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Status and life history notes on the native fishes of the Alvord Basin, Oregon and Nevada

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STATUS AND LIFE HISTORY NOTES ON THE NATIVE FISHES OF THE ALVORD BASIN, OREGON AND NEVADA

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ABSTRACT.— Three fishes, two species of *Gila*, and an undescribed subspecies of cutthroat trout, are endemic to the Alvord Basin. Historically, the Alvord cutthroat trout, *Salmo clarki* ssp., inhabited the larger creeks of the basin but has been extirpated in pure form because of introgression with introduced rainbow trout, *Salmo gairdneri*. *Gila boraxobius* is restricted to the thermal waters of Borax Lake and its outflows in the northern part of the basin. This species is endangered because of alteration of its fragile habitat. The Alvord chub, *G. alvordensis*, is recorded from 16 localities throughout the basin, including springs, creeks, and reservoirs. Although *G. alvordensis* as a species is not in jeopardy, many populations are small and could be easily eliminated by habitat destruction or by the introduction of exotic fishes. Competition with exotic guppies, *Poecilia reticulata*, has extirpated the Thousand Creek Spring population of Alvord chubs.

Both species of *Gila* are opportunistic omnivores, consuming primarily chironomids, microcrustaceans, and diatoms. The Borax Lake chub also consumed large numbers of terrestrial insects, but specialized feeding on molluscs was noted in the West Spring population of Alvord chubs. Borax Lake chubs spawn throughout the year; however, most spawning occurs in early spring. Borax Lake chubs mature at a small size, occasionally less than 30 mm standard length, and seldom live more than one year. Alvord chubs are typically much larger than the Borax Lake species and live at least into their fifth year.

The Alvord Basin of southeastern Oregon and northwestern Nevada is an endorheic part of the Great Basin province. Aquatic habitats are sparse and consist primarily of Trout Creek in Oregon, the Virgin-Thousand Creek system in Nevada, as well as several small streams and springs (Fig. 1). During the late Pleistocene, a lake of over 1,200 km^2 covered much of the valley floor (Snyder et al. 1964). As pluvial waters dried, fishes were restricted to remaining permanent springs and creeks. Three native fishes are endemic to the Alvord Basin. Chubs, genus *Gila*, occupy many of the isolated waters in the Alvord Basin and have diverged into two species. The Alvord chub, *Gila alvordensis*, is the most common fish in the basin and occurs in a variety of springs and creeks. The Borax Lake chub, *G. boraxobius*, is restricted to Borax Lake and its outflows in Oregon. The Alvord cutthroat trout, *Salmo clarki* ssp., is the third fish native to the basin. Historic habitat for the Alvord cutthroat trout consisted of the larger streams in the basin, such as Trout and Virgin creeks. Another undescribed subspecies of cutthroat trout occurs in Willow and Whitehorse creeks just east of the Trout Creek Mountains in a separate basin. Although exhibiting affinities for the Alvord cutthroat trout, the subspecies found in Willow and Whitehorse creeks will not be treated further in this report.

Our knowledge of the native fishes of the Alvord Basin is limited. The monograph of Great Basin fishes by Hubbs and Miller (1948) provided the first detailed account of the Great Basin ichthyofauna and included a brief discussion of the native Alvord Basin fishes and their isolation. However, all the Alvord Basin fishes remained undescribed until 1972, when Hubbs and Miller (1972) diagnosed the Trout Creek population of *Gila* as *G. alvordensis*. Our studies have resulted in the description of *Gila boraxobius* (Williams and Bond 1980) and a further description of *G. alvordensis* with a taxonomic analysis of seven disjunct populations of the species (Williams 1980, Williams and Bond 1980). Characters of the Alvord cutthroat trout have been provided by Behnke (1979), but the subspecies remains undescribed. The only published life history information on Alvord

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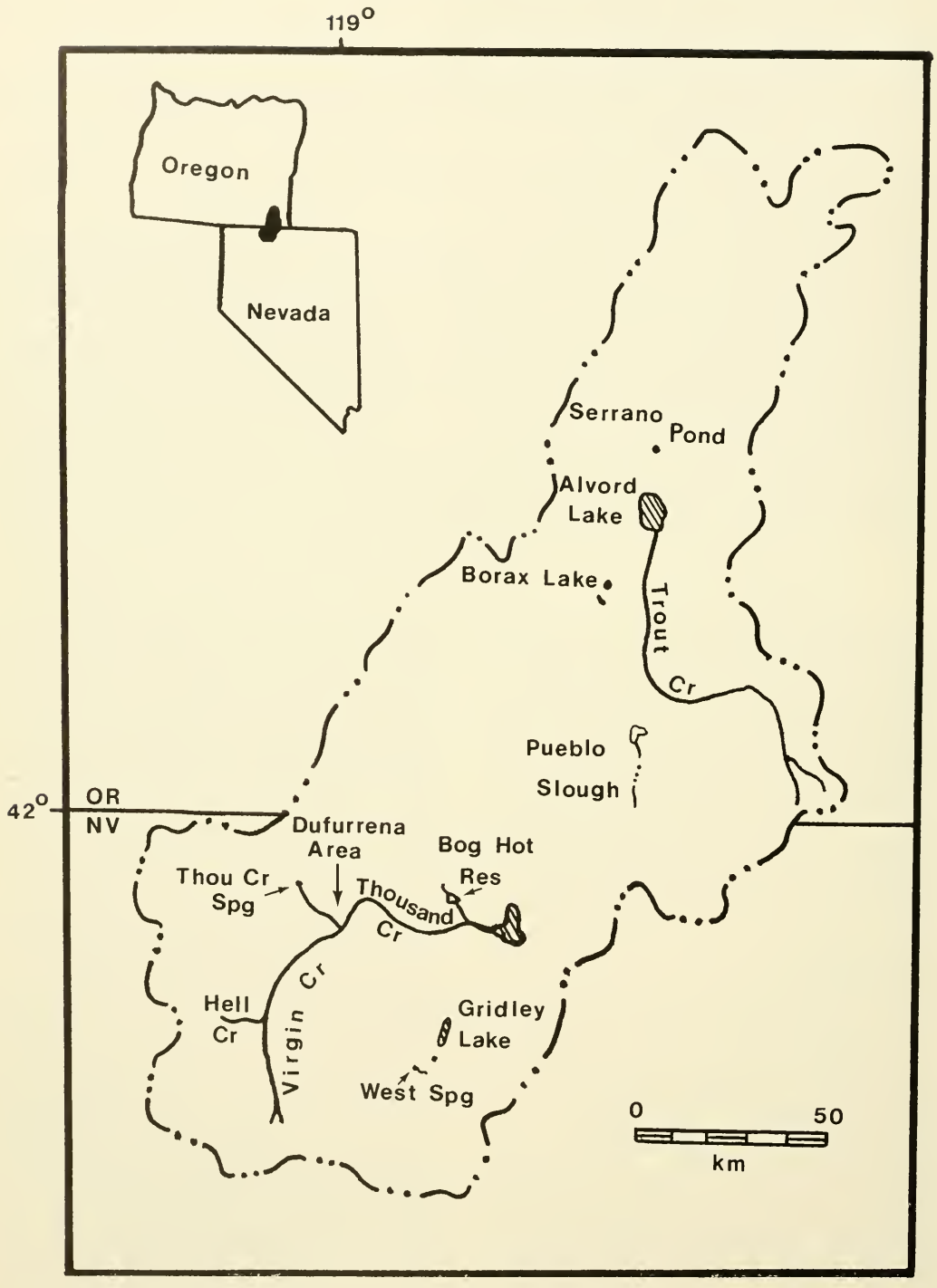

Fig. 1. Map of major aquatic habitats in the Alvord Basin, Oregon and Nevada.

Basin *Gila* consists of a study of feeding ecology by Williams and Williams (1980). This paper documents the distribution and status of the native fishes of the Alvord Basin and presents additional information on their life history.

MATERIALS AND METHODS

The distribution and status of fishes was determined by field surveys, museum records, and testimony of local residents. Many of the habitats in the Oregon part of the basin were known prior to this work. On the other hand, the Nevada part of the basin had received little attention by ichthyologists, and therefore most of our survey efforts were focused in the southern one-half of the basin. Surveys were conducted from 12 June 1978 to 26 August 1979 and from 13 to 15 April 1982. Habitats were sampled with 3 m seines (9.5 mm mesh), dip nets, fish traps, backpack electroshocker, and 15 m gill nets (51 mm mesh). Fishes utilized in this study are deposited at Oregon State University (OS), The University of Michigan Museum of Zoology (UMMZ), Tulane University (TU), and the University of Nevada, Las Vegas (UNLV).

Information concerning reproduction, longevity, and adult sex ratio was determined for Borax Lake chubs collected monthly from March 1978 to January 1979. Fish were collected from the southwest one-quarter of Borax Lake. Specimens were preserved in 10 percent formalin and transferred to 45 percent isopropanol after one week. Standard length (SL) of specimens was measured to the nearest 0.1 mm with dial calipers. After blotting fish dry on paper towels, wet weight was measured to the nearest 0.01 g. A gonadosomatic index was calculated by weighing the left ovary or testis to the nearest 0.001 g, multiplying by two, thereby accounting for the right gonad, and dividing by fish weight. Three classes of ova were identified: class I—mature ova, yellow color, 0.7 to 1.2 mm diameter; class II—immature ova, opaque white color, 0.4 to 0.6 mm diameter; and class III—immature ova, transparent, 0.1 to 0.3 mm diameter. The number of ova was enumerated in females that possessed only class I and/or class II ova. By this method, accurate counts could be obtained and these numbers are probably more indicative of the actual number of eggs deposited during spawning. In females shorter than 35 mm SL, all ova were counted in both ovaries. In females 35 to 50 mm SL, all ova were counted in the left ovary, then multiplied by two to derive the total number of ova. Ova were enumerated in larger females by multiple subsamples of the ovary. Age was determined by examining annuli of scales taken from the left side of the body above the lateral line. Monthly collections were grouped into seasons as follows: spring (March–May), summer (June–August), fall (September–November), and winter (December–February).

POPULATION ACCOUNTS

Alvord Cutthroat Trout, *Salmo clarki* ssp.

The Alvord cutthroat trout, *Salmo clarki* ssp., is now extinct in pure form. This native trout was known from Virgin Creek in Nevada and Trout Creek in Oregon, but probably existed in several of the larger Alvord Basin creeks during recent times (Hubbs and Miller 1948).

TROUT CREEK (Harney County, Oregon).— The Alvord cutthroat trout occurred in the headwater canyon area of Trout Creek, where it flows through the Trout Creek Mountains. Introgression of introduced rainbow trout, *Salmo gairdneri*, with the native cutthroat was already noticeable in 1934 collections of fish made in Trout Creek by Carl L. Hubbs, although trout from more headwater localities were quite similar in appearance to pure Alvord cutthroat trout (Behnke 1979). Cutthroat trout pigmentation was evident in many specimens collected by one of us (CEB) in 1953 and 1957, but none had basibranchial teeth. Trout collected from Trout Creek in 1972 (Behnke 1979) and 1978 to 1980 (our collections) exhibited only rainbow trout characteristics and we conclude that the native trout has been extirpated from this creek. Collections made from Cottonwood Creek and other streams draining the Trout Creek Mountains yielded only rainbow trout.

VIRGIN CREEK (Humboldt County, Nevada).— Thirty small (<15 cm) Alvord cutthroat trout were collected from Virgin Creek in or near Virgin Creek Gorge by Carl L. Hubbs in 1934 (UMMZ 130532). Behnke (1979) considers these specimens to be pure native cutthroat trout and provides their description as follows: body with fewer than 50 relatively large round spots, spots concentrated posteriorly and above lateral line; few

spots on caudal fin. Gill rakers 20 to 26. Lateral series scales 122 to 152. Scales above lateral line 33 to 37. Pelvic fin rays 8 or 9. Branchiostegal rays 8 or 9. Vertebrae 59 to 63. Trout collected in 1971 (OS 3832, OS 3834) from approximately the same region of Virgin Creek exhibited typical rainbow trout features (Behnke 1979). During 1978 surveys, we found only rainbow trout or introgressed trout in Virgin Creek at and upstream of the north end of Virgin Creek Gorge. No fish were found in Virgin Creek Gorge at the nexus of Hell and Virgin creeks. The upstream sections of Virgin Creek, in Virgin Creek Gorge near Alkali Ranch, also are fishless. Although we received reports of large trout from beaver ponds in Virgin Creek Gorge downstream of Wilson Ranch, none could be secured for examination. The large number of introduced rainbow trout in Virgin Creek Gorge would seem to preclude the survival of pure Alvord cutthroat trout in Virgin Creek. An extensive survey of Hell Creek, the only permanently flowing tributary of upper Virgin Creek, revealed only a single fish, which was typically rainbow in character. This individual was apparently able to ascend the falls separating Hell and Virgin creeks during a flood. The negative survey of Hell Creek in 1978 and 1979 causes us to consider the Alvord cutthroat trout to be extinct.

Borax Lake Chub, *Gila boraxobius*

The Borax Lake chub, *Gila boraxobius* Williams and Bond, is restricted to the thermal waters of Borax Lake and its outflows. *Gila boraxobius* was described in 1980 and is considered a dwarf relative of *G. alvordensis* (Williams and Bond 1980).

BORAX LAKE (T37S, R33E, Sec 14; Harney County, Oregon).— Borax Lake is a relatively shallow 4.1 ha natural lake that receives water from several thermal springs. These springs issue into the bottom of the southwest portion of the lake at approximately 35 to 40 C. Lake temperature is typically 29 to 32 C but can vary from 17 to 35 C depending on season, weather, and distance from the spring sources. The water is clear. Substrates range from rocky outcroppings in the southeast portion of the lake to gravels in the north and soft, easily roiled silt in the remainder of the lake. The lake shoreline consists of salt crusts, which have been deposited by the lake waters. These salt deposits have built up over hundreds or, more probably, thousands of years until the lake is now 10 m higher in elevation than the surrounding land. Historically, the lake waters overflowed along the south and southwest shoreline, creating a marsh. These outflows also provided water for Lower Borax Lake, a reservoir southwest of Borax Lake. Adjacent to Borax Lake are two small pools, one about 25 m southwest of Borax Lake and an artificial pool about 75 m west of the lake.

Borax Lake chubs occur throughout Borax Lake except in the hot spring inflows. Observations at Borax Lake indicated that Borax Lake chubs avoided water with a temperature above 34 C. These observations are supported by unsuccessful attempts to chase the chubs into hot spring inflow areas. In aquaria, Borax Lake chubs lost equilibrium when water temperature was raised to 34.5 C, indicating a critical thermal maximum near this temperature. Borax Lake chubs also occurred in small numbers in the two small pools near Borax Lake. The pools are apparently formed from Borax Lake overflow waters.

The Borax Lake chub is a dwarf species that typically reaches maturity at 30 to 35 mm SL. Males as small as 28.6 mm SL are highly tuberculate and females as small as 31.8 mm SL have been found with mature eggs. Typical adult size is 33 to 45 mm SL. The largest male collected from Borax Lake was 50.6 mm SL, whereas two exceptionally large females, 90.4 and 93.0 mm SL, have been collected from Borax Lake.

Most spawning probably occurs in early spring, although some spawning can occur year around. The gonadosomatic index was highest in females during March and April, with mature, class 1 ova present during March, April, and January (Table 1). Ovaries were usually poorly developed during May through August. In males, the gonadosomatic index was highest in April and September, when testes averaged 0.97 and 1.11 percent body weight, respectively. A search of museum specimens disclosed large females with mature ova collected on 17 June (OS 4137)

and 11 September (OS 4106). Thus, spawning may occur at any time of the year. However, a major spawning in early spring is supported by observation of numerous larval chubs during April, May, and early June. Young fish, eight to 15 mm SL, typically inhabit the shallow cove areas along the west and south margins of Borax Lake. Water is cool, only a few cm deep, and vegetation is common in the coves.

Ova number increases dramatically with fish length. The number of ova was determined in eight females 32.7 to 93.0 mm SL, that contained only class I and/or class II ova. The smallest females examined, 32.7 and 34.5 mm SL, contained 75 and 82 ova, respectively. Larger females, 39.0, 39.3, 44.6, and 49.4 mm SL contained 252, 246, 380, and 362 ova, respectively. The exceptionally large females, 90.4 and 93.0 mm SL contained 2,143 and 6,924 ova, respectively. Although females larger than 60 mm SL are very rare in Borax Lake, their contribution to recruitment may be substantial.

Most Borax Lake chubs live one year, with few age I and II fish present. Annuli development, although difficult to discern, indicated that the 90.4 and 93.0 mm SL females were probably age III. This appears to be the maximum age achieved by chubs in Borax Lake. A length frequency analysis of 113 individuals collected 5 August 1977 appears in Figure 2. Because most spawning occurs in spring, with young of approximately 10 mm SL prominent in May and June, most fish in the August collection are probably young-of-the-year. Some age I fish, 33 mm to 51 mm SL are present, whereas the two larger individuals are probably age II (Fig. 2). Most older fish are females. Adults (>33 mm SL) typically comprised less than 25 percent of specimens collected during March, April, and May. The percentage of adults in monthly collections then increased until reaching a peak of 82 percent during November.

Based on monthly collections made throughout the year, the sex ratio of 190 individuals greater than or equal to 30 mm SL was 1.0 ♂ :1.3 ♀ . Seasonally, the sex ratio was as follows: spring (n = 23) 1.0 ♂ :1.3 ♀ , summer (n = 67) 1.0 ♂ :1.9 ♀ , fall (n = 50) 1.0 ♂ :1.1 ♀ , and winter (n = 50) 1 ♂ :1 ♀ . The larger number of females may be indicative of higher survivorship following spawning.

The feeding ecology of Borax Lake chubs has been reported by Williams and Williams (1980). The relative importance of foods varied seasonally, but diatoms, microcrustaceans, and chironomid larvae were often the primary foods consumed. Terrestrial insects were important foods during summer and fall (Williams and Williams 1980).

LOWER BORAX LAKE (T37S, R33E, Sec 15; Harney County, Oregon).— Lower Borax Lake is a reservoir that receives water from the southwest outflow creek of Borax Lake. Water levels of Lower Borax Lake fluctuated seasonally, often holding little water during summer. Unfortunately, alteration to Borax Lake during 1979 diverted water away from the reservoir. Prior to the diversions, the reservoir occasionally harbored Borax Lake chubs that entered from the southwest outflow creek. It is doubtful that Borax Lake chubs ever spawned in Lower Borax Lake and the population was probably dependent on an influx of fish from Borax Lake via the outflow creek.

TABLE 1. Monthly reproductive characteristics of female Borax Lake chubs longer than 30 mm SL.

Month	n	x̄ SL	Gonadosomatic index			Classes of ova present
			Range	x̄	SD	
March	3	38.0	0.91–5.01	2.89	2.05	I,II,III
April	5	33.1	0.78–10.56	3.45	4.13	I,II,III
May	4	34.8	0.45–0.55	0.51	0.05	III only
June	7	35.9	0.53–2.38	1.01	0.66	II,III
July	8	44.0	0.50–1.54	1.06	0.37	III only
August	8	37.4	0.16–1.60	0.95	0.41	II,III
September	5	38.3	0.70–4.56	2.48	1.61	II,III
November	5	39.3	1.28–2.13	1.61	0.34	II,III
December	8	42.5	1.20–4.45	2.02	1.03	II,III
January	7	41.4	0.99–2.27	1.59	0.48	I,II,III

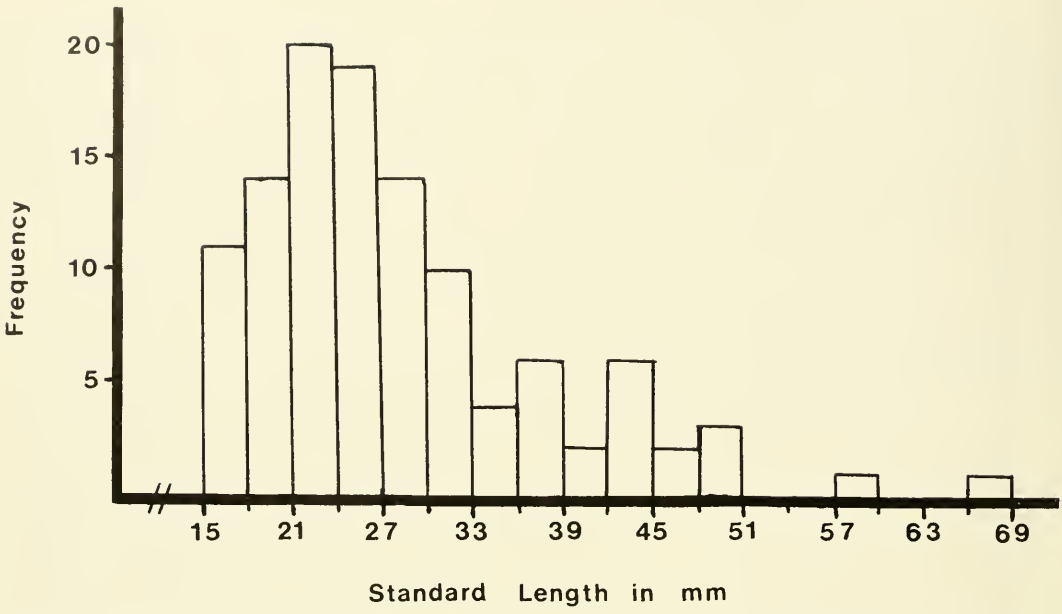

Fig. 2. Length frequency of 113 Borax Lake chubs, *Gila boraxobius*, collected 5 August 1977 from Borax Lake, Oregon.

Alvord Chub, *Gila alvordensis*

The Alvord chub, *Gila alvordensis* Hubbs and Miller, was found in 16 habitats located throughout much of the basin in Oregon and Nevada. The species was collected from a variety of habitats, including springs, creeks, and reservoirs. The species has been collected from Juniper Lake, Oregon (Bond 1974), although its presence appears attributable to an introduction because the lake dries during drought years.

SERRANO POND (T36S, R33E, Sec 1; Harney County, Oregon).— Serrano Pond is a 0.1 ha reservoir that receives water from a cool-water spring approximately 60 m distant. Water flows from the spring at approximately 17 C and water temperature in the pond is typically 16 to 21 C during the summer. The substrate of the relatively shallow pond is primarily silt. The water is somewhat turbid and aquatic vegetation is abundant. Recent alteration to this area has resulted in a diversion canal draining part of the flow away from the pond. Alvord chubs are absent from the spring, but are abundant in remaining waters of the pond and in the diversion creek. More than 100 fish can be easily collected from the pond in a single seine haul during the summer. Adult males are typically about 50 mm SL and adult females average approximately 65 mm SL, but females greater than 80 mm SL are occasionally collected.

Alvord chubs from Serrano Pond are highly opportunistic feeders. Bottom invertebrates are grazed extensively, as are midwater crustaceans and diatoms. Very few foods are consumed from the water's surface. Chironomid larvae, diatoms and cladocerans were the principal foods during summer, and ostracods, harpacticoid copepods, and chironomid pupae were of secondary importance (Williams and Williams 1980). Eighty-nine percent of the intestines examined by Williams and Williams (1980) contained one food that accounted for more than 50 percent of intestinal volume. Thirty-nine percent of the intestines contained one food, chironomid larvae, diatoms, or cladocerans, almost exclusively.

TROUT CREEK AND ALVORD LAKE (Harney County, Oregon).— Trout Creek is the largest stream in the Alvord Basin and discharges an average of 15 cfs, as measured in the canyon area 8 km east of Trout Creek Ranch (Libbey 1960). The creek heads in Trout Creek Mountains just north of the Nevada border. In the headwaters, Trout Creek flows

through canyon areas where its waters are clear and fast-flowing. Water temperature in the canyon is cool during summer, near 15 C, and colder during winter months. As Trout Creek leaves the canyon and enters the valley floor, flows decrease and water temperatures increase. Naturally lower summer flows and irrigation diversions often reduce the lower portions of Trout Creek to an intermittent stream during late summer. Turbidity is often high (visibility 1 cm) in lower reaches during summer. Substrate type changes from mostly gravel in upstream areas to silt in downstream sections. Trout Creek eventually empties into Alvord Lake, a remnant of the large lake that covered the valley during pluvial times. Alvord Lake varies greatly in size and occasionally dries completely during drought years.

Alvord chubs are common, although not abundant, in upstream canyon areas, and abundant in downstream sections. Introduced rainbow trout, *Salmo gairdneri*, also occur in upstream regions of Trout Creek. This is the only habitat where *Gila* occur sympatrically with another fish in the Alvord Basin. Alvord chubs in the canyon area are large, the longest measuring 122 mm SL. Three specimens 113 to 122 mm SL are all age class IV. Downstream areas also produce large Alvord chubs, although maximum length appears somewhat less. Color differences between Alvord chubs in the canyon and downstream areas are striking. Alvord chubs from the canyon are very dark, nearly black, dorsally, with golden sides possessing some black speckles, and a silver belly. In sections of Trout Creek in the valley floor, Alvord chubs are lighter in color, exhibiting a light green color on the dorsal part of the head and body, silver sides without speckles, and a white belly. All fins of *Gila* from Trout Creek are translucent red or orange in color except at the tips, which are white.

PUEBLO SLOUGH (T40S, R35E and T41S, R35E; Harney County, Oregon).— Pueblo (=Denio) Slough is a wetland area approximately 13 km long, extending from Tum Tum Lake in the north to just north of the Nevada border in the south. Various marsh, spring, and creek areas south of Tum Tum Lake provide most of the habitat in the slough. Water in Pueblo Slough is provided by Van Horn and Colony creeks, which drain the Pueblo Mountains, as well as at least 25 springs in the slough itself. These springs are mostly cool and shallow. Red Point School (T40S, R35E, Sec 14) is located in approximately the center of the slough. In August, Alvord chubs were collected from a shallow, clear pool at Red Point School where water and air temperatures were 15 and 17 C, respectively. Alvord chubs were abundant in the pool. Despite searches for chubs in streams draining the Pueblo Mountains, none could be found—although small rainbow trout were collected in lower Van Horn Creek.

BOG HOT RESERVOIR (T46N, R28E, Sec 17; Humboldt County, Nevada).— Bog Hot Reservoir is a relatively small impoundment fed by thermal waters flowing from Bog Hot Springs. Water issues from Bog Hot Springs at approximately 44 C and flows for 1.2 km before entering Bog Hot Reservoir. Water from Bog Hot Springs enters the reservoir at about 30 C. Typical water temperatures in the reservoir are 20 to 21 C during early summer. The waters of Bog Hot Reservoir are slightly turbid (visibility 31 cm), and the substrate is mostly silt with some gravel. Alvord chubs are abundant in Bog Hot Reservoir but are absent in Bog Hot Springs and in practically all the inflow creek between the springs and the reservoir. No Alvord chubs were found upstream of the 31.1 C boundary, where water from the inflow creek enters Bog Hot Reservoir.

Alvord chubs collected from Bog Hot Reservoir on 13 June 1978 were in spawning condition. On that date, water and air temperatures were 20.4 and 20.7 C, respectively. The fish were collected from open, slightly turbid water, 30 to 40 cm deep. Young-of-the-year fish 10 to 15 mm SL were abundant in the reservoir during June 1978, indicating a spawning season from at least April until July. Most young were observed in the shallow northwest end of the reservoir near the warm inflow creek.

BOG HOT CREEK (T46N, R28E; Humboldt County, Nevada).— Bog Hot Creek flows for approximately 5.2 km below Bog Hot Reservoir before entering Thousand Creek. Parts of Bog Hot Creek below the reservoir have

been diverted or otherwise modified by agricultural practices. Alvord chubs were not collected in Bog Hot Creek except in the lower reaches near Thousand Creek. One poeciliid, probably a guppy, was observed in the highly modified section of the creek about halfway between the reservoir and Thousand Creek. In the downstream part of Bog Hot Creek, Alvord chubs were rare to common during an April 1982 survey and occurred primarily in pools 20 to 46 cm in depth. Water and air temperatures on 15 April 1982 were 2.3 C and 1.5 C, respectively. The water was clear, but appeared brown and quite acidic.

UNNAMED SPRING (T46N, R26E, Sec 31; Humboldt County, Nevada).— This spring, measuring 2.4 m wide and 5 m long at its maximum extent, is by far the smallest habitat supporting fish in the Alvord Basin. Maximum depth is 77 cm. The water is clear and the substrate is an easily roiled silt. Water temperature was 11.4 C (air 7.5 C) during April and 18.2 C (air 20.4 C) during June. The unnamed spring is well isolated from nearby Thousand Creek by approximately 100 m of greasewood flat. The closest waters of Thousand Creek do not support Alvord chubs. The nearest population occurs approximately 1 km away in Dufurrena Pond 19.

A very small population of Alvord chubs, estimated at slightly less than 100 individuals, inhabits the spring. Many seine hauls, each encompassing the entire spring, yielded 52 fish during an April 1982 survey. The Alvord chubs ranged in size from 32 mm SL to, considering the small size of the habitat, an amazingly large 87 mm SL individual. No juveniles were seen during April, but young-of-the-year were observed on 14 June, when water temperature had risen to 18.2 C. Juveniles occurred among rushes, *Juncus* sp., in water only a few cm deep. Adults were occasionally observed darting across the open center of the spring, but spent most of the daylight hours under a narrow band of floating algal mats along the periphery of the spring.

THOUSAND CREEK SPRING (T46N, R26E, Sec 31; Humboldt County, Nevada).— Thousand Creek Spring forms the headwaters of Thousand Creek. The clear spring waters achieve a maximum depth of approximately 31 cm. Substrates are mostly fine gravels with some silt. Water and air temperatures during June were 27.1 and 18.2 C, respectively. Currently, the spring is inhabited by swarms of exotic guppies, *Poecilia reticulata*. Guppies have become established here and in the spring pool at nearby Dufurrena Campground. Competition from introduced guppies probably extirpated Alvord chubs from Thousand Creek Spring. Alvord chubs have not been recorded from Thousand Creek Spring, but their historic presence is indicated by the occurrence of Alvord chubs in downstream areas of Thousand Creek and in a nearby spring. Except for the presence of guppies, Thousand Creek Spring appears to provide a suitable habitat for Alvord chubs.

THOUSAND CREEK AND CONTINENTAL LAKE (Humboldt County, Nevada).— Thousand Creek heads at Thousand Creek Spring, flows through the Dufurrena area, where it receives Virgin Creek, and then enters Thousand Creek Gorge. Below the gorge, Thousand Creek becomes braided and receives water from Bog Hot Creek before eventually emptying into Continental Lake. In the Dufurrena area, Thousand Creek is dammed at several locations to create reservoirs. Thousand Creek is usually turbid (visibility 7 cm), shallow, and about 1 to 2 m wide. The substrate is mostly silt. In Thousand Creek Gorge, the creek is surprisingly deep (>300 cm) and cool, near 15 C during late summer. Below the gorge, Thousand Creek is often intermittent during summer, when water temperatures can reach 27 C. Typical summer and fall water temperature is 16 to 18 C. Alvord chubs are abundant in Thousand Creek except in some upstream areas where guppies have been introduced or habitat has been altered by reservoir construction. Guppies are abundant in Thousand Creek Spring and occur sporadically in Thousand Creek between Thousand Creek Spring and Dufurrena Pond 19. None were found downstream of Dufurrena Pond 19. Thousand Creek contains many large Alvord chubs; the largest measured 104.9 mm SL. During summer, Alvord chubs concentrate in deep pools in downstream areas of Thousand Creek. Continental Lake usually dries completely during summer, but harbors Alvord chubs during winter months.

The sex ratio of 23 adults greater than 35 mm SL was 1.1 ♂ :1.0 ♀ . Food habits of Alvord chubs collected during June from Thousand Creek were reported by Williams and Williams (1980). They found 10 foods in the intestines, of which chironomid larvae, cladocerans, copepods, and ostracods were of greatest importance. Chironomid larvae occurred in all intestines examined and accounted for approximately 26 percent mean volume (Williams and Williams 1980). Microcrustaceans comprised almost 45 percent mean volume of intestines, whereas diatoms accounted for only 5 percent mean volume. No terrestrial insects were observed in the intestines. Alvord chubs in Thousand Creek appear to feed primarily on bottom invertebrates and midwater crustaceans, avoiding surface foods.

DUFURRENA POND 19 (T46N, R26E, Sec 32; Humboldt County, Nevada).— Dufurrena Pond 19, approximately 1 km downstream of Thousand Creek Spring, is the first reservoir on Thousand Creek. The reservoir is shallow (typically < 50 cm) and moderately turbid (visibility 14 cm). Alvord chubs occur in the reservoir but are not abundant. Young-of-the-year (<20 mm SL) were abundant during June in the inflow diversion creek feeding the reservoir. At this time, the inflow creek was shallow (< 8 cm) and clear, with water and air temperatures of 14.5 and 13.0 C, respectively.

DUFURRENA POND 22 (T45N, R26E, Sec 2; Humboldt County, Nevada).— Dufurrena Pond 22 is a reservoir fed by waters of Thousand and Virgin creeks. The water is very turbid (visibility 2 cm) and shallow (typically 15 to 20 cm deep). Water level fluctuates greatly with season. During late summer, the reservoir is reduced to a small pool. Water and air temperatures during June were 17.6 and 13.2 C, respectively. Alvord chubs are abundant and achieve a large size in the reservoir.

VIRGIN CREEK (Humboldt County, Nevada).— Virgin Creek heads near the southern extent of the Alvord Basin, flows north through the more than 300-m-deep Virgin Creek Gorge, and then flows east until reaching Thousand Creek. Springs scattered along most of the length of Virgin Creek provide its flow. Alvord chubs are abundant in Virgin Creek from the north end of Virgin Creek Gorge to the nexus of Virgin and Thousand creeks. Alvord chubs are absent in Virgin Creek Gorge, where introduced rainbow trout are common. Virgin Creek below the gorge is cool, relatively shallow, and moderately turbid (visibility 10 cm). Below the gorge, water temperature is typically 15 to 18 C during summer months and maximum depth is usually less than 75 cm. The substrate is mostly silt.

WARM SPRING (T45N, R25E; Humboldt County, Nevada).— Warm Spring and its outflow are tributary to Virgin Creek approximately 2.5 km downstream from Virgin Creek Gorge. The outflow creek is a small, clear-water stream with an easily roiled silt bottom. Summer water and air temperatures of the creek just below the spring were 26.0 and 26.4 C, respectively. Alvord chubs are abundant in the outflow creek. The spring itself was not sampled, but Carl Hubbs collected Alvord chubs from the spring in 1934 ("Italian Camp Spring," UMMZ 130533). The steep gradient and low flow of the Warm Spring crenon as it approaches Virgin Creek inhibits mixing between the Virgin Creek and Warm Spring populations of Alvord chubs. Although Warm Spring flows through Virgin Valley Ranch, the spring and outflow creek have been only slightly altered and no exotic fish were present during a 1978 survey of the spring system.

DUFURRENA POND 13 (T45N, R26E, Sec 17; Humboldt County, Nevada).— Dufurrena Pond 13 is the only reservoir on Virgin Creek between Virgin Creek Gorge and Thousand Creek. Water characteristics are typically those of Virgin Creek except that maximum depth is greater (almost 2 m) and aquatic vegetation is abundant. Alvord chubs are common to abundant just upstream and downstream of the reservoir but are rare in the pond itself.

GRIDLEY SPRINGS (T44N, R27E, Sec 22; Humboldt County, Nevada).— Gridley Springs is a series of approximately 17 cool-water springs located on an alkali flat just south of the Gridley Lake playa. Many of the springs are little more than seeps, but a few have spring pools nearly 2 m deep with outflow creeks 30 or 40 m in length. During April 1982, most of the spring waters were

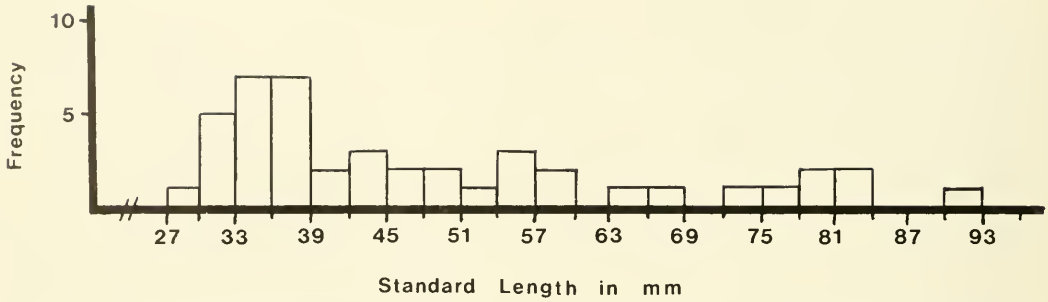

Fig. 3. Length frequency of 44 Alvord chubs, *Gila alvordensis*, collected 14 April 1982 from Gridley Springs, Nevada.

clear, with a temperature of 12 C (air 10 C). Rushes, *Juncus* sp., were the dominant plants around the springs, with some larger springs also harboring pondweed, *Potamogeton* sp., and cattails, *Typha* sp. Only one of the 17 springs examined contained Alvord chubs. This spring is located near the northwestern margin of the Gridley Springs series. Alvord chubs were found in the outflow creek, which extended approximately 40 m and was 3 m wide at its greatest extent. Only a trace of current could be detected in the creek. The water was unusually turbid, visibility 4 cm, with a maximum depth of 30 cm. Water temperature was 11.5 C (air 6.8 C) on 14 April 1982. The bottom was silt. Unlike most of the larger springs in the area, this spring contained only rushes along its margin. The Gridley Springs area is overgrazed by cattle and horses, but it is not known to what extent this is detrimental to the Alvord chub population.

Alvord chubs were not abundant in the outflow creek, but were common enough to collect 50 fish in three short seine hauls. Forty-four individuals collected in April 1982 ranged in size from 27 to 91 mm SL, but were mostly 30 to 38 mm SL (Fig. 3). The sex ratio of 32 individuals greater than 35 mm SL was 1 ♂ :3 ♀ .

West Spring (T44N, R27E, Sec 20; Humboldt County, Nevada).— West Spring issues from the base of Big Mountain and forms West Creek, which flows into the alkali flat south of Gridley Springs. The waters of West Spring are clear and shallow. Maximum depth is 12 cm over a gravel and sand substrate. Water and air temperatures recorded during summer were 21.8 and 20.4 C, respectively. Alvord chubs are common in the spring and its outflow creek. The largest of 33 individuals collected on 18 August 1978 was 62.8 mm SL. The sex ratio of 30 adults greater than 40 mm SL was 1 ♂ :1 ♀ . Alvord chubs collected during August from West Spring fed exclusively or almost exclusively on small hydrobiid snails. This snail, which occurs in great abundance, apparently represents an undescribed species endemic to West Spring (Jerry Landye, pers. comm.).

West Creek (T44N, R27E, Sec 20, 28, 29; Humboldt County, Nevada).— West Creek flows for nearly 3 km before emptying into the alkali flat approximately 2 km south of Gridley Springs. Because West Creek is formed by West Spring, water characteristics are similar for both. The creek is quite small, often 1 to 2 m in width and less than 15 cm deep. Current is moderate in the upper reaches but slows considerably upon reaching the flat. Alvord chubs occur throughout the creek, but are somewhat smaller than those in West Spring.

Discussion

The Alvord cutthroat trout, Alvord chub, and Borax Lake chub are all restricted in distribution to waters of the Alvord Basin. The Alvord cutthroat trout is now extinct but formerly occurred in larger creeks of the basin. Hybridization with introduced trout caused the demise of the native form. The Borax Lake chub has the most restricted natural distribution of the three fishes, occurring only in Borax Lake and adjacent lake outflows. The Alvord chub is relatively widespread in the basin and was recorded from 16 localities, including Bog Hot Reservoir, Bot Hot Creek, Thousand Creek Spring, an unnamed spring,

Dufurrena Pond 19, Dufurrena Pond 22, Dufurrena Pond 13, West Spring, and West Creek as new locality records.

Because of the fragility of the small aquatic habitats and the overall paucity of water in the basin, the two extant native fishes are easily threatened by the activities of man. The naturally restricted range of the Borax Lake chub and threats from geothermal energy development prompted the American Fisheries Society to list the species as threatened in 1979 (Deacon et al. 1979). Also during 1979, several portions of the north and east shoreline of Borax Lake were altered so that overflow waters exited the lake to the north and east rather than to the south and west, as was the historical condition. This alteration caused Lower Borax Lake as well as the marsh and pools to the south and west to dry, thus eliminating Borax Lake chubs from these waters. Leasing of surrounding lands for geothermal exploration and alteration of the shoreline caused the U.S. Fish and Wildlife Service temporarily to list the Borax Lake chub as an endangered species on 28 May 1980. As a result of the listing, geothermal exploration was prohibited from a one-mile buffer zone around Borax Lake. The emergency listing has since been supplemented by a final rulemaking that designated the species as endangered pursuant to the Endangered Species Act. The Alvord chub has fared better than the Borax Lake species because of its wider distribution. Nevertheless, competition with exotic guppies has extirpated the Thousand Creek Spring population of Alvord chubs, and other populations are threatened by habitat alteration. The Alvord chub appears easily eliminated by the presence of exotic fishes. Thousand Creek reservoirs stocked with game fish, such as Dufurrena Ponds 20 and 21, lack Alvord chubs. White crappie, *Pomoxis annularis*, pumpkinseed, *Lepomis gibbosus*, and largemouth bass, *Micropterus salmoides*, were collected from Dufurrena Ponds 20 and 21.

Borax Lake chubs are dwarf and typically mature at 30 mm SL. Adults are usually 33 mm to 45 mm SL and typically live for one year. A few Borax Lake chubs, mostly females, live more than one year. Adult Alvord chubs are larger, achieving more than 100 mm SL in Trout and Virgin creeks. Even in very small springs, such as the unnamed spring and Gridley Springs, Alvord chubs achieve 90 mm SL. The presence of large chubs in the cool springs and creeks indicates a longer life span for the Alvord chub than typically occurs for the Borax Lake species. Borax Lake chubs spawn year around in their thermal lake habitat, but a spring spawning peak is indicated. Alvord chubs appear to spawn only once a year in their thermally fluctuating habitats. Both species of *Gila* are opportunistic omnivores, consuming primarily chironomids, microcrustaceans, and diatoms. The Borax Lake species also consumed large quantities of terrestrial insects during summer and fall. The Alvord chubs in West Spring are unusual in that they are greatly dependent on the endemic hydrobiid snail for food.

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