Portions Applicable to Preston-Lund-Kirch Town area

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COMPARATIVE STATUS OF FISHES ALONG THE COURSE OF THE PLUVIAL WHITE RIVER, NEVADA

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ABSTRACT.—Fish populations were sampled at 11 locations along the course of the pluvial White River, southeastern Nevada, in the 1960s and in 1983, and 3 sites in early 1984. The locations included Preston Big, Preston Town, and Lund Town springs, White River Valley, White Pine County; Moorman, Hot Creek, and Flag springs, White River Valley, Nye County; and Hiko, Crystal, and Ash springs, Pahranagat Valley, Lincoln County; and Moapa Valley Water District Spring and the Moapa River at Home Ranch, Moapa Valley, Clark County. Comparisons of species composition and abundance were made and, where possible, were related to historical data on settlement and habitat modifications.

Negative impacts have accelerated during the past 20 years and the fishes in most of these sites have declined dramatically, because of habitat alteration and reduction, and introductions of non-native species. One species became extinct before 1955, and our investigations show recent extirpations of taxa at two localities. Two taxa currently are listed as endangered. We submit rationale for endangered status for an additional seven taxa, threatened status for one, and special concern status for another. Only two fishes in this system presently remain comparatively safe.

During late Pleistocene—early Holocene pluvial stages, the White River of southeastern Nevada flowed southward from its headwater tributaries in northern White River Valley, through Pahranagat Valley into Kane Springs Wash, cut southeastward through Arrow Canyon into Moapa Valley, joined the pluvial Carpenter River (Meadow Valley Wash) and emptied into the Virgin River above its confluence with the Colorado River (Hubbs and Miller, 1948; Miller and Hubbs, 1960; Fowler et al., 1973; Smith, 1978; Williams and Wilde, 1981). Surface flows in this system are now confined to the White River (northern White River Valley), outflows of thermal springs in White River, Pahranagat, and upper Moapa valleys, and the Moapa River which drains into the northwestern end of the Overton Arm of Lake Mead (Blackwelder, 1943; Miller and Hubbs, 1960; Fig. 1). Native fishes of this system probably were more widely distributed in pre-Pleistocene times, but their isolation in these mostly disjunct waters for perhaps the last 10,000 years (R. R. Miller in Williams and Wilde, 1981) has resulted in differentiation.

Historical data typically are lacking in reports concerning man's impact on southwestern aquatic systems. Miller (1961), Minckley and Deacon (1968), Deacon (1979) and others summarized these impacts, and generally categorized them as activities that physically or biologically degrade habitats (e.g., habitat disturbance or introductions of exotic and other nonnative flora and fauna). Habitat alterations are known to have begun before the first settlers arrived.

Selected fish populations along the course of the pluvial White River were sampled extensively during the mid 1960s by J. E. Deacon, F. A.

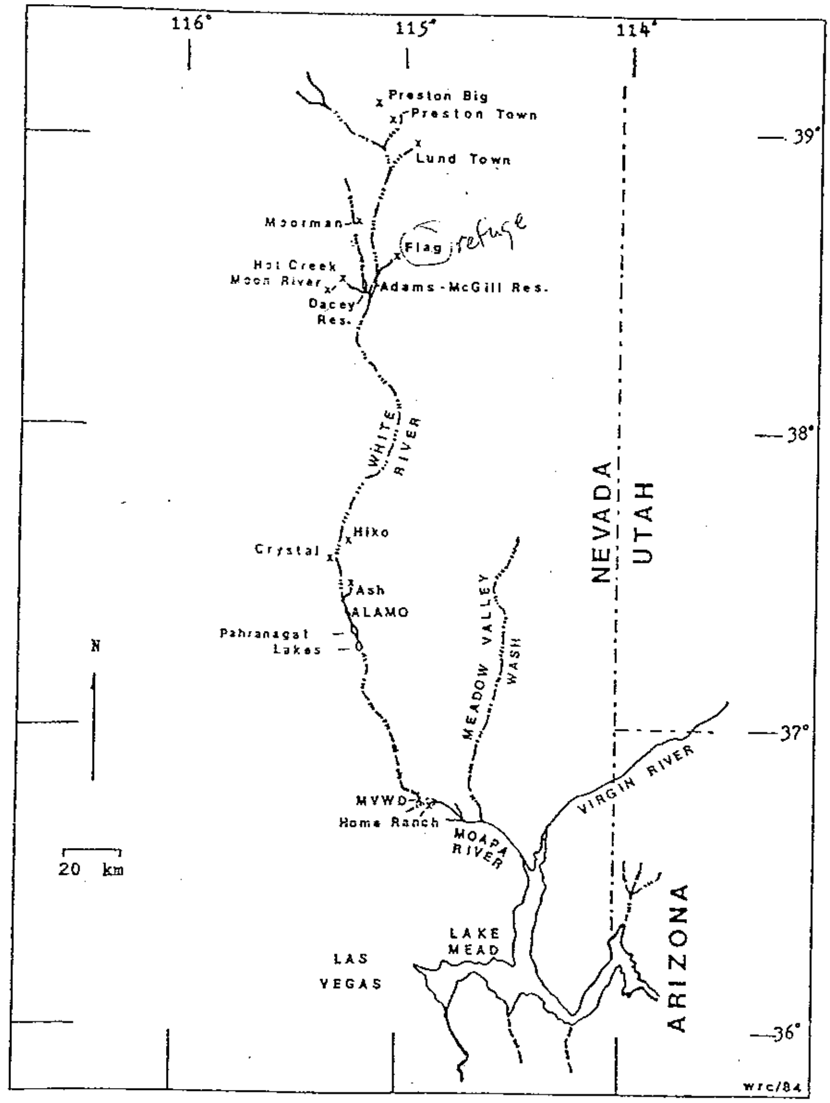

FIG. 1.—Map of the pluvial White River drainage, southeastern Nevada.

Espinosa, Jr., and B. L. Wilson using screened 44 x 23 cm baited minnow traps. In this study, data were collected during July and November 1983 and at three sites in March 1984 to compare present-day species composition and relative abundance to those found in the 1960s. Preston Big, Preston Town, and Lund Town springs, White River Valley, White Pine County; Moorman, Hot Creek, and Flag springs (and an examination of Moon River Spring), White River Valley, Nye County; Hiko, Crystal, and Ash springs, Pahranagat Valley, Lincoln County; Moapa Valley Water District (MVWD) Spring and the Moapa River at Home Ranch, Moapa Valley, Clark County, were the waters sampled (Fig. 1). Historical information for these sites was reviewed to determine dates of settlement, local history, and, where known, modification by man.

Materials and Methods.—Unbaited, unscreened 44 x 23 cm galvanized minnow traps (6.4 mm mesh) were placed at several sites in spring systems (except for Preston Town Spring) for a period of two hours in July 1983. Unscreened minnow traps baited with bread were used in November 1983 and March 1984. Underwater observations with face mask and snorkle were made during July in springs and their outflows (Preston Big, Lund Town, Hiko, Crystal, and Ash springs) to confirm species composition and alleviate trapping bias. Fishes in Preston Town Spring and the Moapa River at Home Ranch were collected with a 6.4 mm mesh, 2.7 x 1.2 m nylon minnow seine. All fishes captured during sampling were counted, recorded, and released.

Results.—*White River Valley*.—In 1880, the federal government granted some two million acres in eastern Nevada to the state. A policy was established whereby this land could be purchased by individuals at $1.25 per acre, with a 25¢ per acre downpayment. Buyers recognized that ownership of springs dictated land control so that when lands were sold, springs, and usually 16.2 ha immediately around them, were purchased first. When an individual completed paying for the land, he was granted a patent, or title, from Nevada; if, however, the individual defaulted on payment, the land reverted and could be resold. Through default by some landowners, a few individuals were able to acquire vast amounts of land along the upper course of the pluvial White River (Georgetta, 1972).

Preston Big Spring.—This spring lies north of the town of Preston. Like other upper valley springs, it is cool (21.7°C) at the outflow. The area was first settled in the 1870s (see Preston Town Spring account below for other historical information).

Vegetation in Preston Big Spring in 1983 remained the same as described by Miller and Hubbs (1960) and Williams and Wilde (1981). Fishes known to have occurred in this spring included White River spinedace (*Lepidomeda albivallis*), an undescribed subspecies of speckled dace (*Rhinichtyhys osculus*), White River desert sucker (*Catostomus clarki intermedius*), and Preston White River springfish (*Crenichthys baileyi albivallis*) (Williams and Wilde, 1981). Spinedace were in the outflow in the mid to late 1960s and afterwards (Fig. 2), but trapping, seining, electroshocking, and underwater observations indicated its disappearance shortly before 1980 (Deacon et al., 1980). We concur with Williams and Williams (1982) and Deacon and Williams (1984) that this species has been extirpated from this spring and its outflow.

A second species appears to have been extirpated more recently. The White River desert sucker, which typically avoids minnow traps in Preston Big Spring (Fig. 2), was last collected at this locality by seining and electroshocking in July 1980 (Deacon et al., 1980). None was caught or observed in 1983, and we believe it also has been extirpated from this spring and its outflow. J. Hutchings (pers. comm. 1983) reported dead suckers in downstream irrigation structures in summer 1982, apparently killed by a heavy dose of copper sulfate. It is possible that applications of copper sulfate prior to 1980 also were responsible for extirpation of spinedace.

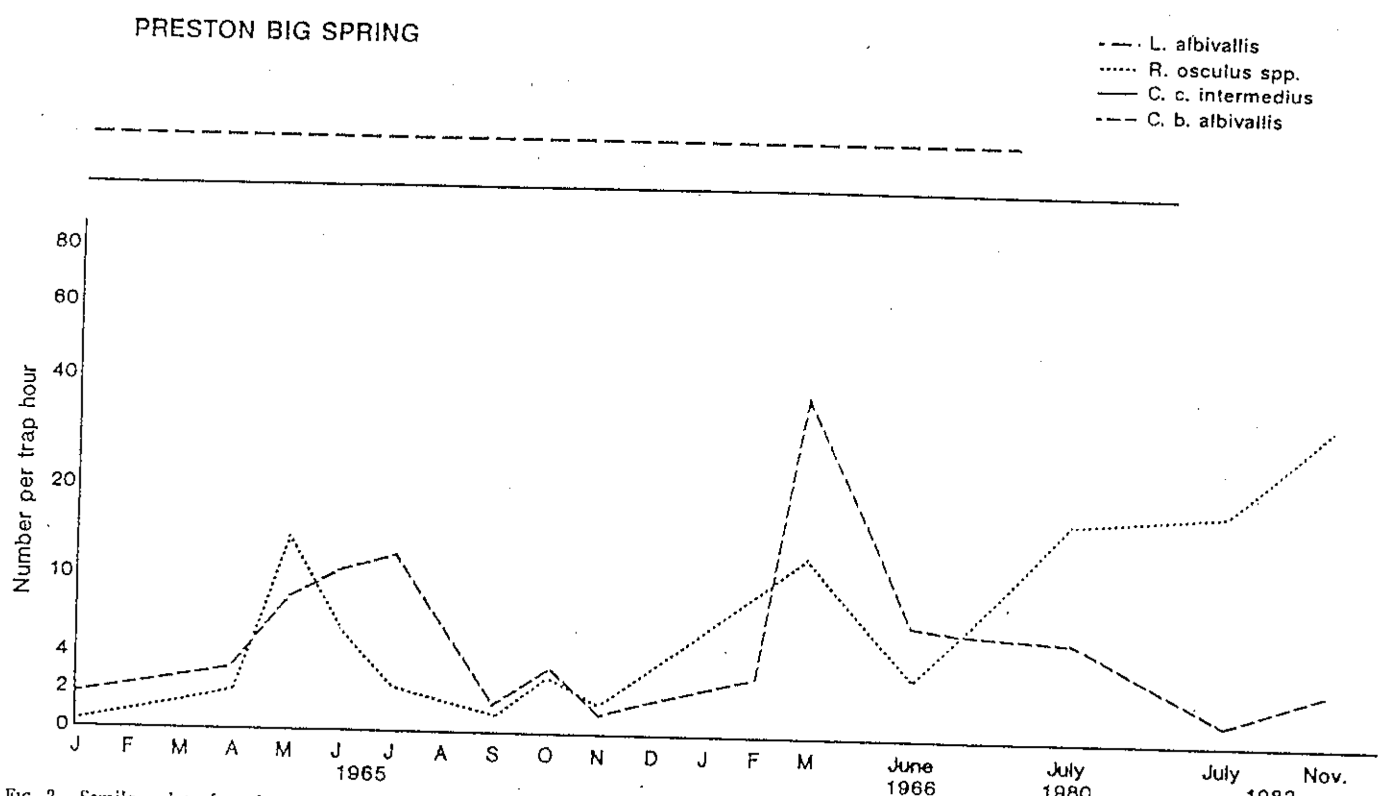

FIG. 2.—Semilog plot of catch per trap hour of *Rhinichthys osculus* and *Crenichthys baileyi albivallis* at Preston Big Spring, 1965-1983. The straight lines represent occurrence of *Lepidomeda albivallis* and *Catostomus clarki*.

The speckled dace population has increased dramatically in recent years, becoming the dominant species following disappearance of spinedace (Fig. 2). This suggests that speckled dace expanded its niche breadth to include at least a portion of the niche formerly occupied by spinedace. Springfish, however, appear to have declined or, at least, not to have increased in abundance inresponse to extirpation of spinedace and probable extirpation of desert suckers.

Loss of spinedace at this locality and the more recent, probable extirpation of desert suckers makes it seem unlikely that remnant populations of these fishes remain in downstream irrigation ditches. Should such exist, their natural reinvasion of the spring and its immediate outflow would be precluded by a recently installed (June 1980) irrigation pipe, that accomodates the entire flow of Preston Big Spring at a point approximately 1.6 km downstream from the source.

Major threats to fishes in Preston Big Spring and its outflow presently include overdosing with copper sulfate for algal control and habitat elimination from channelization, piping, etc. Nevada Department of Wildlife (NDOW) personnel, in cooperation with the local Water Conservation District, have been attempting to demonstrate to farmers that a slow-drip, low-dose introduction of copper sulfate can be effective in controlling algae without killing fishes and other non-target organisms (J. Hutchings, pers. comm. 1983).

Preston Town Spring.—During the 1870s, the Moddock's and Adams Ranch (Maddox Ranch, *fide* Read [1965]) was established by settlers at this location. It may have been owned by and operated for the wealthy landowner and White Pine County Commissioner, J. R. Withington (Wilcox's [1949], "J. R. Worthington" or Read's [1965] "J. D. Whittingdon"). This man also owned Tom Plane Ranch (later to become Lund). Withington had purchased patents on many springs and was reported to own every important stream in White Pine County. The Church of Jesus Christ of the Latter-day Saints (Mormons) acquired Moddock's and Adams and Tom Plane ranches in 1890; the former was occupied by Mormons in 1896, but settlement really began in 1898 when the new town was named for William B. Preston. The town was laid out around Preston Town Sring, described as a "warm, watercress-bordered haven" (Read, 1965; Georgetta, 1972).

This is a small, cool (21°C) spring that historically hosted the same fishes as Preston Big Spring. Its nearby confluence with the outflow of Preston Big Spring was altered in the mid to late 1970s, following introduction and establishment of guppies (*Poecilia reticulata*) prior to 1961 (Deacon et al., 1964). Increasing guppy populations may have stressed native fishes, followed by further, greater stress when this spring was disconnected from the outflow of Preston Big Spring and substantial habitat reduction severely altered flow length. The result was extirpation of all native fishes except Preston White River springfish. Only the spring source and 15 m of its outflow remain relatively pristine; downstream from this point, all spring discharge is captured and piped for local agriculture. In July 1983, with four seine hauls that sampled more than 50% of the available habitat, we captured three small springfish among many hundreds of guppies.

TABLE 1.—*Catch per trap hour and number of fish captured by species at Lund Town Spring. Most records are for 8 traps. Abbreviations: • = number of fishes captured; #/thr = number per trap hour; S = screen mesh; U = 6.4 mm mesh (unscreened); B = baited; N = not baited.*

DATE	TRAP TYPE		*L. albivallis*		*R. osculus* ssp.		*C. c. intermedius*		*C. b albivallis*		*G. affinis* and *P. reticulata* (a)	
	MESH	BAIT	•	#/thr	•	#/thr	•	#/thr	•	#/thr	#	#/thr
29 Jan 65			26	3.25	268	33.50	6	0.75	2	0.25	51	6.40
4 Apr 65			14	7.00	136	68.00	0	0	0	0	252	126.00
2 May 65			56	14.00	251	62.75	0	0	0	0	16	4.00
16 May 65			22	8.50	186	71.50	0	0	0	0	5	1.90
20 June 65	S		0	0	174	21.75	1	0.12	0	0	3	0.40
27 July 65			3	1.12	84	10.50	0	0	0	0	9	10.50
26 Sept 65	S		1	0.125	110	13.75	0	0	0	0	67	0.37
27 Nov 65	S		35	4.40	226	28.25	1	0.125	1	0.125	365	45.60
6 Feb 66			11	1.40	180	22.50	1	0.125	9	1.125	335	41.90
28 July 83	U	N	0	0	32	2.00	3	0.20	0	0	9	0.60
12 Nov 83	U	B	6	0.40	369	27.30	13	0.96	0	0	75	5.50
25 Mar 84	U	N	18	0.82	250	11.36	39	1.77	0	0	26	1.18

(a) since early trap records for these fishes were combined, we treated 1983-84 data similarly.

Lund Town Spring.—This was the site of the Tom Plane Ranch, settled in the 1870s. The first flour mill in White Pine County was built at the spring head in the late 1870's. Mormons settled in 1898, naming the new town for Anthony H. Lund. The town grew north of the spring and a canal system carrying water from the spring was designed by William A. Terry (Read, 1965). The main, open irrigation ditch was replaced by a pipeline in June 1983.

Lund Town Spring has the largest spring pool in the upper valley. Its native fish fauna, the same as that which once inhabited Preston Big and Preston Town springs, remains extant. It also hosts two introduced species, mosquitofish (*Gambusia affinis*) and guppies. Diversity and abundance of native fishes, the relatively unmodified habitat, plus the cool temperature (20°C) apparently have precluded a potential takeover by introduced fishes.

Underwater observations indicated that trapping data (Table 1) did not accurately reflect composition or distribution of fishes in this spring. Whereas no spinedace were trapped in July 1983, more than 20 adults were observed; spinedace were caught in November 1983 (Table 1). While this spring pool has never been known to host a large population of Preston White River springfish, several adults were observed near the southwestern spring "boils." White River desert suckers were common to abundant. Mosquitofish occupied shallows around the spring pool (but not its swift outflow), and guppies were confined primarily to shallows and vegetated areas in the southeast quadrant of the pool.

Moorman Spring.—Often cited as Morman Spring in the literature, this spring is listed as Moorman Spring on topographic maps. It was probably named for Confederate Captain William C. Moorman who, with his two sons, moved to the upper valley in the 1870s (Read, 1965).

Moorman Spring contains a single fish, the Moorman White River springfish (*Crenichthys baileyi thermophilus*), which also inhabits nearby Hot Creek and Moon River springs (Williams and Wild, 1981). This spring is considerably warmer (37-38°C) than springs to the north. Although the outflow has been altered since Deacon sampled there in the 1960s, springfish remained plentiful (Fig. 3). Abundance increased with distance from the spring source, with individuals scarce to common in the upper 195 m and numerous to abundant beyond that point. In winter, when temperatures decrease in the downstream outflow, springfish move upstream toward warmer spring sources. The spring supports a 1.2-1.6 ha marsh, approximately 210 m downstream from the source; no springfish were observed in the marsh in July 1983.

Hot Creek.—Hot Creek is the outflow of Hot Creek Spring, located approximately 23.7 km south of Moorman Spring and 12 km west-southwest of Sunnyside, the former site of Hot Creek Ranch (see below under Flag Springs). Hot Creek is the major effluent into the southwestern end of Adams-McGill Reservoir.

Adams-McGill Reservoir and adjacent property were acquired by the Nevada Department of Fish and Game (now Nevada Department of Wildlife [NDOW]) in 1959. The reservoir was drained and the dike rebuilt to impound 341 surface ha in 1960. Prior to drawdown, T. C. Frantz (NDOW) sampled the reservoir in may 1960. Bluegill (*Lepomis macrochirus*) had been stocked into this reservoir much earlier by the previous owner; none was found and, in fact, the reservoir was devoid of fishes. This was and remains surprising, because the nearby Carpenter River and its reservoirs contain native desert suckers and speckled dace, coexisting with introduced rainbow trout (*Salmo gairdneri*) and, in Eagle Valley and Echo Canyon, also with golden shiners (*Notemigonus crysoleucas*) probably released by a bait-raiser.

Following renovation of Adams-McGill Reservoir, largemouth bass (*Micropterus salmoides*) were introduced (2,902 individuals) in March and May 1961 from stocks obtained from Ruby Marsh, Elko County, and Lake Mead, Clark County. Subsequent introductions of threadfin shad (*Dorosoma petenense*), bullhead catfishes (*Ictalurus melas* and *I. nebulosus*), and bluegill failed to establish. The forage base for largemouth bass and stocked, catchable-size rainbow trout in Adams-McGill Reservoir is insects, particularly larvae of dragonflies and damselflies.

In 1966, Hot Creek was officially designated as a refuge for White River springfish (the form now recognized as a subspecies, the Moorman White River springfish). This was the first officially designated fish sanctuary in the U.S. With additional funding from the Bureau of Sport Fisheries and Wildlife (now the U. S. Fish and Wildlife Service [USFWS]) to Nevada Southern University (now the University of Nevada, Las Vegas [UNLV]), the Nevada Department of Fish and Game fenced the area and installed "exotic fish barriers" (Miller and Pister, 1971) in the outflow channel leading to Adams-McGill Reservoir and the realigned ditch into recently constructed Dacey Reservoir

Largemouth bass appeared in Dacey Reservoir prior to 1973, probably from an unauthorized introduction from Adams-McGill Reservoir. Also in 1973, an insufficient fall (0.5 m) was noted on the downstream fish barrier; it washed out in 1974 and largemouth bass entered the refuge, threatening

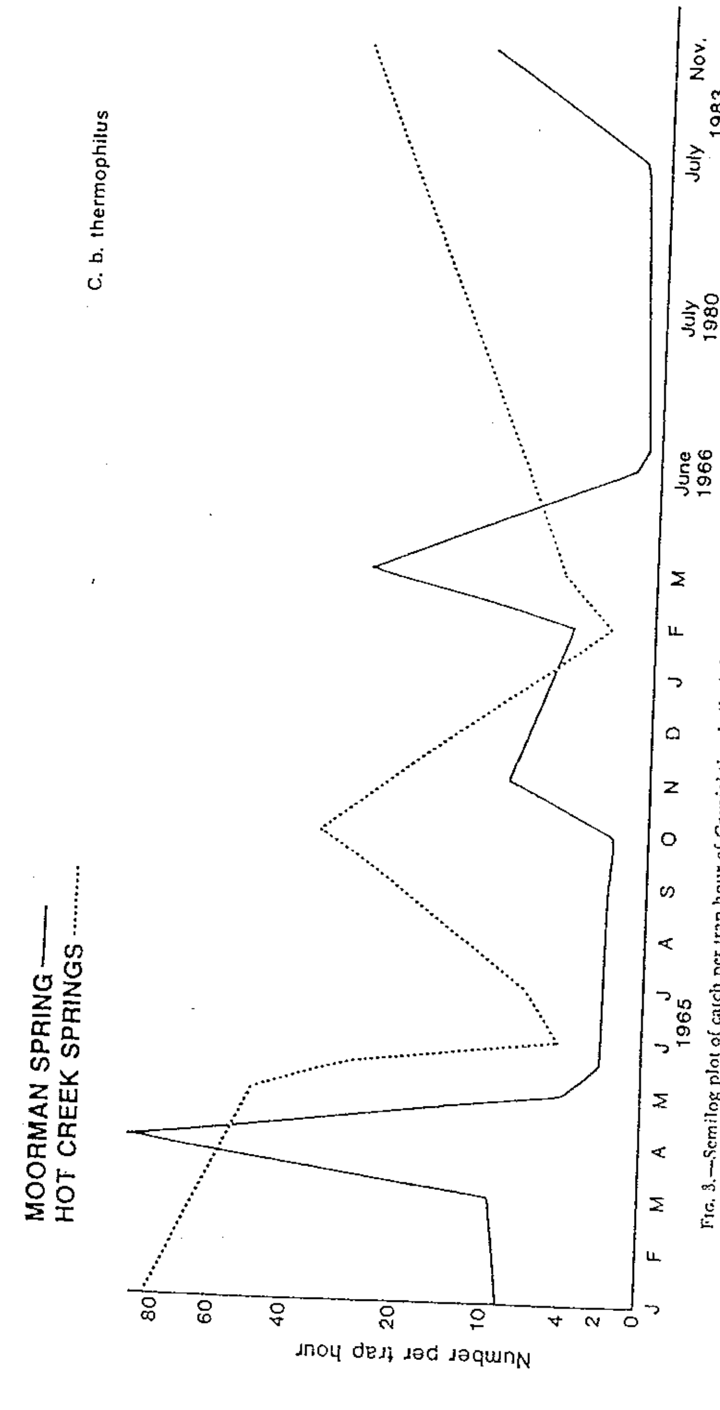

FIG. 3.—Semilog plot of catch per trap hour of *Crenichthys baileyi thermophilus* at Moorman and Hot Creek springs, 1965-1983.

the survival of springfish. This invasion could have been through the drainage ditch to Dacey Reservoir or the Hot Creek channel into Adams-McGill Reservoir. In February 1978, bass were eradicated from the refuge by use of antimycin, and integrity of the fish barrier was reestablished. Springfish, having survived in remote, vegetation-choked spring sources that bass could not penetrate, reestablished an abundant population (Fig. 3).

Moon River Spring.—We briefly visited Moon River Spring, approximately 4.2 km south of Hot Creek Spring, in November 1983. This site was settled by Jacob Moon and his wife in 1872 (Read, 1965). The spring pool appeared to be in excellent condition, although we found recently burned planks and other debris in the outflow downstream, near the former site of Moon River Ranch. No trapping was attempted. The only fish known to inhabit this spring and its outflow is the Moorman White River springfish (Williams and Wilde, 1981); we observed them in the spring and its outflow.

Flag Springs.—Three springs emerge on the site of the Wayne E. Kirch Wildlife Management Area headquarters at Sunnyside. This was the site of Hot Creek Ranch, first settled in the early 1870s by the Smith brothers (Read, 1965). It was subsequently purchased by Jewett W. Adams in 1882. Adams, Governor of Nevada from 1883 to 1886, purchased defaulted land patents (often those of J. R. Withington) and soon owned large tracts in the White River Valley. White Pine County land surveyor William N. McGill was doing the same to the north. Both men were successful in mining ventures and the cattle business. Following collapse of the cattle market in 1895, both, reluctantly, began raising sheep. These men formed a partnership and later a corporation that owned 37,232 ha of eastern Nevada. The Adams-McGill Company was financially successful and, during 1912-1913, spent $280,000 for "cleaning" and "digging out" springs and construction of reservoirs, including Adams-McGill Reservoir. McGill's son William, an engineer, supervised this work (Wilcox, 1949; Georgetta, 1972).

In November 1983, we placed minnow traps in the outflow of each spring for periods of one-half to one hour. One White River spinedace (another avoider of minnow traps) was caught in the northern spring and five speckled dace were trapped in the southern. No fishes were caught in the rapidly flowing middle spring, although several small individuals, probably spinedace, were seen below the trap. White River desert suckers were collected downstream from these springs in 1982, above a pond in which we observed young largemouth bass in 1983. John Pedretti, a student at UNLV, collected four spinedace and 256 speckled dace in 6 trap hours in the northern spring on 24 March 1984; 71 speckled dace were taken in 10 trap hours of effort in the southern spring.

Springfish in the White River Valley.—The three major populations of White River springfish, representing two subspecies, show contrasting seasonal patterns of abundance, especially in 1983 (Figs. 2, 3). These differences may be a consequence of the differential effects of the thermal environment on reproductive success and survival. The Preston White River springfish in Preston Big Spring (21.7°C) reached maximum abundance in summer 1965. Data suggest a similar situation for spring/summer 1966 and 1980. Data for 1983, however, differ markedly from this pattern, suggesting that excessive doses of copper sulfate that probably were responsible for disappearance of spinedace and probable extirpation of desert suckers also may have adversely impacted springfish.

Populations of springfish in Moorman and Hot Creek apparently have not been adversely affected over the 20 years of record. They do seem to show an annual cycle of abundance in these warmer waters (35-37 and 32°C, respectively) that peaks in winter (Fig. 3).

Pahranagat Valley.—This valley is named for the Pahranagat Indians (Thompson and West, 1881; Hulse, 1971; Townley, 1973) who, with other Southern Paiutes, may have been attracted to the valley by springs before A.D. 1000 (Fowler et al., 1973; Griffin, 1976). Thompson and West (1881) cited Pahranagat as meaning "watermelon" (which we reject), referring to a crop raised by these Indians. Melons also were reported as grown by Indians in southeastern Arizona in the 1500s; references to "native...large" melons that when sliced and dried "taste like figs" likely are to pumpkin (D. F. Austin, pers. comm. 1984) or Papago squash (W. L. Minckley, pers. comm. 1984) and not to "cantaloupe" as Winship (1966) suggested. Melons (watermelon, cantaloupe, etc.) are native to Africa (Purseglove, 1966) and could not have arrived in North America prior to settlement.

Before channelization of springs such as Crystal in the 1850s to early 1860s by Pahranagat Indians, outflow areas probably were bogs used for agriculture. These Indians grew squash, some wheat, a small sunflower, grass seeds (Thompson and West, 1881), and a "melon" which we believe was pumpkin. "Pah" meant water, and we suggest that "ranagat" meant pumpkin or squash, or may have been a generic term for any native, melon-like cucurbit. A map of 1865 vintage (Townley, 1973) labeled the valley as Pah Ranagat.

Approximately 400 Pahranagat Indians lived in the valley in 1865. They irrigated their crops via ditches from spring outflows (Thompson and West, 1881; Townlee, 1973; Griffin, 1976; see Crystal Springs account below for other historical information).

Silver was discovered in Pahranagat Mountains in March 1865. By 1866, miners had built four small towns in the northern region, one of which was Hiko. An estimated 500 residents had settled and all irrigable land in the valley was claimed. Also in 1866, Lincoln County was created, and Congress, not realizing that the Pahranagat mines were in Nevada, yielded to pressures from Nevada mining proponents and added one degree longitude to Nevada from Utah. In 1867, a southern triangle of Arizona land and what are now Clark and southern parts of Nye County (including Pahrump Valley and Ash Meadows) was added to Lincoln County (Thompson and West, 1881; Hulse, 1969, 1971; Elliott, 1973). The silver boom ended in 1868 and the population of Hiko, the only viable town in the upper valley, dropped to below 100 (Townley, 1973).

Hiko Spring.—Hiko is a Paiute word meaning "White man's town" (Townley, 1973). It was designated as the Lincoln County seat in 1867

Hulse, 1971; Elliott, 1973; Townley, 1973). The silver mines were located approximately 16 km west, and ore processing stamp mills (first a five-stamp mill and later a 10-stamp mill) were constructed 0.8 km southwest of the town (Hulse, 1971). Stamp mills require water, which we assume had to be diverted by impounding and redirecting outflow from Hiko spring. In the valley south of Hiko Spring are two impoundments, Nesbitt and Frenchy lakes, which in 1865 were called Hatch's and Shutt's lakes, respectively (Townley, 1973); they are now included in the Key Pittman Wildlife Management Aea.

Native fishes known from Hiko Spring and its outflow were Pahranagat roundtail chub (*Gila robusta jordani*), Pahranagat speckled dace (*Rhinichthys osculus velifer*), and Hiko White River springfish (*Crenichthys baileyi grandis*) (Williams and Wilde, 1981). Tanner (1950) noted the scarcity of Pahranagat roundtail chub in outflows of Hiko and Crystal springs and suggested its possible future extintion. Modification of the outflow prior to 1963 apparently was responsible for the extirpation of both the chub and dace, since both were absent when Deacon first collected there on 2 February 1963. Deacon last collected Pahranagat speckled dace from this system in a shallow marsh below the spring on 1 October 1966.

Largemouth bass from Ruby Marsh, Elko County, were stocked into Nesbitt Lake in May 1959 and May 1963; an additional stocking was made in March 1964 with bass taken from Honeybee Pond in the Overton Wildlife Management Area, Clark County. A double set of fish screens was installed to prevent upstream movement of bass through several km of concrete irrigation ditches. Mosquitofish appeared in Hiko Spring between June 1964 and January 1965. Shortfin mollies (*Poecilia mexicana*) and largemouth bass were first observed there in February 1965. The Hiko White River springfish was extirpated from Hiko Spring between February 1966 and June 1967 (Minckley and Deacon, 1968; Deacon, 1979; Williams and Wilde, 1981). Hiko Spring (26°C) now supports only mosquitofish and shortfin mollies (Fig. 4). Its outflow presently is piped to nearby agricultural lands; the only surface water remaining is that impounded at the spring source. Efforts to reestablish a population of Hiko White River springfish through plantings are in progress by NDOW and UNLV. Success of these plantings is doubtful, especially because someone introduced convice cichlids (*Cichlasoma nigrofasciatum*), probably captured from Crystal Springs, into the spring pool by June 1984 (T. M. Baugh, pers. comm. 1984).

Crystal Springs.—Crystal Springs was the site of the first settlement in Pahranagat Valley (1865) and became the first Lincoln County seat in 1866 (Thompson and West, 1881; Townley, 1973). The largest irrigation ditch dug by Pahranagat Indians prior to arrival of the first settlers captured outflow from Crystal Springs. It was 2.4 m wide, 1.8 m deep, and several km in length, and dug using metal tools shaped from iron collected by the Pahranagats from wagons abandoned by Mormon explorers who died in Death Valley in 1849 (Thompson and West, 1881). Where the Pahranagats learned irrigation techniques is unknown; the Spring Valley Shoshone, to the northeast, irrigated maize (Jorgensen, 1980) and a Mormon missionary,

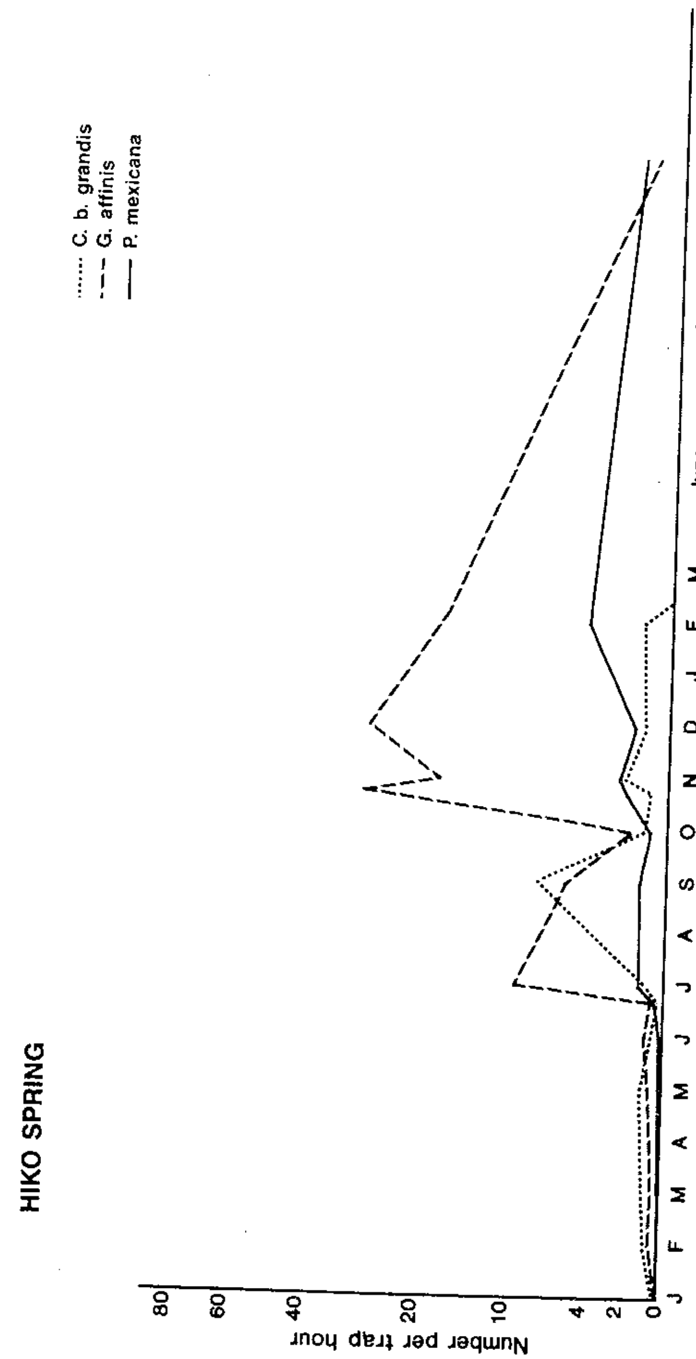

FIG. 4.—Semilog plot of catch per trap hour of fishes at Hiko Spring, 1965-1983.

Jacob Hamblin, was teaching Indians in southwestern Utah and the Moapa Valley, Nevada, how to irrigate (Corbett, 1952). There doubtless was contact between these tribes and it is probable that the Pahranagats learned their irrigation techniques from other Indians.

According to C. L. Hubbs' field notes (Williams and Wilde, 1981), the known native fish fauna of Crystal Springs and its outflow consisted of Pahranagat roundtail chub, Pahranagat speckled dace, White River desert suckers, and Hiko White River springfish. Crystal Springs was stocked with largemouth bass by Nevada Department of Fish and Game, probably in May 1959 when Nesbitt Lake was stocked. Bass left the spring via the outflow, did not reproduce, and were not present in February 1961 when Deacon first collected there. Throughout the 1960s, springfish were abundant in the 28°C spring pools and common in the outflow. Speckled dace were abundant and common carp (*Cyprinus carpio*) were rare in the outflow but absent from spring pools. Both roundtail chubs and desert suckers were absent.

Since introduction of shortfin mollies and convict cichlids in the 1970s (Williams and Wilde, 1981; Courtenay and Deacon, 1982), numbers of both springfish (Fig. 5) and speckled dace have declined sharply. Twenty-eight trap hours of effort in the outflow of Crystal Springs by J. Pedretti on 24 March 1984 resulted in capture of 255 convict cichlids, 10 shortfin mollies, and no speckled dace. A few speckled dace were last seen in the outflow by T. M. Baugh (pers. comm. 1983) on 2 November 1983.

Another factor that may have contributed to decline of Hiko White River springfish in Crystal Springs is periodic manipulation of headpool water levels via a control structure into the outflow channel. When the structure is closed, water levels in the impoundments rise and outflow is forced into a narrow irrigation ditch at the southwestern end of the main impoundment (T. M. Baugh and C. Hubbs, pers. comm. 1983) substantially reducing flow in the main outflow channel. Vegetation in the southwestern ditch is sparse, providing little cover. Springfish, however, enter the ditch when it is flowing,but convict cichlids and shorfin mollies remain in the impoundments (T. M. Baugh, pers. comm. 1984). Our observations of this and other subspecies of White River springfish indicate that these fishes fare best in flowing spring situations where there has been minimal habitat disturbance and where introducted fishes are absent.

Ash Springs.—Of the three spring systems in Pahranagat Valley, Ash Springs is the warmest (34°C) and historically may have been the least altered. It was first the home of the Ash Utes who were hunters rather than cultivators (Thompson and West, 1881) and later became a stopover for travelers (Williams and Wilde, 1981).

Outflows of both Crystal and Ash springs connect seasonally or periodically to create a southward flow into the artificial Upper and Lower Pahranagat lakes (Fig. 1). Pahranagat lakes were at one time a single impoundment called Dike Lake. It was later divided into upper and lower sections by USFWS, with the upper "lake" designed as waterfowl habitat. Prior to construction of those impoundments, drainage was into Maynard Lake at the southern end of the valley. Pahranagat lakes contain common

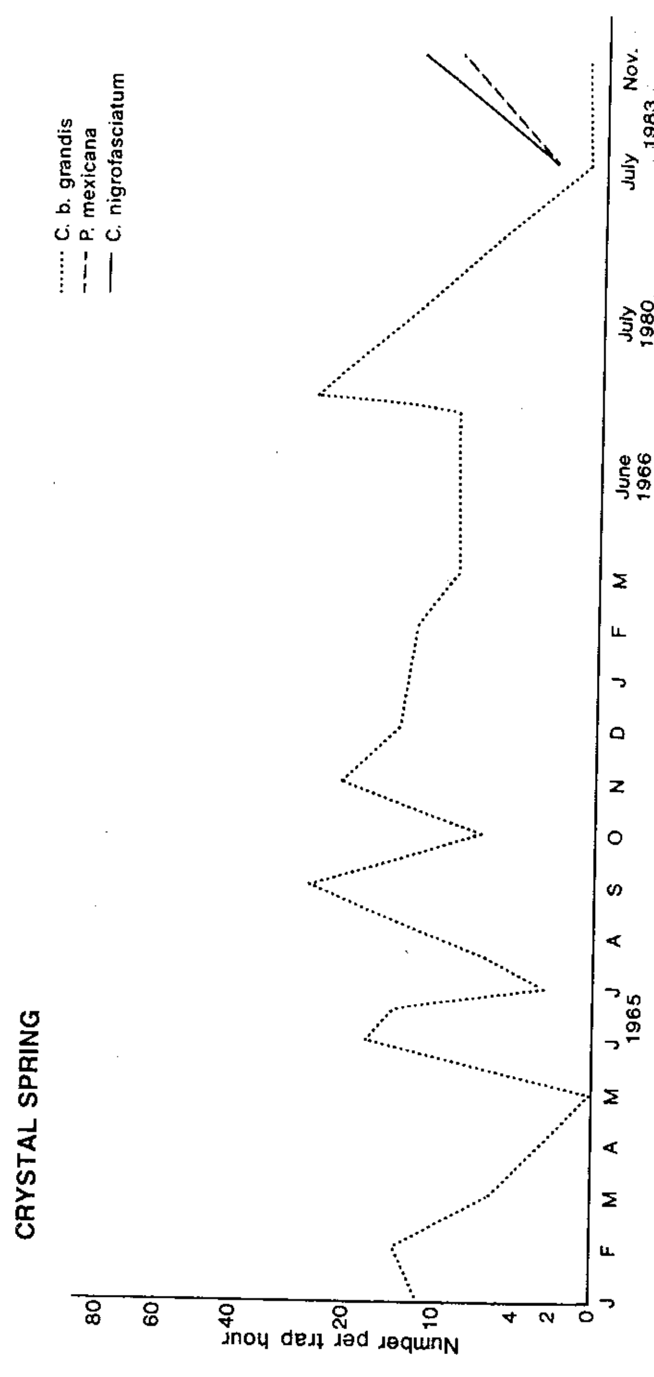

FIG. 5.—Semilog plot of catch per trap hour of fishes at Crystal Springs, 1965-1983.

carp, black bullheads (*Ictalurus melas*), largemouth bass, and perhaps white crappie (*Pomoxis annularis*). Maynard Lake is alkaline, now usually dry, and fishless, although it formerly contained speckled dace.

Miller and Hubbs (1960) recorded fishes of Ash Springs and its outflow as Pahranagat roundtail chub, Pahranagat spinedace (*Lepidomeda altivelis*), Pahranagat speckled dace, White River desert suckers, and White River springfish (*Crenichthys baileyi baileyi*). Gilbert (1893) recorded speckled dace as associated with springfish in the headpool area. Isolation of the headpool from flowing water downstream was probably sufficient to have eliminated dace from there and the spring pools of Crystal Springs.

Miller and Hubbs (1960) described Pahranagat spinedace on the basis of specimens captured in 1938 from the outflow of Ash Springs at two sites, approximately 9.7 km north and south, respectively, of Alamo. They indicated that spinedace were not found near sources of Ash, Crystal, or Hiko springs, and suggested that "it shunned constantly warm water." Common carp were present with all native fishes of the Ash Springs outflow in 1938, following its introduction to the Pahranagat lakes area decades earlier. In 1955, Miller and Hubbs (1960) failed to find any Pahranagat spinedace or White River desert suckers in the Ash Springs system. They attributed demise of spinedace and "probable local extirpation" of suckers to an increase in water temperature from an irrigation ditch, mostly to the presence of large numbers of carp and mosquitofish, and perhaps to establishment of bullfrogs (*Rana catesbiana*), another introduced species.

Hubbs and Deacon (1965) reported establishment of newly introduced fishes in Ash Springs and its outflow, and Courtenay and Deacon (1982) reviewed the history of these fishes over the past two decades. As of 1983, fishes of the headpool impoundment and its immediate outflow consisted only of White River springfish, mosquitofish, shortfin mollies, and convict cichlids (Fig. 6). Relatively small numbers of Pahranagat roundtail chub, Pahranagat speckled dace, and springfish are still downstream at Burns Ranch, 10.9 km north of Alamo (Hardy, 1982; Hardy and Deacon, in press). Sailfin mollies (*Poecilia latipinna*), reported from this outflow by Hubbs and Deacon (1965), were not collected there in 1980 (Courtenay and Deacon, 1982), but a few individuals have been observed by N. Kanim (pers. comm. 1983) over the past two years.

In November 1983, an increase was noted in numbers of springfish in the headpool and its immediate outflow (Fig. 6). We learned that there had been a drawdown and subsequent refilling of the downstream recreational pool during summer 1983. This may have, at least temporarily, improved springfish habitat by restoring stream flow and causing a downstream flushing of introduced fishes. Springfish may have responded to improved habitat and subsequent refilling of the pool more quickly than did introduced fishes. If so, we expect relative abundance of springfish to decline as introduced fishes reestablish dominance. Interestingly, the infrequent water level manipulations in Ash Springs may have the opposite effect on resident springfish than the more regular manipulations at Crystal Springs.

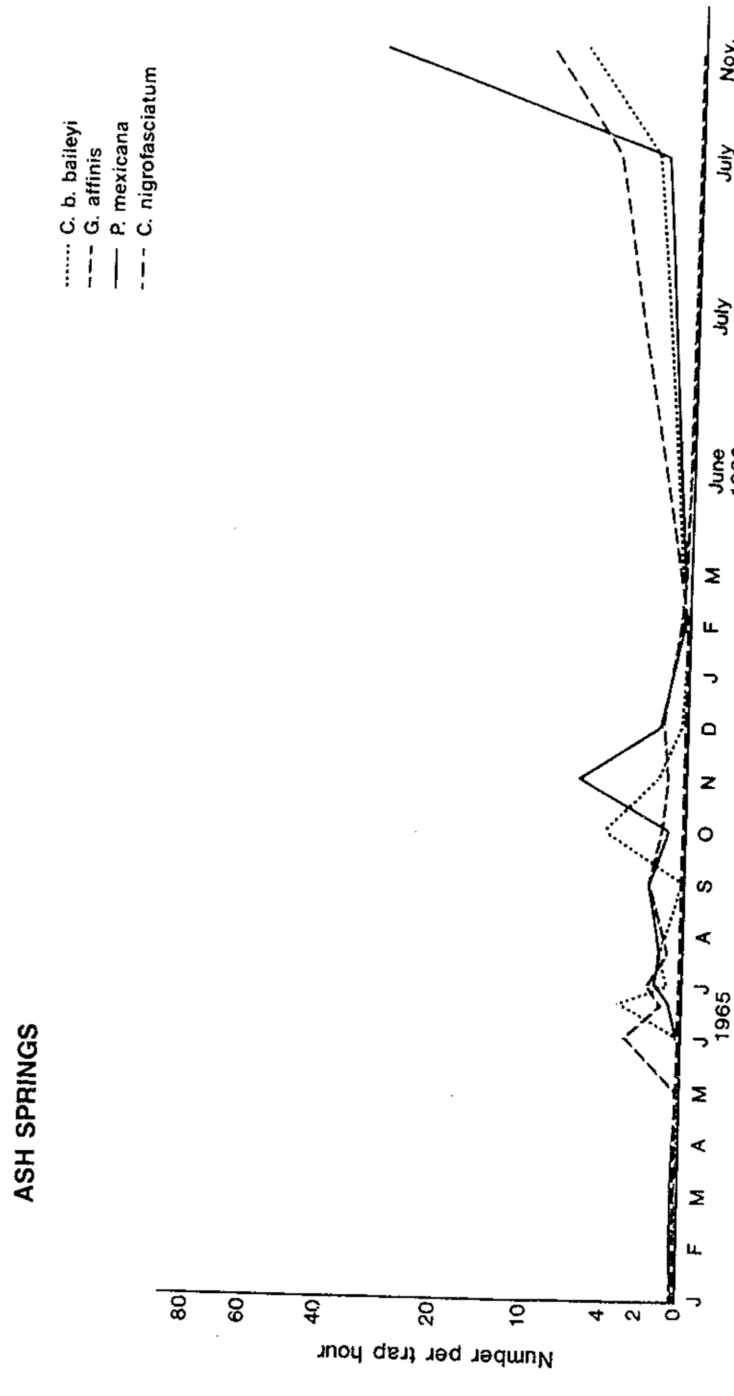

FIG. 6.—Semilog plot of catch per trap hour of fishes at Ash Springs, 1965-1983.

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Moapa Valley.—Early packers on the California Trail referred to what is now called Moapa River as the Muddy River and to local Paiutes as the Muddy Indians. Kit Carson camped in the valley in 1847 and noted the river as Muddy River in his diary. An 1853 map of the New Mexico Territory cited the river as El Riío Atascoso, meaning "the boggy river" (Fleming, 1967).

A Morman, Addison Pratt, traveled up Moapa River in 1849 and found some of its headwater springs. In his records, he states, "I found some fish in the creek much resembling a well known fish in the rivers of New England, called carp. They bite readily at a hook, the largest of them weighing near a pound." (Corbett, 1968); this may have been the first record of the Moapa roundtail chub (*Gila robusta* spp.).

The Moapa Valley and environs were settled by Mormons from Utah in the 1860s; Thompson and West (1881), Hafen and Hafen (1954), Fleming (1967), Corbett (1968), Hulse (1969) and others provided accounts of these settlements. Only one Mormon was reported to have settled in the upper Moapa Valley in 1868 in an area with "brooks running through it" (Corbett, 1968), probably referring to spring outflows near Home Ranch.

Following addition of one degree longitude to Nevada in 1866 and a subsequent dispute with Nevada over taxation, Mormons abandoned Moapa Valley in 1871 to return to Utah (Hulse, 1969; Elliott, 1973). The area was reoccupied in 1880 by Mormons who again developed it for agriculture (Hulse, 1969). In recent years, resorts have been developed near some warm springs. Some spring pools and areas along outflows have been converted into concrete-lined swimming pools, and no aquatic habitats presently represent a pristine condition.

Moapa Valley Water District (MVWD) Spring.—Known native fishes of this spring (and other headwater springs in upper Moapa Valley) are Moapa dace (*Moapa coriacea*) and Moapa White River springfish (*Crenichthys baileyi moapae*) (Williams and Wilde, 1981). This site has been altered considerably since it was sampled extensively by J. E. Deacon and B. L. Wilson in 1968; a large pool, then present, is now dried. Because this habitat has been so disturbed and altered, we do not include a comparison of the 1960s results (Wilson et al., 1966; Deacon and Wilson, 1967; Deacon and Bradley, 1972; Cross, 1976) with 1983 trapping data.

While several springs emerge on this property, only one now has flow sufficient to provide habitat that can be sampled using minnow traps. MVWD Spring emerges at 33°C. Between 2126-2330 hrs on 28 July 1983, nine minnow traps in the spring and its outflow captured eight Moapa dace and five springfish. Courtenay and Sada walked the length of the upper outflow at 1200 hrs on 29 July; no Moapa dace or springfish were seen, but a very few mosquitofish and shortfin mollies were observed within the first 10 m below the springhead, the sites of two traps used the previous night.

The USFWS is currently developing a native fish sanctuary for springfish and Moapa dace at the location of a former resort in the upper valley.

Moapa River at Home Ranch.—Outflows of several headwater springs in upper Moapa Valley coalesce through what is now mostly agricultural land to form upper Moapa River. An undescribed subspecies of roundtail chub, along with Moapa dace, Moapa speckled dace (*Rhinichthys osculus moapae*), and Moapa White River springfish are the known native inhabitants of upper Moapa River (Deacon and Bradley, 1972; Cross, 1976; Williams, 1978; Williams and Wilde, 1981). Miller and Alcorn (1946) recorded mosquitofish in the upper river area as early as 1938, and Deacon et al. (1964) reported introduction of shortfin mollies in early 1963.

On 29 July 1983, seven seine hauls, covering 200 m of river, were made through upper Moapa River at Home Ranch, immediately upstream from the road fording the river. Three springfish, 108 mosquitofish, 83 shortfin mollies, and 1 bullfrog were captured. Roundtail chub and Moapa speckled dace, never numerous in recent years, were taken there by Deacon as recently as July 1981 and, just downstream, by Courtenay and P. Greger in November 1981.

Discussion.—Man's utlization of spring systems along the pluvial White River has had a long history. We wish we had detailed data about use and modifications of these systems, paticularly by early settlers and subsequent landowners; unfortunately, such data do not exist to our knowledge. One might conclude that these systems may have been so modified that even Gilbert (1893) failed to find several fishes that once occurred there.

Early settlers used gravity flow and earthen dams that leaked and washed out with floods, thus not forming permanent barriers. They farmed small areas, generally dictated by the amount of water that could be delivered. Their irrigation canals probably provided suitable habitat for several native fishes.

It is evident, however, that negative impacts have accelerated during the past 20 years, and status of native fishes in these systems has declined dramatically. These impacts may be categorized into alteration or reduction of habitats to facilitate agriculture and introductions of nonnative species.

There have been extinctions and population shifts of native fishes. The White River spinedace and, apparently, White River desert sucker have been extirpated from Preston Big Spring within the past four years, probably due to overuse of copper sulfate. Numbers of Preston White River springfish have declined and the population of speckled dace has increased substantially (Fig. 2).

The same native fishes that historically occupied Preston Big Spring also lived in Preston Town and Lund Town springs. Only Preston White River springfish, now extremely rare and on the verge of local extirpation, remain in Preston Town Spring; the three other natives were eliminated by habitat reduction, disconnection of the confluence with the outflow of Preston Big Spring, and an extremely large population of guppies. All native fishes remain present in Lund Town Spring, despite presence of mosquitofish and guppies (Table 1). Preston White River springfish have never been numerous there but several adults were seen in July 1983.

In our opinion, the status of White River spinedace and Preston White River springfish is endangered and these fishes should be so listed.

The White River desert sucker is now found only in the flowing portions of upper White River, Lund Town Spring, and, perhaps, still in Flag Springs. This clearly is a fish of special concern.

Populations of Moorman White River springfish probably remain plentiful in all three spring outflows in which it is native (Figs. 4, 5); the one we did not trap was Moon River Spring. Although Moorman Spring is in a relatively remote location, its flow pattern was modified within the past two decades, a clear indication that this habitat, like others along the pluvial White River, remains vulnerable to perceived needs of the landowner. Hot Creek Spring outflow is an officially designated refuge for White River springfish; failure of a downstream control structure in 1974 and the fact that the public does have access to this outflow present some factor of vulnerability, but certainly not to the extent of privately owned spring outflows.

Springs in Pahranagat Valley have a long history of use and modification. Man's impact on these springs has been considerable. The only fishes known to have been common to all three spring systems were Pahranagat roundtail chub and Pahranagat speckled dace. Hiko and Crystal springs hosted Hiko White River springfish and Crystal and Ash spring outflows contained White River desert suckers; we submit that the last also probably occupied the outflow of Hiko Spring at one time. Ash Springs also contains an endemic, the White River springfish.

All native fishes are gone from Hiko Spring (Fig. 4), the apparent result of impoundment, reduced flow, introduced fishes and the introduced parasitic copepod *Lernea*. The last to disappear was the Hiko White River springfish, extirpated before June 1967 (Deacon, 1979). This species is now restricted to Crystal Springs where its numbers have declined sharply and it is the only native fish in the spring pools (Fig. 5). The population is very low. In our opinion, the Hiko White River springfish is on the verge of extinction and should be immediately listed as endangered, with Crystal Springs designated as critical habitat. Efforts to reestablish this taxon in Hiko Spring were being made recently and, if successful, could have justified reconsideration of this recommendation. A recent introduction of convict cichlids into Hiko Spring may well preclude success of such efforts.

At Ash Springs, White River springfish are present, but in numbers considerably reduced from the early 1960s. There has been a recent, perhaps transitory, increase in this population, possibly a result of favorable habitat manipulation during summer 1983 (Fig. 6). Pahranagat roundtail chub and Pahranagat speckled dace, with extremely few White River springfish, can be found in low numbers downstream at Burns Ranch. Pahranagat spinedace and White River desert suckers have been extinct in this system for several decades. The status of Pahranagat roundtail chub is clearly endangered and, in our opinion with regard to the population decline since the 1960s, we believe White River springfish should be listed as endangered. The distinctive Pahranagat speckled dace of Crystal and Ash springs has also declined alarmingly since the late 1960s and is presently endangered.

The Moapa dace is listed as endangered. The extremely low numbers of Moapa speckled dace and Moapa roundtail chub strongly suggest the same status for these fishes. The Moapa White River springfish is abundant on the Moapa National Wildlife Refuge and in a few other local springs; its status probably is best defined as threatened.

Habitat alteration and reduction appear to have significantly impacted native fishes along the course of the pluvial White River. These fishes are descendants of riverine of stream-dwelling ancestors; therefore, flow has to be an important biologic factor to them. Interruption of flow patterns through impoundment of spring pools, near-source capture of outflows for agricultural purposes, construction of impoundments within outflows, severing previously joined outflow systems, and artificial manipulation of water levels in impounded headpools would stress fishes used to natural spring flows. Loss of historical flow patterns may have been the major factor involved in initial declines of Pahranagat roundtail chub.

Introductions of non-native fishes into these already altered habitats would further stress native species through biological habitat reduction (spatial competition), even in the absence of such factors as competition for food or predation by aliens. We suggest, therefore, that introduced, non-predatory fishese, along with habitat alteration and reduction, may have functioned in a synergistic manner in adversely impacting native fishes along the course of the pluvial White River.

Finally, the potential for predation on native fish populations by introduced species cannot be ignored. Such predation could occur through feeding on eggs or larvae or via incidental ingestion when feeding on substrates (algae, rooted aquatic plants, or bottom sediments) where native fishes often spend parts of their early life history stages. We probably underestimate these kinds of predation as negative impacts because they are difficult to observe, demonstrate, or measure, and, therefore, presently are impossible to evaluate.

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Literature Cited

BLACKWELDER, E. 1943. Origin of the Colorado River. Bull. Geol. Soc. Am. 45:551-556.

CORBETT, P. H. 1952. Jacob Hamblin, the peacemaker. Deseret Book Co., Salt Lake City, Utah.

CORBETT, P. S. 1968. A history of the Muddy Mission. Ph.D. dissert., Brigham Young Univ.

COURTENAY, W. R., JR. AND J. E. DEACON. 1982. Status of introduced fishes in certain spring systems in southern Nevada. Great Basin Nat. 42:361-366.

CROSS, J. N. 1976. Status of the native fish fauna of the Moapa River (Clark Co., Nevada). Trans. Amer. Fish. Soc. 105:503-508.

DEACON, J. E. 1979. Endangered and threatened fishes of the west. Great Basin Nat. Mem. 3:41-64.

—— AND W. G. BRADLEY. 1972. Ecological distribution of fishes of Moapa (Muddy) River in Clark County, Nevada. Trans. Amer. Fish. Soc. 101:408-419.

——, T. B. HARDY, J. LANDYE, J. POLLARD, W. TAYLOR AND P. GREGOR. 1980. Environmental analysis of four aquatic habitats in east-central Nevada, June-July, 1980. Interim summary rept. to HDR Sciences (Contract no. HDR/RPA15).

——, C. HUBBS AND B. ZAHURANEC. 1964. Some effects of introduced fishes on the native fish fauna of southern Nevada. Copeia 1964:384-388.

—— AND J. E. WILLIAMS. 1984. Annotated list of the fishes of Nevada. Proc. Biol. Soc. Washington 97:103-118.

—— AND B. L. WILSON. 1967. Daily activity cycles of *Crenichthys baileyi*, a fish endemic to Nevada. Southwest. Nat. 12:31-44.

ELLIOTT, R. R. 1973. History of Nevada. Univ. Nebraska Press, Lincoln.

FLEMING, L. A. 1967. The settlements on the Muddy, 1865 to 1871, "a God forsaken place." Utah Hist. Quart. 35:147-172.

FOWLER, D. D., D. B. MADSEN AND E. A. HATTORI. 1973. Prehistory of southeastern Nevada. Desert Res. Inst. Publ. Soc. Sci. 6:1-145.

GEORGETTA, C. 1972. Golden fleece in Nevada. Venture Publ. Co., Reno.

GILBERT, C. H. 1893. Report on the fishes of the Death Valley expedition collected in southern California and Nevada in 1891, with descriptions of new species. N. Am. Fauna 7:229-234.

GRIFFIN, J. T. 1976. The lower Pahranagat Valley: its importance to the prehistory of southern Nevada. Senior thesis I & II, Univ. Nev. Las Vegas.

HAFEN, L. R. AND A. W. HAFEN. 1954. Old Spanish Trail, Santa Fe to Los Angeles, with extracts from contemporary records and including diaries of Antonio Armijo and Orville Pratt. Arthur H. Clark Co., Glendale, Cal.

HARDY, T. B. 1982. Ecological interactions of the introduced and native fishes in the outflow of Ash Spring, Lincoln County, Nevada. M.S. thesis, Univ. Nev. LasVegas.

——AND J. E. DEACON. In press. Introduced fishes of the American southwest. Southwest. Nat.

HUBBS, C. L. AND R. R. MILLER. 1948. Two new, relict genera of cyprinid fishes from Nevada. Occ. Pap. Mus. Zool. Univ. Mich. 507:1-30.

HUBBS, C. AND J. E. DEACON. 1965. Additional introductions of tropical fishes into southern Nevada. Southwest.Nat. 9:249-251.

HULSE, J. W. 1969. The Nevada adventure, a history. Univ. Nev. Press, Reno.

——. 1971. Lincoln County, Nevada: 1864-1909; history of a mining region. Nev. Stud. Hist. & Pol. Sci. 10.

JORGENSEN, J. G. 1980. Western Indians. W. H. Freeman and Co., San Francisco.

MILLER, R. R. 1961. Man and the changing fish fauna of the American southwest. Pap. Mich. Acad. Sci., Arts, and Lett. 46:365-404.

—— AND J. R. ALCORN. 1946. The introduced fishes of Nevada, with a history of their introduction. Trans. Amer. Fish. Soc. 73:173-193.

—— AND C. L. HUBBS. 1960. The spiny-rayed cyprinid fishes (Plagopterini) of the Colorado River System. Misc. Publ. Mus. Zool. Univ. Mich. 115:1-39.

—— AND E. P. PISTER. 1971. Management of the Owens pupfish, *Cyrpinodon radiosus*, in Mono County, California. Trans. Amer. Fish. Soc. 100:502-509.

MINCKLEY, W. L. AND J. E. DEACON. 1968. Southwestern fishes and the enigma of "endangered species." Science 159:1424-1432.

PURSEGLOVE, J. W. 1968. Tropical crops; dicotyledons I. Longmans, London.

READ, E. 1965. White Pine lang sync; a true history of White Pine County, Nevada. Big Mountain Press, Denver.

SMITH, G. R. 1978. Biogeography of intermountain fishes. Great Basin Nat. Mem. 2:17-42.

TANNER, V. 1950. A new species of *Gila* from Nevada (Cyprinidae). Great Basin Nat. 10(1-4):31-36.

THOMPSON, T. H. AND A. A. WEST. 1881. History of Nevada with illustrations and biographical sketches of its prominent men and pioneers. Thompson and West, Oakland, Cal. (from 1958 reproduction, publ. by Howell-North, Berkeley, Cal.).

TOWNLEY, J. M. 1973. Conquered provinces: Nevada moves southwest, 1864-1871. Charles Redd Monogr. West. Hist. 2. Brigham Young Univ., Provo.

WILCOX, W. 1949. Adams-McGill: range barons. The Nevada Magazine 4(2):18-20, 33-34, 45-47.

WILLIAMS, C. D. AND J. E. WILLIAMS. 1982. Summer food habits of fishes from two springs in east-central Nevada. Southwest. Nat. 27:437-445.

WILLIAMS, J. E. 1978. Taxonomic status of *Rhinichthys osculus* (Cyprinidae) in the Moapa River, Nevada. Southwest. Nat. 23:511-518.

——— AND G. R. WILDE. 1981. Taxonomic status and morphology of isolated populations of the White River springfish, *Crenichthys baileyi* (Cyprinodontidae). Southwest. Nat. 26:485-503.

WILSON, B. L., J. E. DEACON AND W. G. BRADLEY. 1966. Parasitism in the fishes of the Moapa River, Clark County, Nevada. Trans. Cal.-Nev. Sect., Wildlife Soc. 1966:12-23.

WINSHIP, G. P. (ed.). 1966. (Translation of) The journey of Coronado, by Pedro de Casteñeda. Univ. Microfilms, Ann Arbor, Mich.

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