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TWO NEW, RELICT GENERA OF CYPRINID FISHES FROM NEVADA

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THE strong tendencies toward isolation, endemism, and relict distribution that characterize the fishes of the arid American West (Hubbs, 1941: 65–68; Hubbs and Miller, in press) are most spectacularly illustrated by the distinct genera of very limited distribution. Among those described, the best examples are the cyprinodonts, *Empetrichthys* Gilbert (1893: 233; Miller, in press) and *Crenichthys* Hubbs (1932: 3; Hubbs and Miller, 1941: 1). The 2 cyprinid genera herein described, *Moapa* and *Eremichthys,* are apparently even more notable for their restricted occurrence. Like *Empetrichthys* and *Crenichthys,* they are endemic to Nevada. The 4 constitute 25 per cent of the known native fish genera of the state.

Moapa, new genus

Genotype, *Moapa coriacea,* new species.

The uniserial pharyngeal teeth typically number 5 on the left side and 4 on the right. The upper ones have a moderately strong hook and a faceted rather than excavated grinding surface. The hook and grinding surface grade toward obsolescence on the lower, rather stumpy teeth.

The rather strong lower pharyngeal arch (Fig 1*B*) is hooked on the thin, morphologically inner edge. The 2 arms, measured from the teeth, are of subequal length. The lower arm is moderately slender, terete, and curved. Below the main teeth the concave outer face is rather precipitous and lacks a shelf on which teeth of the outer (lesser) row might develop.

No trace of a barbel can be found. The premaxillary groove although continuous is shallower on the median line than it is laterally. A hidden frenum, therefore, might be described as present. Both lips are rather thick. The upper lip is expanded at the front in a somewhat shield-shaped form. The snout and upper lip are about equal in forward projection, but the lower jaw is definitely included. When the mouth is tightly closed, the rather long maxillary fold is hidden between the rostral fold and the upper lip. The rostral-maxillary crease is scarcely continued onto the side of the snout. The fold of each lower lip is about twice as long as the width of the isthmus between the folds of either side. The weakly curved gape is subhorizontal. The maxillary extends nearly to or a little beyond the vertical from the front of the eye.

As measured from the angle of the gill arch, the much restricted first gill slit is about as long as the eye. As the upper arm of the gill slit is scarcely developed, the pharyngeal roof shows almost no tendency to form a septum. The short, soft gill rakers number only 5 to 9, including all rudiments (Table II). There are no pseudobranchiae. The intestine is short (about one-half the standard length). It is straight posteriorly, but moderately coiled upon itself anteriorly, where it makes about three U-shaped convolutions. The peritoneum is blackish.

The scales are very small and deeply embedded, giving the skin a distinctly leathery texture. In outline the scales are roughly subcircular. Radii are scattered on all fields. The scales along the lateral line number about 70 to 80. Especially on the trunk these scales are slightly larger than those immediately above or below the lateral line. This is particularly true of the breeding males. The lateral line is typically complete, rarely somewhat disrupted. It is very slightly decurved behind the head and is straight posteriorly.

The origin of the dorsal fin lies directly over or slightly behind the pelvic insertion, closer to the caudal base than to the tip of the snout. This short-based fin has 8, occasionally 7, principal rays. None of the rays are spiny. The first ray

TABLE I

FIN RAY COUNTS IN 100 SPECIMENS EACH OF *Moapa coriacea* AND *Eremichthys acros* (U.M.M.Z. No. 136874)

Species	Number of Dorsal Rays			
	7	8	Mean	SE
Moapa coriacea	5	95	7.95	±.02
Eremichthys acros	9	91	7.91	±.03

Species	Number of Anal Rays					
	7	8	9	10	Mean	SE
Moapa coriacea	13	87	......	......	7.87	±.03
Eremichthys acros	21	78	......	1	7.81	±.05

Species	Number of Caudal Rays						
	17	18	19	20	21	Mean	SE
Moapa coriacea	1	1	97	1	......	18.98	±.02
Eremichthys acros	1	5	90	3	1	18.98	±.04

Species	Number of Pectoral Rays								
	13	14	15	16	17	18	19	Mean	SE
Moapa coriacea	5	48	44	3	......	......	......	14.45	±.06
Eremichthys acros	......	1	5	38	47	7	2	16.60	±.08

Species	Number of Pelvic Rays					
	6	7	8	9	Mean	SE
Moapa coriacea	1	14	85	......	7.84	±.04
Eremichthys acros	1	5	92	2	7.95	±.03

is minute; the second, short and closely appressed to the third. The anal fin, also short-based, has a concave border, giving it a slightly falcate appearance. It has 7, or commonly 8, principal rays. The well-forked caudal fin is equilobate. There are usually 8 pelvic rays, but the number is occasionally reduced to 7, or even to 6 (Table I).

GENERIC COMPARISONS.—In dealing with the relationships of *Moapa,* four other cyprinid genera need be considered. The

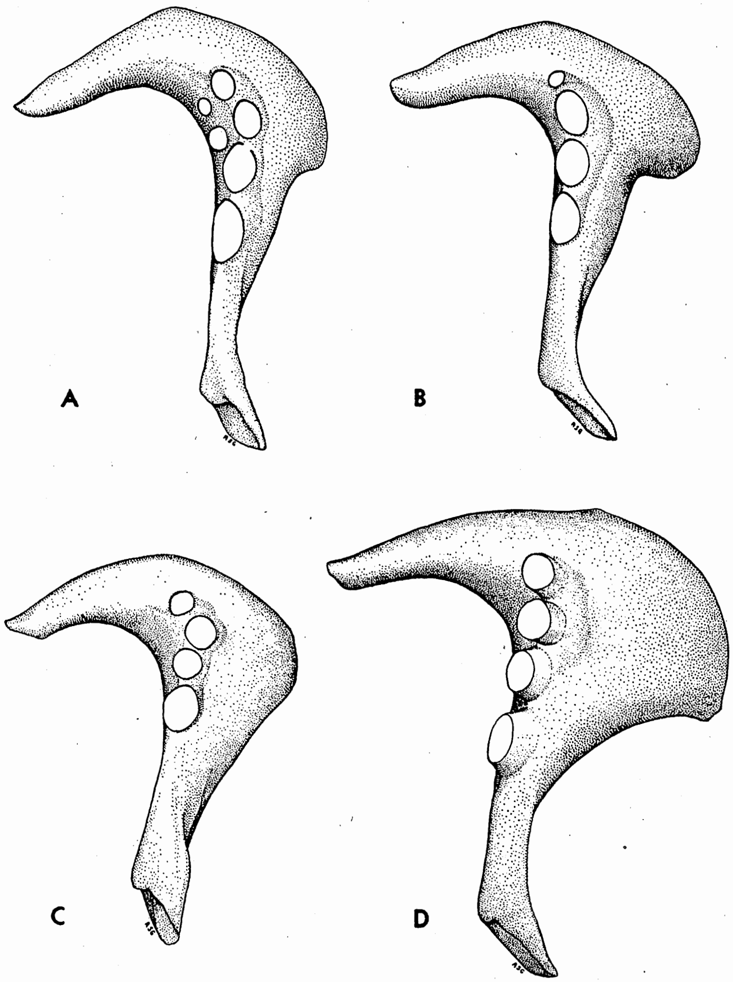


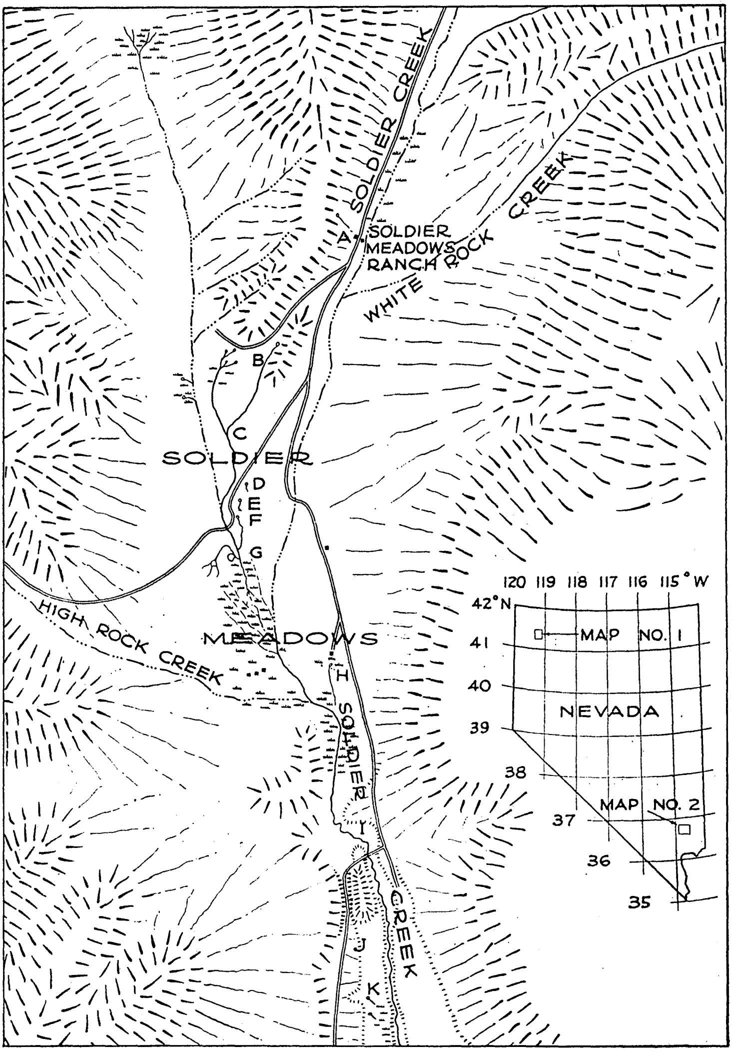
Fig. 1.—Comparison between right pharyngeal arches of four genera of cyprinid fishes. The number and position of the teeth are represented by the alveoli. *A, Gila robusta,* U.M.M.Z. No. 124819, 63 mm. in standard length. *B, Moapa coriacea,* U.M.M.Z. No. 124822, 57 mm. long. *C, Siphateles obesus,* U.M.M.Z. No. 141605, 63 mm. long. *D, Eremichthys acros,* U.M.M.Z. No. 136874, 57 mm. long. Drawn by Ann Green.

dental formula of the new genus, 5—4, is characteristic of most forms of *Siphateles,* but the shape of the pharyngeal arch (Fig. 1 *B*) is very different, rather closely resembling that of *Gila* (Fig. 1 *A*). In no other special way does *Moapa* resemble *Siphateles,* which genus, moreover, is unknown, either Recent or fossil, in the faunally distinctive Colorado River basin.

In appearance the new genus approaches *Gila,* particularly the race of *G. robusta* that inhabits the same stream, but it differs from all species of that genus in the lack of teeth in the lesser (outer) row. In the relatively small, subinferior, nearly horizontal mouth, in the development of radii on all fields of the scale, in the leathery skin, and in the strong basicaudal spot, *Moapa* differs from *Gila* as a whole, but that genus, as at present constituted (Miller, 1945), is so diverse that none of these additional differences are consistently trenchant.

Moapa resembles *Rhinichthys* (including *Apocope*) in the small, subinferior mouth, in the numerous scales, and in the development of radii on all fields of the scales. It differs from that genus in the consistently uniserial rather than usually biserial dentition and in having 5 rather than 4 teeth in the principal row on the left arch.

In many respects *Moapa* agrees very closely with *Agosia,* which is rather widely distributed in the lower Colorado River system and in rivers farther south (Miller, 1946: 206). These genera have in common: (1) a small, subinferior and nearly horizontal mouth, with the lower jaw included; (2) pharyngeal arches of similar shape; (3) a hidden frenum; (4) a rather small eye; (5) small scales, with radii on all fields; (6) a broad, blackish mid-dorsal stripe; and (7) a conspicuous black spot at the base of the caudal fin. This spot (Pl. I, Fig. 1) is better developed in *Moapa coriacea,* however, than it is in any other western minnow. In many other features, as in coloration, in position of dorsal fin, and in number of gill rakers, *Moapa* and *Agosia* are very similar. *Moapa* differs from Agosia in the tooth formula, which is typically 5—4, rarely 4—5, instead of consistently 4—4; in the lack of a barbel (a

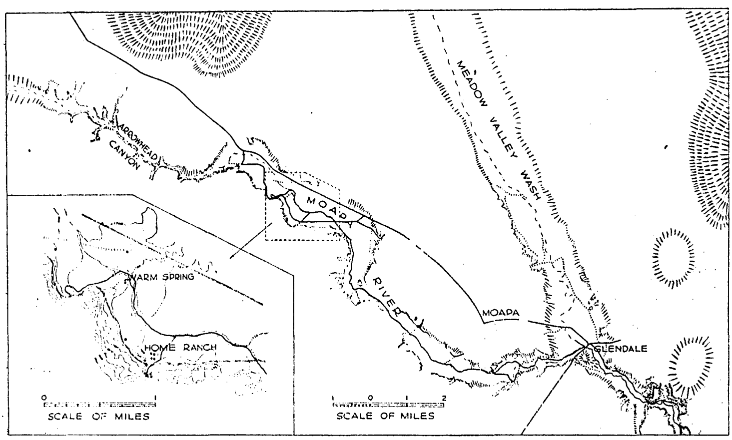


Map 1. Soldier Meadows Basin and Vicinity, Humboldt County, Nevada.

Based chiefly on a sketch by E. Voigt, Land Office surveyor, from the Land Office survey sheets for Township 40 N., Range 25 E., and adjacent townships; with additions from field work by authors. The area covered, about 7 by 10 miles, is indicated on the insert map of Nevada, which also shows the area covered by Map 2.

small one is consistently evident in *Agosia*); and in the leathery skin.

DISTRIBUTIONAL AND SPECIATIONAL CONSIDERATIONS.—A rather thorough exploration of the relict waters of the Great Basin and of the adjacent, rather indefinitely separated drainage basin of the Colorado River indicates that this new cyprinid genus is remarkably restricted in distribution. It has been found only in the warm-spring sources of Moapa River, and in the immediately adjacent part of this small river, in Clark County, Nevada (Map 2). These springs lie in an arc, about



Map 2. Moapa River and its Valley, Clark County, Nevada, from the vicinity of Glendale to above Arrowhead Canyon.

Based on Sheet B, Plan of Muddy River, U. S. Geological Survey (1937), with additions from map by Carpenter (1915: Pl. I). The general location is indicated on insert, Map 1. Ruport Warm Spring is labeled WARM SPRING. Potter Ranch is represented by the dot about 0.5 mile northwest of Home Ranch. The warm spring tributary at Potter Ranch is not shown.

3 miles in length, near the foot of the stony terraces of an ancient river, a short distance below the mouth of the great lava fissure of Arrowhead Canyon (Pl. III). This canyon lies in the course of Pluvial White River, discussed below.

On some maps Moapa River is named Muddy River, and the Indian word "Moapa" is said to mean "muddy." On most maps, including the state base map issued by the United States Geological Survey, the name "Muddy Creek" by error is entered along the lower course of a long, intermittent tributary, Meadow Valley Wash.

Until the construction of Hoover Dam and the subsequent flooding of its lower course by an arm of Lake Mead, Moapa River was a short though swift and sizeable tributary of Virgin River and hence of the Colorado River. It is one of the disrupted remnants of Pluvial White River, which, probably in Wisconsin time, drained a large area of southeastern Nevada (Carpenter, 1915: 53–58; Hubbs, 1941; Hubbs and Miller, in press). The other relict waters of Pluvial White River, which we have explored nearly to the source of the ancient river about 175 miles to the northward, do not appear to be inhabited by *Moapa* or by any relative closer than *Gila.* As Hubbs and Miller (1941) noted, most of these waters are faunistically circumscribed by the common and exclusive occurrence of *Crenichthys baileyi* (Gilbert). Neither *Moapa* nor *Crenichthys* was obtained in the remnant waters, along Meadow Valley Wash, that represent another main Pluvial tributary of Virgin River (Hubbs and Miller, in press). The fishes of those waters, like the other species in the remnants of Pluvial White River, are Colorado River types.

Moapa, like *Eremichthys,* is presumably a relict. From the preceding discussion of relationships, it is concluded that *Moapa* probably arose from *Agosia,* or, more likely, that both were derived from a common ancestral type.

DERIVATION OF NAMES.—The generic name *Moapa* is derived from the Moapa River, to which the new genus is apparently restricted. The specific name, from the Latin *coriaceus* ("leathery"), refers to the texture of the skin.

Moapa coriacea, new species

(Fig. 1 *B,* and Pl. 1, Fig. 1)

TYPES.—The holotype, a ripe female 74 mm. long to caudal base, was seined by Carl L. Hubbs, Robert R. Miller, and Alex Calhoun at Home Ranch in one of the sources of Moapa River

[= Muddy River], 7.5 miles by road northwest of Moapa, Clark County, Nevada, on July 12–13, 1938. It is deposited in the University of Michigan Museum of Zoology (No. 143186). Of the paratypes, 267 (U.M.M.Z. No. 124822), 18 to 69 mm. long, were obtained with the holotype. Ten others (U.M.M.Z. No. 133545), 33 to 49 mm. long, were collected in Warm Springs in the same region by Nathan B. Fruchter on April 24, 1941. We are grateful to Mr. Fruchter, of the Las Vegas station of the United States Fish and Wildlife Service, for the gift of these additional specimens. Other specimens were taken at the same locality by Vasco M. Tanner, who has kindly withheld the publication of his independently derived conclusion that the species is undescribed. His material was examined in Brigham Young University by the senior author in 1942. On December 23, 1947, John A. Kopec took specimens in Ruport Warm Spring, about 1 mile north of Home Ranch, and in a small warm creek (not shown on Map 1) at Potter Ranch, about one-half mile northwest of Home Ranch.

HABITAT AND ASSOCIATES.—*Moapa coriacea* was collected exclusively in warm water, varying only from 87° to 90° F. In Ruport Warm Spring and in the creek at Potter Ranch the pH was determined by Kopec as 7.4 and 7.5, respectively. The water in all of the habitats was very clear but easily roiled and had a slightly sulphurous odor. The stream soon loses the high temperature and becomes very muddy by the erosion of the old lake beds through which it flows, but *Moapa* was not taken under such conditions during extensive seining on several occasions.

In the habitats where *Moapa* was collected, other ecological conditions were quite varied. It was seined in spring pools, in spring feeders, and in the small rivers. In the partly artificial spring-fed pools, the current was slight, but in the creeks and the river it was generally swift. There were traces of algae in the pools and beds of *Potamogeton* in the river. The pools were floored with concrete and spring-deposit gravels, whereas in the creeks, sand, gravel, and mud covered the bottom. The pools were about 10 by 20 feet in major dimensions and 6 inches to 5 feet deep; the creeks were 3 to 8 feet wide and 6 inches to 2 feet deep; and the strongly meandering river was 8 to 20 feet wide and 6 inches to 4 feet deep. In all these habitats the new minnow was rather common and was observed to swim with rapid and sinuous movements at all water levels from the surface to the bottom.

In the spring pools *Moapa coriacea* was associated with a local subspecies of the White River cyprinodont, *Crenichthys baileyi* (Gilbert). In the streams it occurred with that species and with 2 others—a possibly somewhat differentiated form of the cyprinid *Gila robusta* Baird and Girard and the ubiquitously introduced mosquitofish, *Gambusia affinis affinis* Baird and Girard.

DESCRIPTION.—Many of the diagnostic characters of *Moapa coriacea* have already been described. The form of the pharyngeal arch is further indicated by Fig. 1 *B*. The number of pharyngeal teeth is rather constant. Of 15 specimens examined for this character, 14 had 5 teeth on the left side and 4 on the right, and the remaining specimen had the numbers reversed, yielding a dental formula of 4—5. Form and color pattern are portrayed in Plate I, Figure 1. The fin rays and gill rakers are enumerated in Tables I and II. Proportional

TABLE II

GILL RAKER COUNTS IN 30 SPECIMENS EACH OF *Moapa coriacea* AND *Eremichthys acros*

	Number of Gill Rakers								
	5	6	7	8	9	10	11	Mean	SE
Moapa coriacea	3	10	9	6	2	......	......	6.80	±.17
Eremichthys acros	......	......	......	......	6	19	5	9.97	±.11

measurements are summarized in Table IV. The proportions were derived by calculation from measurements made by dial calipers read to 0.1 mm. and estimated to 0.01 mm. The methods of taking measurements and counts were those described by Hubbs and Lagler (1941: 18–20; 1947: 8–15).

The scale counts in all series are rather high. Following there are listed, for each category, the count for the holotype and, in parenthesis, the range and the average for 20 specimens, including the holotype. From opercle to caudal base, 76 (69–79; 73.3). Between origin of dorsal fin and lateral line row, 20 (17–22; 19.1). Between origin of anal fin and lateral line row, 15 (12–15; 13.2). Between insertion of pelvic fin and lateral line row, 14 (11–14; 12.5). Between origin of dorsal fin and occiput (this count could not be made with assured precision), 50 (44–51; 47.0). Around body just in front of dorsal fin (circumference scale counts): above lateral line, 38 (34–40; 37.1); below lateral line, 41 (37–44; 39.9); total, 81 (73–84; 79.0). Around narrowest part of caudal peduncle: above lateral line, 19 (17–21; 18.8); below lateral line, 18 (16–19; 17.3); total, 39 (35–42; 38.1).

The rather slender body tapers quite evenly from the occipital region to the long, narrow peduncle. The dorsal profile curves gently from the origin of the dorsal fin to the snout, with a slight depression at the occiput on many specimens. The ventral and dorsal profiles are similar. There is no ventral keel. The moderately short head is subconical, the snout long and bluntly rounded.

In half-grown and adult fish the sides of the head are densely and finely pigmented down to a line on the level with the premaxillary groove. Behind the eye and especially along the midline of the opercle, the melanophores are more scattered, in some specimens almost completely lacking. Directly under the orbit there is a narrow region of fine pigmentation, which in some examples is almost obliterated. In the young the melanophores are larger and more restricted; virtually none are evident below the orbit, and only a few are scattered on the opercles. The sides of the body are densely pigmented, as they also are, to a lesser extent, in the larger adults. In both young and adult a wide, blackish, mid-dorsal stripe extends from the dorsal fin forward to the occiput and backward to the procurrent caudal rays. An axial streak, somewhat more noticeable in the young than in the adult, begins shortly in advance of the dorsal fin and continues nearly to the black spot at the base of the middle caudal rays. This subcircular to oval or squarish marking is well developed at all stages from the young to the large adults. It provides a ready means of identification.

The life colors of *Moapa coriacea* were carefully noted in the field. The body is deep olive above, with greenish brown blotches along the upper sides and a wide, blackish, mid-dorsal stripe. As in *Agosia,* a roughly circular, bright cream spot lies at the front of the dorsal base. This spot is just in advance of, and contrasts sharply with, a black streak along the middle of the dorsal base. A lateral band of shining golden brown is bounded above by a deep-lying turquoise stripe. The sides are brownish gilt; the belly, whitish.

The nuptial tubercles of the breeding males occur on all fins. They are particularly strong on the pectorals and are conspicuous on principal rays 2 to 6 of the dorsal fin. Relatively well-developed tubercles in the form of small nodules are profusely scattered over the top of the head. There are very

TABLE III

SEX RATIOS OF *Moapa coriacea* AND *Eremichthys acros* AT DIFFERENT SIZES

Standard Length Range in mm.	*Moapa coriacea*		*Eremichthys acros*	
	Males	Females	Males	Females
18 to 30	10	9	10	13
31 to 40	23	19	22	43
41 to 50	22	24	......	29
51 to 60	8	16	......	7
61 to 70	......	6	......	......
Totals	63	74	32	92
Ratios	85	100	35	100

few on the sides of the head, on the nape, or on the sides of the body. The body tubercles are best developed over the upper surface and the sides of the caudal peduncle. Here they are pointed and spinose, but finer than are the blunt-shaped organs on the head. Only a few very small tubercles are discernible on the ventral surface of the caudal peduncle. In a female

TABLE IV

PROPORTIONAL MEASUREMENTS OF *Moapa coriacea*

For each category, that for the holotype excepted, there are given the range and, in parenthesis, the mean. The 10 larger females include the holotype. The paratype series that was used is U.M.M.Z. No. 124822.

Category	Holotype (♀)	20 Larger Types		10 Smaller Paratypes
		10 Females	10 Males	
Standard length, mm.	74	43–74(56.7)	45–58(50.9)	32–40(36.5)
Measurements in thousandths of the standard length				
Dorsal origin to snout tip	542	523–555(543)	517–556(536)	523–564(538)
Dorsal origin to occiput	347	321–361(343)	314–350(333)	316–350(331)
Pelvic origin to snout tip	515	504–529(516)	493–524(503)	503–526(515)
Anal origin to caudal base	333	328–354(341)	319–370(349)	316–358(339)
Body, greatest depth	240	240–269(251)	217–254(235)	225–265(247)
Head length	277	270–290(279)	267–290(277)	268–286(278)
Depth	169	162–185(171)	161–181(169)	165–185(176)
Width	174	152–174(160)	143–171(156)	142–159(149)
Caudal peduncle length	227	223–243(231)	210–251(239)	222–242(229)
Least depth	101	88–104(96)	92–105(97)	83–106(96)
Interorbital, least fleshy width	110	89–110(97)	84–95(90)	78–95(89)
Suborbital, least width	41	36–42(38)	35–40(37)	33–38(35)
Snout length	108	91–108(97)	80–97(91)	83–93(88)
Eye length	54	52–62(58)	55–66(61)	65–76(69)
Upper jaw length	88	77–90(84)	72–93(82)	80–87(82)
Dorsal fin height	177	177–212(190)	185–211(201)	201–221(211)
Anal fin height	150	144–174(159)	154–179(163)	158–179(167)
Basal length	99	94–111(105)	98–115(106)	93–116(104)
Caudal fin, length of longest ray	213	213–240(226)	221–251(237)	237–253(244)
Dorsal fin to lateral line	135	125–139(133)	123–142(130)	122–136(130)
Pelvic insertion to lateral line	92	89–108(96)	74–102(87)	77–95(88)
Pectoral, length left fin	162	162–186(171)	174–201(186)	173–194(181)
Pelvic, length left fin	128	128–140(133)	136–153(143)	138–157(145)

63 mm. in standard length, a few small blunt tubercles are scattered over the head. Elsewhere on her body and fins they are scarcely perceptible.

Sexual maturity was noted in a male only 32 mm. in standard length. A 33 mm. female is swollen with eggs. Though the sexes seem to mature at about the same size, the females appear to attain a somewhat larger size than do the males and to outnumber them in the ratio of 100:85 (Table III).

Eremichthys, new genus

Genotype, *Eremichthys acros,* new species.

The rather heavy-set uniserial pharyngeal teeth number 5 on the left side and 4 on the right. On the left arch the uppermost tooth is somewhat longer and slenderer than the others. It has a weak to rather well-developed terminal hook. This tooth, like the 2 that follow, has a rather broad grinding surface, which varies from saucer-shaped in the half-grown to nearly flat or even somewhat raised in large adults. The grinding surface on the fourth tooth is variable, for it is either more marked, as well developed, or more reduced than those on the anterior teeth. The fifth tooth has neither grinding surface nor hooked tip and is rather small and stumpy, though commonly pointed. The basal parts of all teeth except the first one are heavy and somewhat swollen. The 4 teeth on the right arch are similar to those on the left. The upper 2 are moderately hooked, and the first is smaller and narrower than the second. The hook and grinding surface, flat to slightly saucer-like, tend toward obsolescence on the lower teeth.

The heavy lower pharyngeal arch (Fig. 1 *D*) is very broad across the upper half. The 2 arms, measured from the teeth, are of nearly equal length. The lower arm is moderately broad, flat, and nearly straight. The outer face below the row of teeth descends rather abruptly, leaving no available space on which teeth of an outer (lesser) row might develop.

There is no trace of a barbel or of a frenum. The upper lip (Pl. II, Fig. *B*) is rather thick, and somewhat fleshy, especially medially, where it is expanded backward into a slight concavity of the rostral fold. Laterally, this lip narrows evenly to the corners of the mouth, where it is about one-half as wide as it is at the apex. From the corners of the mouth a little more than half way to the apex of the lower jaw, the lower lip is expanded on each side into a somewhat fleshy lobe (Pl. II, Figs. *A* and *B*). In width each lobe about equals or somewhat exceeds the least distance between the lobes. The contour of the lower jaw is that of a broad U resting within the more rounded U of the upper jaw (Pl. II, Fig. *A*). The nearly straight gape is very slightly oblique. Even anteriorly it lies well below the level of the lower rim of the orbit.

The prominent horny sheaths on the jaws (Pl. II, Fig. *C*) provide the spectacularly distinctive generic character of *Eremichthys*. These sheaths are so loosely attached to the jaws that they may readily be plucked off with a needle. Each is a sharp-edged structure covering most of the arch of the jaw. The upper sheath is slightly narrower than the lower one and closes across the latter for a short distance at each side; elsewhere, when the mouth is closed, the two meet perfectly along their thin, sharp edges. Presumably, this specialized structure is an adaptation for feeding by grazing.

The snout and upper lip project forward equally, and the lower jaw is only slightly included. The maxillary extends about to the vertical from the second nostril.

As measured from the angle of the gill arch, the rather restricted first gill slit is about 1½ times the width of the orbit. A conspicuous, broad valve extends across the pharyngeal roof just behind the horny sheath of the upper jaw. The moderately short, fleshy gill rakers number 9 to 11, including all rudiments (Table II). There are no pseudobranchiae.

The extensively coiled intestine is more than twice as long as the standard length of the fish. The peritoneum is brownish, with an admixture of black pigment.

The irregularly arranged and loosely imbricated scales number about 70 to 80 along the lateral line. They are roughly oval in shape and bear numerous radii on all fields, though on the basal field these are fewer and more incomplete than they are elsewhere. The lateral line, decurved along its anterior half and nearly straight posteriorly, is variously developed. In 30 specimens analyzed for this character, it was complete in 13, interrupted in 10, and incomplete in 7 specimens. The interruption usually occurs below the dorsal fin, where occasionally the lateral line is broken and displaced upward 1 to 3 scale rows. The scales along the lateral line are not enlarged.

The origin of the dorsal fin is much nearer to the caudal base than to the tip of the snout, and in both sexes lies behind the vertical from the pelvic insertion. It is small, rounded, and short-based, with 8, or occasionally 7, principal rays, none of which are spiny. The anal fin is somewhat larger than the dorsal but is similarly shaped. It has 8, or commonly 7, principal rays. The relatively large caudal fin is moderately forked. Its lower lobe is somewhat larger than the upper. The pelvic rays are usually 8, but vary from 6 to 9 (Table I).

GENERIC COMPARISONS.—In determining the validity of *Eremichthys* and in laying a basis for inferences as to its relationships, 2 other genera need be considered. The new genus closely resembles the common dace group *Rhinichthys* (including *Apocope*) in its small size, in general body form, in fin size and position (especially in the posterior placement of the dorsal), and in having small scales with radii on all fields. The dental formula of *Eremichthys*, 5—4, provides a prime distinction, for *Rhinichthys* typically has biserial dentition with 4—4 teeth in the main row. *Eremichthys* is usually further distinguished from *Rhinichthys* by the higher number (9 to 11) of gill rakers, in the preponderance of 8 rather than almost invariably 7 anal rays, and in the lack of barbels. None of the distinctions thus far enumerated is invariable, for *Rhinichthys* occasionally lacks teeth in the second row, very rarely has 5—4 teeth in the main row (see below), may have as many as 9 gill rakers, occasionally has 8 anal rays, and in some localities often lacks 1 or both barbels. Experience in general has shown, however, that despite some inconsistencies these differences have high taxonomic value. The capacity to develop a barbel, for example, is of more significance than its actual presence or absence. Oddly, the local population of *Rhinichthys osculus robustus* in Soldier Meadows shows an approach toward *Eremichthys* in several character expressions. Thus, the dental formula is 1, 4—4, 1 in 9 specimens, but 0, 5—4, 0 (like *Eremichthys*) in 1 example; the gill rakers number 7 to 9, usually 8, in 15; and in 15 specimens the barbels are developed on both sides in 8, on 1 side only in 2, and on neither side in 5. The tendency of *R. o. robustus* to lose these rudimentary structures was quantitatively treated by Snyder (1917: 67), who found, among the 134 specimens that he examined from the Lahontan system, that barbels were lacking on both sides in 51 and on 1 side in 24. The dental formula of 5—4 in the 1 *Rhinichthys* presumably represents a variation rare enough to be called an anomaly, for Snyder found the teeth of the main row to number 4—4 in 10 specimens of *R. o. robustus*, and Schultz and Schaefer (1936: 3), in studying large series of a subspecies identified as *R. o. carringtonii*, never observed a specimen with 5 teeth in the main row on either the left arch or the right (the only variation they observed lay in the occasional lack of the tooth forming the second row). *Eremichthys* is approached by *Rhinichthys* in the horny jaw structure, for in *Rhinichthys* the lower lip is often covered by a rather definite horny sheath, which, however, lacks a biting edge and is much weaker than are the 2 sheaths of the new genus. The coiled intestine of *Eremichthys* contrasts with that of *Rhinichthys*, which, like the gut of most carnivorous American cyprinids, is straight except for a single loop in the form of a collapsed S.

In many respects *Eremichthys* is very similar to *Siphateles*. They have the same dental formula (5—4), and the heavy, strongly curved pharyngeal arch of the new genus (Fig. 1 *D*) is approached by the arch of *Siphateles* (Fig. 1 *C*). *Eremichthys* resembles *Siphateles* in having the gill rakers more numerous than in many American cyprinids, but most forms of *Siphateles* have more than 10 rakers, the modal number in *Eremichthys*. These genera further agree in the preponderance of 8 anal rays and in the invariable absence of barbels. *Eremichthys* differs most strikingly from *Siphateles* in the development of horny sheaths on the jaws. Other valuable though hardly invariable distinctions lie in other mouth structures; in the greater extent of radii on the scales; in the small size attained; and in several other respects.

Distributional and speciational considerations.—An abundance of evidence indicates that *Eremichthys* is confined to the warm springs on the floor and along the northern margin of Soldier Meadows in the Lahontan drainage basin of Nevada. Data on its habitat and associates in this restricted basin are given below, in the account of the 1 species of the genus. It is there shown that this peculiar fish does not even inhabit the outlet stream, either just within the lower end of the Soldier Meadows basin or in the few spring-fed waters that arise in or near the usually dry valley and desert floor below the basin.

The very local occurrence of *Eremichthys* suggests a long occupation of the area. Topographic features are in harmony with the view that the Soldier Meadows basin has long been a wet area. The warm springs may have had their source in Summit Lake, which lies at a much higher elevation about 13 miles northeast of the center of Soldier Meadows and which was the site of a larger ancient lake that appears to have had no outlet in Pluvial times (Hubbs and Miller, in press). There is other evidence that hot springs have existed for a long time in the basin. At the south end, between the double canyons described below, there is a large deposit of hot spring material where the stream now is cool. The long continuity of the springs is further suggested by the abundance on the surrounding flats of Indian artifacts of varied types and different degrees of weathering.

Most of the very flat floor of the Soldier Meadows basin appears to have been a marshy embayment at the head of an arm of Lake Lahontan at its highest stage. But the warm spring habitat was probably not obliterated, for the now extinct spring near location *I* on Map 1, and the springs at locations *A* and *B*, were apparently above the highest lake level. It is possible that *Eremichtys* is a relict from Interglacial or even Preglacial times.

The late Quaternary history of the Soldier Meadows basin is indicated by physiographic features at the lower end (*I* to *J* on Map 1). Lake Lahontan terraces are not evident around the margin of the basin, but the top terrace (the Lahontan level) is a conspicuous notch in the lava rock on either side of the lower end of the now stranded and more westerly of the twin outlet channels. The terrace level is high enough to indicate that much of the Soldier Meadows basin was a shallow bay. The steep canyon seems to have become stranded as an outlet when the present outlet creek cut back through a cross-ridge of alluvium from the mountains to the east. The creek is now rather shallowly entrenched in this alluvium. Proceeding downstream from the outlet channels, one soon encounters other, lower terraces that increase in number, until many of the old lake levels are visible before the "Arm of the Desert" is reached.

In the large collection from location *G* (Map 1), containing 980 specimens of *Eremichthys acros* and 120 of *Rhinichthys osculus robustus*, a single hybrid between these species was recognized by its intermediate characters. This hybrid does not necessarily indicate a very close relationship between the parental genera, because many genera of Cyprinidae that are not very closely related are known to hybridize in nature.

In our opinion this new genus, as well as *Moapa,* is an ancient relict, not a product of recent and sudden evolution. For some reason the warm springs of Soldier Meadows have furnished the only habitat in which it has been able to survive, just as *Moapa* has persisted only in the warm springs at the head of Moapa River farther south in the same state.

On first consideration it would seem that *Eremichthys* is most closely related to *Rhinichthys,* but some of the characters that the 2 genera share, such as the high number and wide extent of the radii on the scales, may well have been independently derived, as they surely have been in other cyprinid genera of the West. The preponderance of evidence seems to favor the view that the genetic relationships are closer with *Siphateles,* a genus that is widespread throughout the Lahontan drainage area and in the basins to the west, northwest, and north.

DERIVATION OF NAMES.—The generic term *Eremichthys,* derived from the Greek, ἐρεμος ("desert"), and ἰχθὺς ("fish"), refers to the arid surroundings in which the fish lives. The specific name *acros,* from the Latin, *acer* ("sharp") and *os* ("mouth"), refers to the sharp-edged sheaths on the jaws.

Eremichthys acros, new species

(Fig. 1 *D,* and Pls. I and II)

TYPES.—The holotype (U.M.M.Z. No. 136873), a nuptial male 38 mm. long to caudal base, was collected by Robert R. and Ralph G. Miller in a spring-fed ditch near the northern edge of Soldier Meadows, Humbolt County, Nevada (at location *C* on Map 1). It was seined on July 5, 1939, with 124 paratypes (U.M.M.Z. No. 136874), 18 to 64 mm. long. The other paratypes were collected by Carl L., Laura C., and Earl L. Hubbs in the same region on July 17, 1942, as follows: 980, U.M.M.Z. No. 141590, 11 to 52 mm. long (location *G*); 620, U.M.M.Z. No. 141596, 11 to 52 mm. long (location *H*); and 60, U.M.M.Z. No. 141598, 17 to 50 mm. long (location *A*). Altogether, the types number 1661.

HABITAT AND ASSOCIATES.—Soldier Meadows, to which this remarkable little minnow seems to be wholly restricted, is a roughly circular depression, about 5 or 6 miles in diameter. This basin (Map 1) is hemmed in on the north, east, and west by steep mountains, and on the south, except at the outlet, by low hills. At several points along a westward-curved arc on the floor of the valley and impinging on the base of the hills, warm springs issue, singly or in groups, usually in conspicuous green clumps of tules. The spring outlets flow into meadowlands, the seepage of which forms the permanent part of Soldier Creek (also known as Soldier Meadow Creek and as Mud Meadow Creek). This small stream when in flood receives much water from the mountains south of Summit Lake and is then tributary to the southwestern part of the desolate Black Rock Desert, an extensive playa that once formed part of the floor of Pluvial Lake Lahontan. Except when it is in flood, the creek is dry for most of its course across the intervening valley and the "Arm of the Desert."

The spring-fed ditch from which the holotype was collected lies about 2 miles southwest of the old Soldier Meadows Ranch (now the Tom Sweeney Ranch), above the road that leads southwest across the basin toward High Rock Lake. The water here was clear and without any marked color or odor. A dense growth of tules bordered the ditch on either side, but the only vegetation in the water was a very limited growth of algae. The bottom was composed of sand, gravel, rocks, and some silt, and the current varied from moderate to swift. The narrow, slightly meandering ditch was as wide as 2 feet and as deep as 1.5 feet. At 9:15 A.M. on July 5 the water temperature was 31.2° C. (88.2° F.); the air, 17.0° C.

In one of the spring sources at the base of the hills to the northward, at location *B* on Map 1, 3 fish obviously of the same species were seen on the same day. Attempts to collect them proved futile, as they were too adept at dodging the net under a protecting marl ledge. At 6:00 A.M. the water temperature here was 38.0° C. (100.4° F.), which is one of the highest temperatures recorded for a cyprinid fish habitat. The only higher value (39.5° C. = 103.1° F.) we have encountered for western North America is that given by Brues (1928: 204) for *Notropis lutrensis* in a spring-fed ditch in New Mexico. Since very few individuals of *Eremichthys* were seen in the spring source (*B*), and since none were observed in the shallow outlet which was traced downstream for some distance, it is concluded that a permanent population was not established here.

The series of 60 paratypes (U.M.M.Z. No. 141598) was taken from a rather sparse population in the outlet of a spring one-fourth mile northwest of the Soldier Meadows Ranch (location *A* on Map 1). This spring flows from a lava fissure on the alluvial slope just below a lava cliff. For a short distance the stream dashes over sand, gravel, and stones, then slackens to a moderate current over clay and mud bottom before the water is consumed in irrigation. *Eremichthys acros* was the only fish here. It was rather scarce among the stones, where in habits it much resembled *Rhinichthys cataractae.* In the more ditchlike water below, young to adult were commoner and were swimming in mid-water. The creek temperature at 7:00 P.M. on July 17, 1942, was 84° (when the air temperature was 75°). Tom Sweeney, local rancher, reported that he had been told that formerly this spring was hot enough to boil eggs, but that it and some other springs in the basin have become cooler in the last 6 years. The water was clear and of good quality. There was much vegetation—herbs above and rushes below. The stream was only 1 to 4 feet wide and only as deep as 6 inches where swift and as deep as 12 inches below.

In the most northerly of the warm springs (locations *A* to *C* on Map 1), no fish other than *Eremichthys acros* was collected or seen. Elsewhere in the basin this species was accompanied in warm springs and ditches by fishes characteristic of the Lake Lahontan drainage system, namely a sucker, *Catostomus tahoensis* Gill and Jordan, and a dace, *Rhinichthys osculus robustus* (Rutter).

The 3 species lived together in a spring tributary to Soldier Meadows, located in the S.W. ¼ of the S.W. ¼ of Section 19, Township 40 N., Range 25 E. (location *G*, Map 1). Here the water, fresh and clear, was alternately open and choked with rushes. It flowed with swift to slight current over a bottom of sand and clay, through a greasewood flat that was generally coated with alkali. The stream was 4 to 15 feet wide and as deep as 2 feet in some pools. At the time of the collection on the morning of July 17, 1942, when the air temperature was 82° F., water temperatures graded from well above 120° to 67° F. This gradation permitted a rough field analysis of temperature responses or resistances. The 3 spring sources (*D* to *F*) with temperatures (from north to south) respectively at 123°, 112°, and well above 120° were, of course, all fishless. The 2 more northerly of these springs (*D* and *E*) soon spread into the rushes and nowhere supported fish life. The hottest one (*F*) had cooled to 102° about one-eighth mile down and there became choked with rushes but contained no fish. It picked up more flow below, but harbored no fish where, with a temperature of 97°, it flowed into the main stream. In the creek just below the spring-feeder mouth there were a few fish at 96°. Just above the spring feeder, at 94°, there were many fish, all or mostly *Eremichthys.* In a backwater pool at this point, with a temperature of 67°, fish of all 3 species were common, but the suckers were all young. In the creek, going downstream from the spring inlet, the sequence was as follows:

97° : *Eremichthys,* plentiful
93° : *Eremichthys,* plentiful
93° : *Eremichthys,* plentiful; 1 *Rhinichthys;* 1 young *Catostomus*
92° : *Eremichthys,* plentiful; increased numbers of *Rhinichthys* and young of *Catostomus*
82° : *Eremichthys,* plentiful; *Catostomus* young, many; *Rhinichthys,* not many.

Below this point the stream broke up in the marshy meadow.

Near the eastern edge of Soldier Meadows, toward the south end of the basin (at location *H* on Map 1), *Eremichthys* was again abundant. Here it lived in a warmish spring, both in the rush-lined spring hole that was 10 feet in diameter and 5 feet deep at the center and in the sluggish surrounding ditches that were 2 to 12 feet wide, less than 12 inches deep, and exposed to the bright sun. In the afternoon, when the air temperature was 84° F., the spring pool registered 80° and the ditches, 79° to 86°. The water was very clear. The bottom was soft, marly sand in the pool and rather firm clay in the ditches. The surrounding region was in part dry pasture and in part wet meadow. Here, *Eremichthys* (U.M.M.Z. No. 141596) was associated with small numbers of *Rhinichthys osculus robustus.* An explanation for the discrepancy in numbers seemed to lie in a disease that caused fleshy swelling in most of the dace (*Rhinichthys*) but in few individuals of *Eremichthys.*

No trace of *Eremichthys* was found in the cooled waters of Soldier Creek just above the outlet canyon (at location *I* on Map 1). In addition to *Catostomus tahoensis* and *Rhinichthys osculus robustus,* which were also taken in the Meadows, another Lahontan species, *Richardsonius egregius* (Girard), was collected here. About 2 miles farther downstream *Rhinichthys o. robustus* was taken in Wheeler Spring (at *K*) on the floor of the Lahontan basin, and this dace, along with *Catostomus tahoensis, Richardsonius egregius* and *Siphateles obesus obesus* (still another Lahontan type), was in the creek. The *Rhinichthys* was collected in artesian outflows at Wheeler Ranch, 22 miles by road south of Soldier Meadows. A little farther south, near the north end of Black Rock Desert, many specimens of the *Siphateles* were seined in a reservoir, and others of this genus along with 1 sucker (*Catostomus tahoensis*) were taken in artesian pools. But nowhere south of Soldier Meadows was a single *Eremichthys* seen.

On ecological grounds and on the basis of local testimony, obtained in 1942, it seems unlikely that *Eremichthys* lives in the reputedly permanent canyon streams that flow southwestward toward the upper end of the Soldier Meadows basin. These waters, however, were not examined. Streams in the drainage basin of High Rock Lake, which in Pluvial times drained perennially into Soldier Meadows, contain only *Rhinichthys osculus* (Hubbs and Miller, in press).

Description.—The outstanding characteristics of *Eremichthys acros* have already been presented. The body form and coloration are shown in Plate I, Figure 2. The shape of the pharyngeal arch is portrayed in Figure 1 *D*. The number of pharyngeal teeth is very constant; in 15 specimens examined for this character, all had 5 teeth on the left side and 4 on the right. The fin rays and gill rakers are enumerated in Tables I and II. Proportional measurements are summarized in Table V.

The scale counts in all series are rather high. Following there are listed, for each category, the count for the holotype and, in parenthesis, the ranges and the average for 30 specimens,

TABLE V

PROPORTIONAL MEASUREMENTS OF *Eremichthys acros*

For each category, that for the holotype excepted, there are given the range and, in parenthesis, the mean. The 10 larger females include the holotype. The paratype series that was used is U.M.M.Z. No. 136874.

Category	Holotype (♀)	20 Larger Types		10 Smaller Paratypes
		10 Females	10 Males	
Standard length, mm.	54	41–60(48.6)	34–41(37.0)	27–31(29.3)
Measurements in thousandths of the standard length				
Dorsal origin to snout tip	609	592–615(604)	577–605(591)	583–611(597)
Dorsal origin to occiput	405	373–414(401)	362–392(381)	376–401(387)
Pelvic origin to snout tip	561	541–571(558)	533–560(546)	531–566(552)
Anal origin to caudal base	312	305–321(314)	302–330(316)	306–330(321)
Body, greatest depth	291	274–303(289)	260–300(282)	264–316(297)
Head length	292	276–316(296)	282–300(292)	280–305(295)
Depth	208	205–222(212)	188–208(198)	187–212(203)
Width	189	175–205(188)	159–181(170)	163–191(175)
Caudal peduncle, length	227	195–227(212)	218–242(230)	211–245(230)
Least depth	120	120–135(128)	122–139(129)	119–130(124)
Interorbital, least fleshy width	114	102–129(115)	88–105(96)	90–103(95)
Suborbital, least width	43	41–52(45)	37–42(39)	36–41(39)
Snout length	110	98–121(106)	88–100(94)	87–94(91)
Eye length	52	49–60(55)	57–62(60)	64–69(65)
Upper jaw length	103	89–108(99)	85–100(94)	87–94(91)
Dorsal fin height	158	158–174(167)	158–191(174)	162–181(172)
Anal fin height	149	149–177(161)	156–166(161)	148–169(158)
Basal length	104	89–112(101)	91–99(96)	86–104 (95)
Caudal fin, length of longest ray	213	213–236(225)	206–240(227)	210–234(225)
Dorsal origin to lateral line	152	147–162(156)	142–169(158)	140–168(157)
Pelvic insertion to lateral line	100	93–126(106)	95–120(105)	90–115(102)
Pectoral, length left fin	162	162–185(175)	176–209(192)	151–189(169)
Pelvic, length left fin	104	104–117(111)	111–129(120)	100–125(113)

including the holotype. From opercle to caudal base, 75(68–78; 72.9). Between origin of dorsal fin and lateral line row, 17(15–18; 16.7). Between origin of anal fin and lateral line row, 12(10–13; 11.0). Between insertion of pelvic and lateral line row, 11(9–12; 10.8). Between origin of dorsal fin and occiput (this count could not be made with assured precision), 48(45–54; 48.8). Around body just in front of dorsal fin (circumference scale counts): above lateral line, 31(30–35; 32.6); below lateral line, 36(30–37; 33.6); total, 69(62–74; 68.2). Around narrowest part of caudal peduncle: above lateral line, 19(17–20; 18.7); below lateral line, 17(15–18; 16.7); total, 38(34–39; 37.3).

The body (Pl. I, Fig. 2), deep and heavy-set forward, tapers rather rapidly behind the origin of the dorsal fin. The dorsal profile is evenly and broadly arched from the snout to the origin of the dorsal fin and is slightly concave from that fin to the procurrent caudal rays. The ventral contour is similar, but is less curved. The least depth of the caudal peduncle is less than half the greatest depth of the body. There is no ventral keel. The moderate head is suboval, the snout rather short and very blunt.

No very distinctive coloration characterizes the preserved specimens of this species, although some, especially young ones, have a rather conspicuous dark streak along the middle of each side. The head of large adults is covered above with dense, fine black pigment, which extends down to a short distance below and behind the orbit. Most of the opercle and preopercle is silvery, with only scattered melanophores over the surface. The lips are a conspicuous lead-black, which is darker in the young than in the adults. In the young and half-grown the melanophores of the head region are larger and more scattered, and the silvery background is more prominent. The lower sides and the ventral surface of the caudal peduncle, particularly in the young, exhibit large, irregularly scattered, expanded melanophores (a feature characteristic also of the genus *Siphateles*). Such specks are evident also on the cheeks and opercle, and extend forward below the eye onto the snout.

The sides of the body are densely and finely pigmented, particularly about the scale centers, in both young and adult, although the melanophores are larger in the latter. There is a definite tendency for the formation of a dark, narrow, axial streak in some specimens, especially behind the origin of the dorsal. The mid-dorsal stripe varies in intensity in both young and adult. The belly is whitish or immaculate.

At the time that *Eremichthys* was collected, the following life colors were carefully noted. The body is olive-green above and silvery below, with strong yellow-brass reflections from the mid-sides. Posteriorly, there is a rather bronze lateral band with very indefinite borders. The scales along the sides reflect bluish and greenish iridescence in strong sunlight. The fins are amber over a milky-white background. The deep-lying dorsolateral streak is bright green. The dark nostril spots (Pl. II, Fig. *B*) are conspicuous in life. The sides are often coppery. One definite mutant was bright golden everywhere, especially on the fins.

The nuptial tubercles of the breeding males are minute prominences, scattered over all parts of the head and irregularly over the nape. Elsewhere on the body and on the pectoral fins they are irregularly and inconspicuously developed. The tubercles are so small as to be readily visible only under magnification.

The females of *Eremichthys acros* reach a much larger size than do the males and outnumber them greatly, in the ratio of 100:35 (Table III).

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SUMMARY

The 2 new genera of cyprinid fishes, *Moapa* and *Eremichthys,* are each confined to a single short arc of warm springs in Nevada. They are regarded as relicts rather than as products of recent, rapid evolution, and have probably long occupied their present habitats. *Moapa coriacea* inhabits the headwaters of Moapa River, in the Colorado River drainage, in the now nearly dry course of Pluvial White River. *Eremichthys acros* lives only in the warm springs of Soldier Meadows, which lay approximately on the shoreline of Pluvial Lake Lahontan. *Moapa* was taken in water varying only from 87° to 90° F. *Eremichthys* was found in water as hot as 100.4° F. (38.0° C.) and was common at temperatures of 67° to 97°. The generic criteria of western Cyprinidae are evaluated. *Moapa* is apparently most closely related to *Agosia,* though in some respects it is more like *Gila.* *Eremichthys* has many characters in common with *Rhinichthys,* but is probably most closely related to *Siphateles.* It is remarkable for the horny sheaths that form biting edges on the jaws. A natural hybrid, *Eremichthys acros* × *Rhinichthys osculus robustus* was obtained, as well as a golden mutant of the *Eremichthys.*

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PLATE I

FIG. 1.—Holotype of *Moapa coriacea* from warm springs near the source of Moapa River, southeastern Nevada; 74 mm. in standard length; U.M.M.Z. No. 143186.

FIG. 2.—Paratype of *Eremichthys acros* from Soldier Meadows, Humboldt County, Nevada; 58 mm. long; U.M.M.Z. No. 136874. Photographs by Clarence M. Flaten.

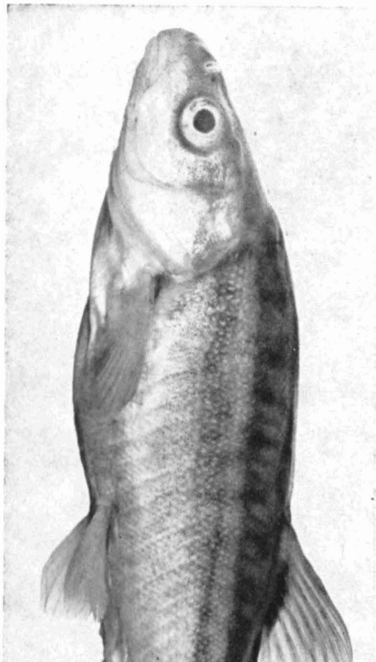


FIG. 1

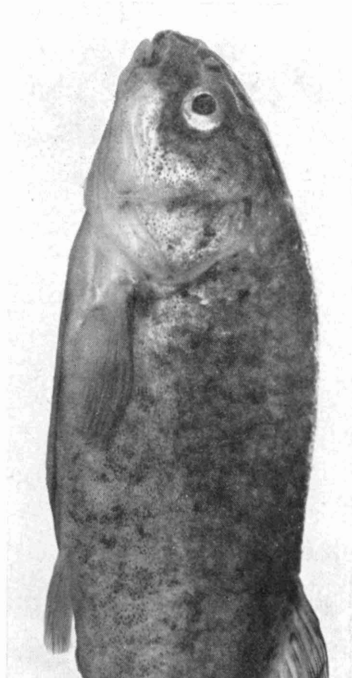
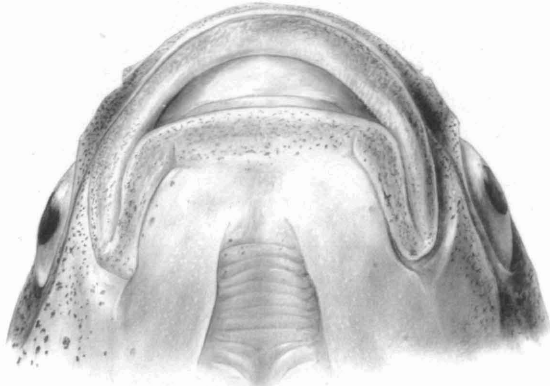


FIG. 2

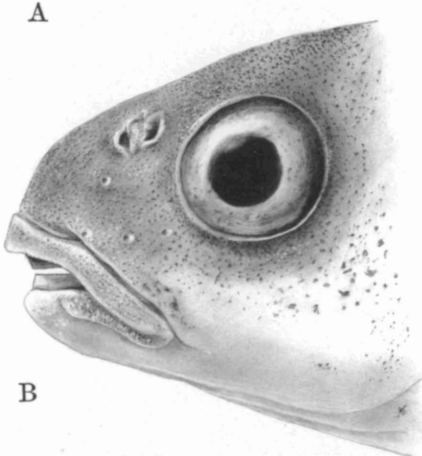
PLATE II

Ermichthys acros, New Genus and Species. Drawn by Grace Eager.

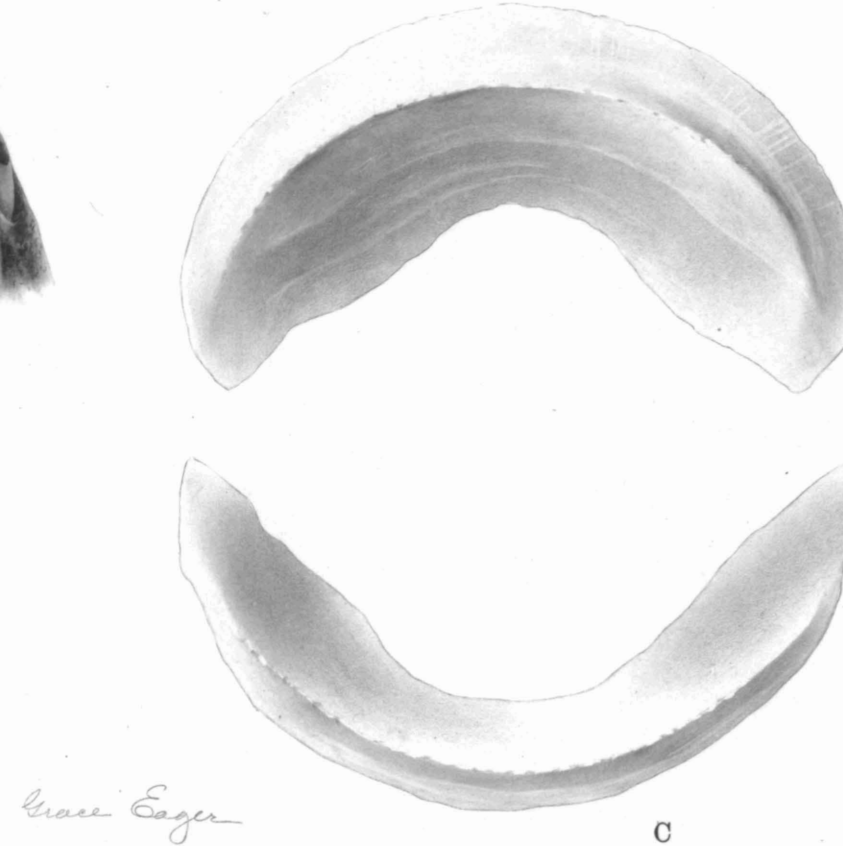
A. Oblique view of mouth.
B. Lateral view of anterior part of head.
C. Horny sheaths dissected from upper and lower jaws.



A



B



C

PLATE III

Arrowhead Canyon, Clark County, Nevada, in the now dry course of Pluvial White River (Map 2). Photographed by Robert R. Miller.