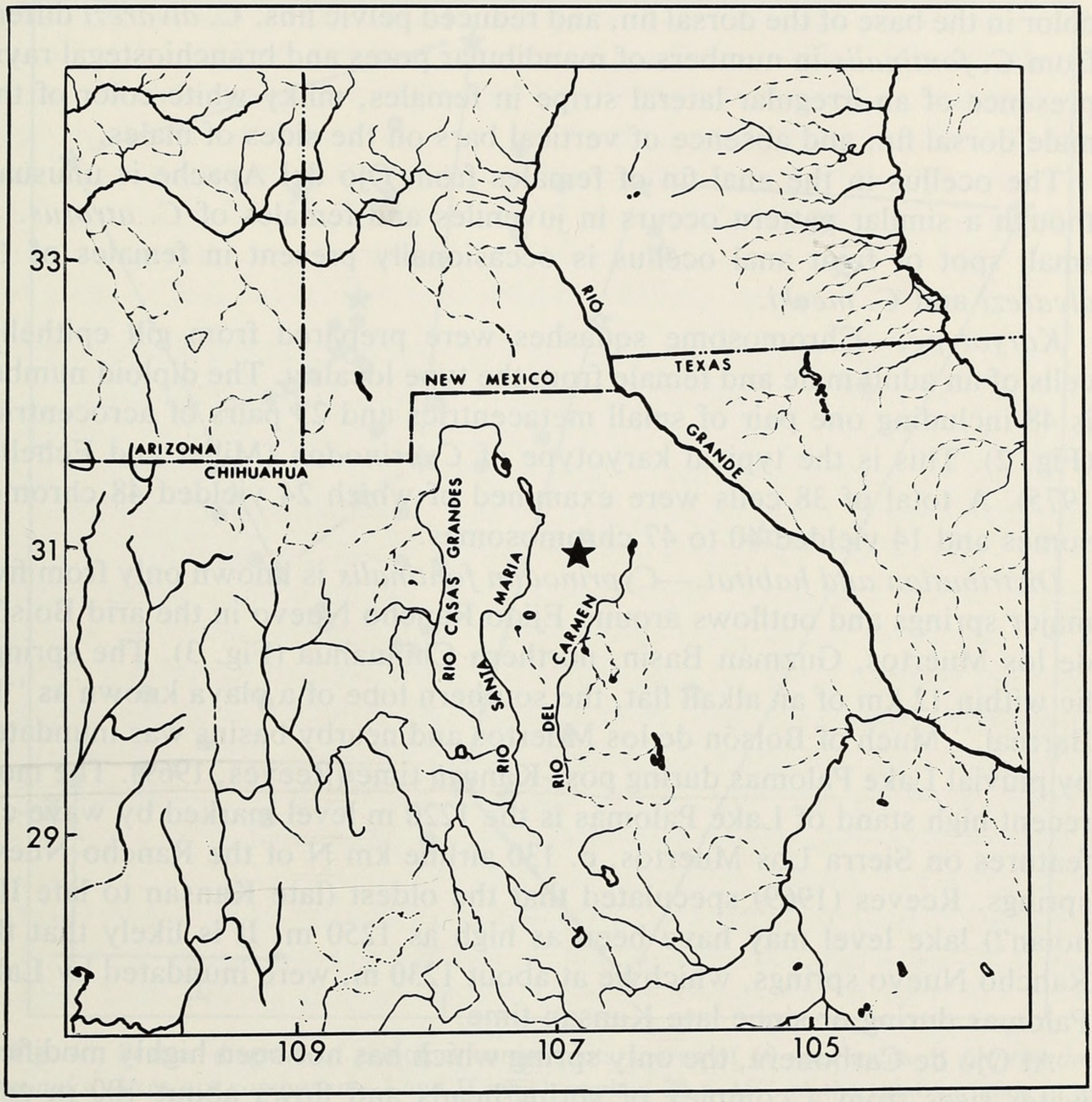

Fig. 3. Location of the habitat of *Cyprinodon fontinalis* in a complex of springs, marked by a star, in Chihuahua, northwestern Mexico.

developed for a *Cyprinodon*, about the same as in *C. nevadensis* (see Miller, 1956:fig. 1). In this respect, it differs from *C. variegatus*, *C. eximius*, *C. nazas*, *C. alvarezi* and *C. meeki* and closely resembles *C. atrorus*, *C. latifasciatus* and *C. macrolepis*. Further resemblances between *C. fontinalis* and *C. macrolepis* include low values for meristic characters: lateral scales 23–26 and 23–24, respectively; gill rakers 16–20 and 17–22; and total vertebrae 27 or fewer in both. These two species differ in coloration, head-pore counts and the stronger mandible of *C. fontinalis*.

The lower jaw is unusually prominent in the new species, equalled only by that of *C. alvarezi*. These species are also similar in general head and body form, presence of a wide terminal band on the male caudal fin, dusky color in the base of the dorsal fin, and reduced pelvic fins. *C. alvarezi* differs from *C. fontinalis* in numbers of mandibular pores and branchiostegal rays, presence of an irregular lateral stripe in females, milky white color of the male dorsal fin, and absence of vertical bars on the sides of males.

The ocellus in the anal fin of females from Ojo del Apache is unusual, though a similar pattern occurs in juveniles and females of *C. atrorus*. A small spot or faint anal ocellus is occasionally present in females of *C. alvarezi* and *C. meeki*.

Karyotype.—Chromosome squashes were prepared from gill epithelial cells of an adult male and female from the type locality. The diploid number is 48 including one pair of small metacentrics and 23 pairs of acrocentrics (Fig. 2). This is the typical karyotype of *Cyprinodon* (Miller and Echelle, 1975). A total of 38 cells were examined of which 24 yielded 48 chromosomes and 14 yielded 40 to 47 chromosomes.

Distribution and habitat.—*Cyprinodon fontinalis* is known only from five major springs and outflows around Ejido Rancho Nuevo in the arid Bolsón de los Muertos, Guzmán Basin, northern Chihuahua (Fig. 3). The springs lie within 12 km of an alkali flat, the southern lobe of a playa known as "El Barreal." Much of Bolsón de los Muertos and nearby basins was inundated by pluvial Lake Palomas during post-Kansan time (Reeves, 1969). The most recent high stand of Lake Palomas is the 1220 m level marked by wave-cut features on Sierra Los Muertos, c. 130 airline km N of the Rancho Nuevo springs. Reeves (1969) speculated that the oldest (late Kansan to late Illinoian?) lake level may have been as high as 1250 m. It is likely that the Rancho Nuevo springs, which lie at about 1230 m, were inundated by Lake Palomas during or since late Kansan time.

At Ojo de Carbonera, the only spring which has not been highly modified, water rises from a complex of spring-heads and flows about 100 m as a shallow brook (less than 10 cm deep) before entering an irrigation system. *Cyprinodon fontinalis* is most abundant in solution holes which reach nearly a meter in depth and 1.5 m in diameter. It also occurs along the undercut banks of the outflow. Aquatic vegetation is sparse, consisting of filamentous algae, *Chara, Nasturtium,* and submerged grass. Substrates range from quicksand in the solution holes to gravel in the outflow. The water temperature in the spring was 27°C on 28 May 1978 and 6 June 1979.

C. fontinalis also occurs in irrigation ditches and four springs which have been impounded (Ojo Solo, Ojo de las Varas, Ojo El Medio, and Ojo del Apache). Pupfish are most abundant in water less than 0.5 m deep over sandy substrates; moving water is avoided. Aquatic vegetation is sparse though *Typha* and submerged grass occur around the pond margins. Water temperatures ranged from 25.5 to 28.0°C on 6–7 June 1979.

Gambusia affinis has been introduced and is common at all localities. Black bass are present by local account, but none was seen; an introduced

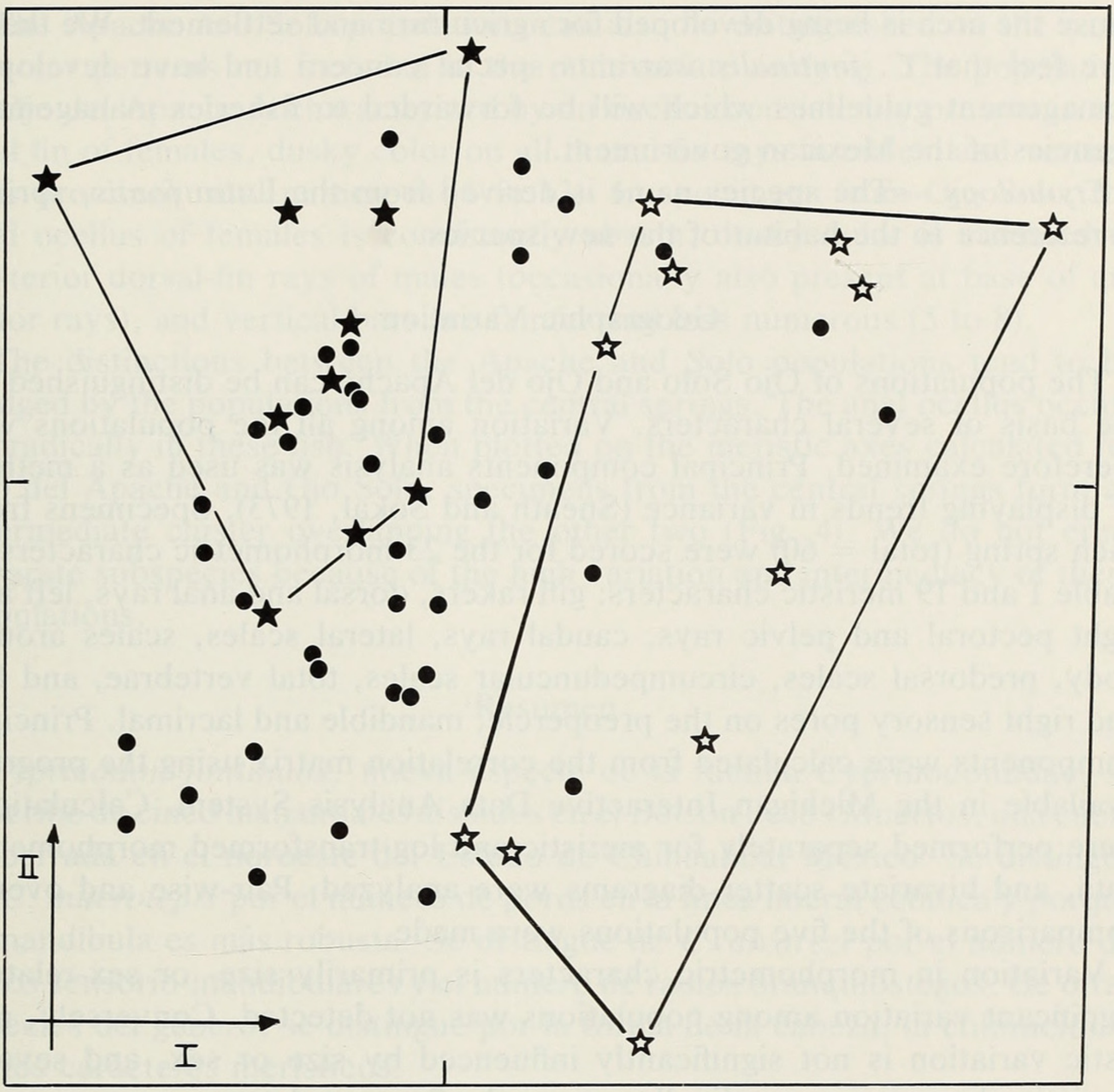

Fig. 4. Scatter diagram of principal components scores of 60 specimens of *Cyprinodon fontinalis*. Axes are components I and II which explain 20 + 15% of the total variance in an analysis of 19 meristic characters. Solid stars, Ojo del Apache; open stars, Ojo Solo; solid dots, central springs (Ojo de Carbonera, Ojo El Medio, Ojo de las Varas).

catfish, *Ictalurus melas,* was taken at Ojo Solo. The only native fish sympatric with *C. fontinalis* is an undescribed species of *Notropis,* known only from Ojo Solo.

A new species of crayfish, genus *Cambarellus,* from Ojo de Carbonera and nearby springs is being described by Hobbs (1980).

Status.—The original distribution and population size of *C. fontinalis* are unknown because its habitat had already been considerably modified when field studies were first undertaken in 1978. It is reasonable to infer, however, that the pupfish has suffered a decline in numbers because it is presently more abundant in remnant natural habitat (Ojo de Carbonera) than in the man-made ditches and impoundments at the other springs. Further modifications of the aquatic habitat at Ejido Rancho Nuevo can be expected because the area is being developed for agriculture and settlement. We therefore feel that *C. fontinalis* warrants special concern and have developed management guidelines which will be forwarded to fisheries management agencies of the Mexican government.

Etymology.—The species name is derived from the Latin *fontis,* spring, in reference to the habitat of the new species.

Geographic Variation

The populations of Ojo Solo and Ojo del Apache can be distinguished on the basis of several characters. Variation among all the populations was therefore examined. Principal components analysis was used as a method of displaying trends in variance (Sneath and Sokal, 1973). Specimens from each spring (total = 60) were scored for the 23 morphometric characters of Table 1 and 19 meristic characters: gill rakers, dorsal and anal rays, left and right pectoral and pelvic rays, caudal rays, lateral scales, scales around body, predorsal scales, circumpeduncular scales, total vertebrae, and left and right sensory pores on the preopercle, mandible and lacrimal. Principal components were calculated from the correlation matrix using the program available in the Michigan Interactive Data Analysis System. Calculations were performed separately for meristic and log-transformed morphometric data, and bivariate scatter diagrams were analyzed. Pair-wise and overall comparisons of the five populations were made.

Variation in morphometric characters is primarily size- or sex-related; significant variation among populations was not detected. Conversely, meristic variation is not significantly influenced by size or sex, and several meristic characters vary clinally among the five populations.

The populations from the three central springs (Carbonera, El Medio and Las Varas) cannot be distinguished on the basis of meristic characters. When scattered according to their scores on any two of the first ten principal components, specimens from these springs (which are close together and connected by irrigation ditches) form a single cluster.

A scatter diagram of specimens from the two more remote, isolated springs (Apache and Solo) reveals two distinct clusters (Fig. 4). Characters contributing strongly to the first component are, in order of importance, pelvic-fin rays, preopercular sensory pores and body-circumference scale rows. The second component is most strongly influenced by anal-fin rays, vertebrae, dorsal-fin rays and mandibular sensory pores.

Preopercular and mandibular sensory pores show the greatest differences in frequency distributions between populations (Table 2). In all other meristic characters, modal values are nearly the same for all populations. Separate clusters are formed by the Apache and Solo populations because their characters vary slightly, but in a direction which is characteristic for each population.

The Apache and Solo populations can also be distinguished on the basis of color patterns not included in the multivariate analysis. The population of Ojo del Apache is characterized by an ocellus consistently present in the anal fin of females, dusky color on all dorsal-fin rays in males, and vertical bars prominent and numerous (6 to 13). In specimens from Ojo Solo, the anal ocellus of females is consistently absent, dusky color is confined to posterior dorsal-fin rays of males (occasionally also present at base of anterior rays), and vertical bars are fainter and less numerous (5 to 8).

The distinctions between the Apache and Solo populations tend to be bridged by the populations from the central springs. The anal ocellus occurs sporadically in these fish. When plotted on the meristic axes calculated for Ojo del Apache and Ojo Solo, specimens from the central springs form an intermediate cluster overlapping the other two (Fig. 4). We do not erect separate subspecies because of the high variation and intermediacy of these populations.

Resumen

Cyprinodon fontinalis, nueva especie de la familia Cyprinodontidae, se describe de cinco manantiales aislados en el Bolsón de los Muertos, una cuenca cerrada en el noroeste del Estado de Chihuahua, México. Se distingue de *C. macrolepis* por el número de poros en la línea lateral cefálica y porque la mandíbula es más robusta. Se distingue de *C. alvarezi* por el número de poros sensorio-mandibulares y el número de radios branquióstegos. De otras especies del género, se distingue por la forma de la cabeza, la coloración y varios carácteres merísticos.

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Division of Biological Sciences and Museum of Zoology, The University of Michigan, Ann Arbor, Michigan 48109.