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FRONTISPIECE. Laguna Grande (=Lago de Churince), Cuatro Ciénegas, Coahuila. View is northeast towards the tip of Sierra de San Marcos. Laguna Grande is the terminus of a Cuatro Ciénegas drainage that begins in Laguna Churince in the extreme western part of the basin. This is the least disturbed drainage in the basin (Minckley 1969). Laguna Grande measures about 1 km long and 0.5 km wide, but is typically less than 1 m in depth. Photograph taken 1 January, 1980 by Dean A. Hendrickson.

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To
Edwin P. Pister
for his unrelenting efforts
to educate society concerning the value of
preserving desert fishes and their habitats.

"The hostile attitude of conquering nature
ignores the basic interdependence of all things and events—
that the world beyond the skin is actually an extension of our bodies—
and will end in destroying the very environment from which we emerge
and upon which our whole life depends."

—Alan Watts, The Book on the Taboo Against Knowing Who You Are. 1969.

"Do you think you can take over the universe and improve it?
I do not believe it can be done.
The universe is sacred.
You cannot improve it.
If you try to change it, you will ruin it.
If you try to hold it, you will lose it."

—Lao Tsu, Taoist sage and philosopher. ca. 600 BC.

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ENDANGERED AQUATIC ECOSYSTEMS IN NORTH AMERICAN DESERTS WITH A LIST OF VANISHING FISHES OF THE REGION

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ABSTRACT

Habitat degradation and the introduction of exotic species are endangering an increasing number of fishes and other aquatic organisms in the desert areas of North America. We identify 164 fishes from North American deserts as endangered, vulnerable, rare or of indeterminate status. Forty-six of these fishes are herein considered endangered. Additionally, 18 recently extinct fishes are recorded from the region. Fifteen ecosystems are identified as providing habitat for 83 of these vanishing fishes. These highly significant aquatic ecosystems, with locations given parenthetically, are: Cuatro Cienegas (Coahuila), Gila River (New Mexico, Arizona and Sonora), Rio Grande (New Mexico, Texas, Chihuahua, Coahuila, Nuevo León and Tamaulipas), Pecos River (New Mexico and Texas), Railroad Valley (Nevada), Colorado River (Colorado, Utah, New Mexico, Arizona, Nevada, California, Baja California del Norte and Sonora), Green River (Wyoming, Colorado and Utah), Pahranagat Valley (Nevada), Parras Valley (Coahuila), La Media Luna (San Luis Potosí), Ash Meadows (Nevada), Upper White River (Nevada), Moapa River (Nevada), Rio Yaqui (Arizona, Chihuahua and Sonora), and Upper Klamath Basin (Oregon and California). A discussion of these ecosystems and their vanishing fishes, amphibians, reptiles and invertebrates are provided. Protection of remaining natural habitats and communities within these areas provide the best opportunity for long-term survival of the constituent rare organisms.

RESUMEN

La degradación del habitat y la introducciOn de especies exoticas están ponienda en peligro un número creciente de peces y otras especies acuáticas en los areas deserticos de Norteamerica. Se han identificado 164 especies de peces de éstas areas

[1] The authors comprise the Endangered Species Committee of the Desert Fishes Council.

Williams, Jack E., Bowman, David B., Brooks, James E., Echelle, Anthony A., Edwards, Robert J., Hendrickson, Dean A. and Landye, Jerry J. 1985. Endangered Aquatic Ecosystems in North American Deserts with a List of Vanishing Fishes of the Region. Journal of the Arizona-Nevada Academy of Science 20:1-62.

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como especies en vias de extinción, vulnerables 6 en un estado indeterminado. De éstas especies, 46 se han catalogado en vías de extinción. Ademas, 18 especies de peces se han registrado recientemente como extinctos. Se ha determinado que los ecosistemas de esas especies en vias de extinción son 15. De ellos, los mas significativos son: Cuatro Cienegas (Coahuila), el Rio Gila (Nuevo Mexico, Arizona y Sonora), el Rio Bravo del Norte (Nuevo Mexico, Texas, Chihuahua, Coahuila, Nuevo León y Tamaulipas), el Rio Pecos (Nuevo Mexico y Texas), el Valle Railroad (Nevada), el Rio Colorado (Colorado, Utah, Nuevo Mexico, Arizona, Nevada, California, Baja California del Norte y Sonora), el Rio Green (Wyoming, Colorado y Utah), el Valle Pahranagat (Nevada), el Valle de Parras (Coahuila), La Media Luna (San Luis Potosi), Ash Meadows (Nevada), el alto Rio White (Nevada), el Rio Moapa (Nevada), el Rio Yaqui (Arizona, Chihuahua y Sonora) y la cuenca alta del Rio Klamath (Oregon y California). Se discuten esos ecosistemas y sus especies de peces, anfibios, reptils y invertebrados en vias de extinción. La protección de los habitats naturales que permanecen dentro de éstas areas provee la major via a la conservación a largo organismos raros.

INTRODUCTION.—During the past century, physical and chemical alteration of habitats and the introduction of exotic species have caused declines of many native aquatic organisms in North American deserts. Despite a depauperate and relatively poorly-known ichthyofauna, 39 fishes from the desert areas of the United States have been listed by the Department of the Interior as endangered or threatened (Williams 1981). Deacon et al. (1979) compiled a more comprehensive list of fishes, endangered, threatened or of special concern, from the United States, Canada and Mexico that included 139 desert fishes from North America. Environmental perturbations have now reached the level that some desert fishes are extinct and entire aquatic ecosystems have been eliminated.

These losses are especially disconcerting because most aquatic organisms inhabiting waters of North American deserts are not well-known. This is particularly true for Mexican fish species as well as for invertebrates, both in the United States and Mexico. Many taxa are undescribed. Additional ecological, taxonomic and systematic work, therefore, is sorely needed.

Although the general decline of aquatic ecosystems in North American deserts has been known for some time (e.g., Contreras-Balderas 1978, Miller 1961, Minckley and Deacon 1968, Pister 1981), this decline has not been quantified other than to develop lists of vanishing species. The primary purpose of this paper is to determine the most significant aquatic ecosystems in North American deserts that are endangered and to discuss their importance in terms of remaining natural areas and constituent aquatic organisms. The continued existence of all aquatic ecosystems in North American deserts is important regardless of their size or diversity. However, it is our intent to focus on those areas that contain large numbers of endangered, threatened or otherwise rare aquatic organisms. In this manner, the need to take immediate measures to preserve these ecosystems becomes more apparent. A second purpose of this paper is to present an updated list of rare fishes from North American deserts. The information presented herein should be revised and expanded with increased knowledge of these aquatic organisms.

METHODS.—The geographic area consideied in this paper corresponds roughly with the limits of the Great Basin, Mohave, Sonoran and Chihuahuan Deserts (see Fig. 1). Additionally, we have included certain basins adjacent to these desert areas, such as the Upper Colorado River Basin, Upper Klamath River Basin, Upper Pit River Basin and Malheur Basin. Thus within the United States, we include parts of Oregon (OR), California (CA), Wyoming (WY), Texas (TX) and Colorado (CO), and all of Nevada (NV), Utah (UT), Arizona (AZ) and New Mexico (NM). Within Mexico, we include parts of Sinaloa (SIN), Durango (DGO), Zacatecas (ZAC) and San Luis Potosi (SLP), and all of Baja California (BCA), Baja California Sur (B CS), Sonora (SON), Chihuahua (CHI), Coahuila (COA), Nuevo León (NLE) and Tamaulipas (TAM).

In delineating the boundary of individual ecosystems, we utilized the distribution of native fishes in the region. Most basins or valleys form easily definable ecosystems because they contain a unique assemblage of native fishes that often is endemic. For example, Ash Meadows constitutes a natural ecosystem because its drainage is endorheic (i.e., internal) and because it harbors a series of endemic fishes, the Ash Meadows speckled dace, Devils Hole pupfish, Ash Meadows Amargosa pupfish, warm springs Amargosa pupfish and Ash Meadows poolfish. However, some ecosystems are less easily defined. For example, we consider the Rio Grande as a single ecosystem, and consider each major tributary (e.g., Rio Conchos and Pecos River) separately. The use of fish distribution to determine ecosystem boundaries is often considered a valid methodology when working with aquatic systems (Hawkes 1975). For an ecosystem to be included herein, it must have provided habitat for at least four rare fishes during recent times.

To indicate the status of individual taxa, we utilize the following categories as defined by the International Union for Conservation of Nature and Natural Resources (IUCN): endangered (E) — taxa in danger of extinction and whose survival is unlikely if the causal factors continue operating; vulnerable (V) — taxa believed likely to move into the endangered category in the near future if the causal factors continue operating; rare (R) — taxa with small world populations that are not at present endangered or vulnerable, but are at risk; indeterminate (I) — taxa that are suspected of belonging to one of the above three categories but for which insufficient information is currently available. All designations given to the aquatic organisms listed herein are those of the Desert Fishes Council's Endangered Species

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Figure 1. Hydrologic map of western United States and Mexico showing endangered aquatic ecosyst desert region: Cuatro Cienegas (COA), Gila River (NM, AZ, SON), Rio Grande (NM, TX, CHI, CO (NM, TX), Railroad Valley (NV), Colorado River (CO, UT, NM, AZ, NV, CA, BCA, SON), Greex ranagat Valley (NV), Parras Basin (COA), La Media Luna (SLP), Ash Meadows (NV), Upper Whit (NV), Rio Yaqui (AZ, CHI, SON) and Upper Klamath Basin (OR, CA).

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Committee and may not always agree with those given for a taxon included in IUCN red data books. Additionally, we include extinct fishes in our ecosystem accounts and list of vanishing fishes. Inclusions of the extinct taxa complete the accounts of the native fauna and emphasize the severity of man's impact on many of these ecosystems.

LIST OF RARE DESERT FISHES.—We record 182 fishes of concern from North American deserts (Table 1). These fishes represent 12 families, with cyprinids being by far the most numerous (84 fishes, 46%). All of these fishes have either exhibited recent declines in distribution and abundance, or are historically rare. Forty-six of them are endangered, 52 are vulnerable, 46 are rare, 20 are indeterminate but suspected of belonging to one of the three previous categories, and 18 are recently extinct. Fifty-two (29%) of the fishes in our list are undescribed, attesting to the poorly-known nature of the North American desert ichthyofauna.

ECOSYSTEM ACCOUNTS.—From our analysis, the North American desert region includes 15 aquatic ecosystems that provide habitat for four or more of the fishes of concern listed in Table 1. These ecosystems are: Cuatro Cienegas (Coahuila), Gila River (New Mexico, Arizona and Sonora), Rio Grande (New Mexico, Texas, Chihuahua, Coahuila, Nuevo Lean and Tamaulipas), Pecos River (New Mexico and Texas), Railroad Valley (Nevada), Colorado River (Colorado, Utah, New Mexico, Arizona, Nevada, California, Baja California del Norte and Sonora), Green River (Wyoming, Colorado and Utah), Pahranagat Valley (Nevada), Parras Valley (Coahuila), La Media Luna (San Luis Potosí), Ash Meadows (Nevada), Upper White River (Nevada), Moapa River (Nevada), Rio Yaqui (Arizona, Chihuahua and Sonora), and Upper Klamath Basin (Oregon and California) (Fig. 1).

CUATRO CILNEGAS, COAHUILA

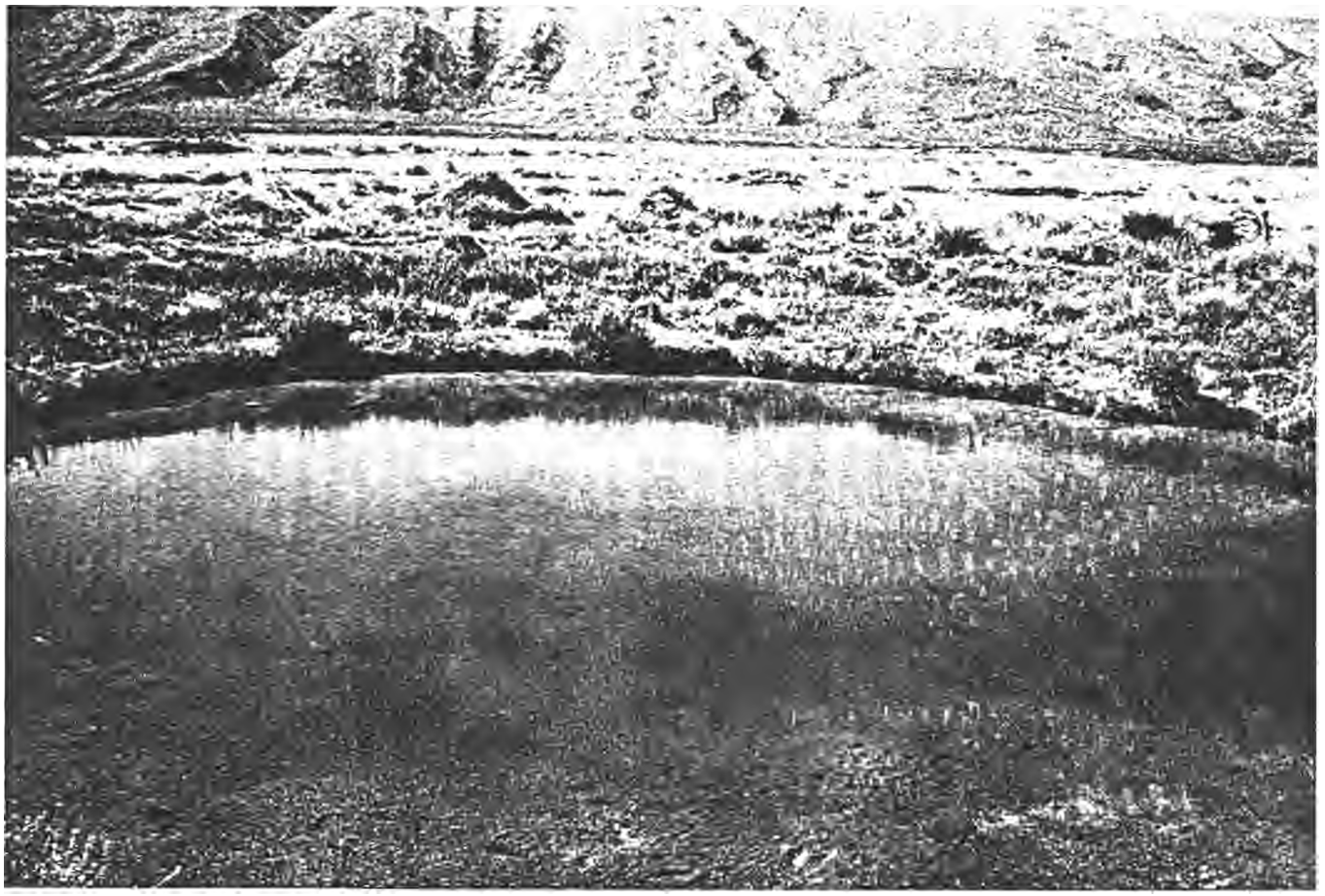

PLATE I. Laguna Escobeda, Cuatro Cienegas, Coahuila. This laguna, which is more than 30 m across and nearly 8 m in depth, provides habitat for Cyprinodon Wasciatus. Photograph taken January 1980 by Dean A. Hendrickson.

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Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
SALMONIDAE — TROUT FAMILY				
1	V	Apache trout	Salmo apache	AZ: Gila River, Little Colorado River
2	V	Lahontan cutthroat trout	Salmo clarki henshawi	NV, CA, OR: Lahontan Basin
3		Colorado cutthroat trout	Salmo clarki pleuriticus	UT, CO, WY: Colorado River Basin, Green River Basin
4	V	Paiute cutthroat trout	Salmo clarki seleniris	CA: Lahontan Basin
5	Ex	Alvord cutthroat trout	Salmo clarki ssp.	NV, OR: Alvord Basin
6		Willow/Whitehorse cutthroat trout	Salmo clarki ssp.	OR: Willow/Whitehorse Basin
7		Humboldt cutthroat trout	Salmo clarki ssp.	NV: Humboldt River Basin
8	V	Bonneville cutthroat trout	Salmo clarki utah	NV, UT, WY: Bonneville Basin
9		Rio Grande cutthroat trout	Salmo clarki virginalis	NM: Pecos River, Rio Grande, Canadian River
10		Baja rainbow trout	Salmo gairdneri nelsoni	BCA: Rio Santo Domingo
11		Gila trout	Salmo gilae	NM: Gila River, AZ: Verde River
12		Rio Mayo trout	Salmo sp.	SON, CHI: Rio Mayo
13		Redband trout	Salmo sp.	OR, ID, NV: Owyhee River drainage; CA: McCloud River; OR: Catlow Valley, Malheur, Warner Basins
14	V	Goose Lake redband trout	Salmo sp. ssp.	OR, CA: Goose Lake
CYPRINIDAE — MINNOW FAMILY				
15	V	Devils River minnow	Dionda diaboli	TX: Rio Grande drainage (Devil's River, San Felipe Cr., Las Moras Cr.); COA: Rio San Carlos
16		Bicolor minnow	Dionda dichroma	SLP: La Media Luna, Rio Verde
17		Saltillo roundnose minnow	Dionda episcopa melanops	COA: springs near Saltillo, Parras Basin (Ex?)
18	V	Nazas roundnose minnow	Dionda episcopa ssp.	DGO: Rio Nazas
19		Mezquital roundnose minnow	Dionda episcopa ssp.	DGO: Rio Mezquital
20		Cuatro Cienegas roundnose minnow	Dionda episcopa ssp.	COA: Cuatro Cienegas
21		Flatjaw minnow	Dionda mandibularis	SLP: La Media Luna, Rio Verde
22	V	Desert dace	Eremichthys acros	NV: Soldiers Meadow
23		Alvord chub	Gila alvordensis	OR, NV: Alvord Basin
24		Fish Creek Springs tui chub	Gila bicolor euchila	NV: Fish Creek Springs
25		Sheldon tui chub	Gila bicolor eurysoma	OR, NV: Guano Basin
26	Ex	Independence Valley tui chub	Gila bicolor isolata	NV: Independence Valley
27	V	Newark Valley tui chub	Gila bicolor newarkensis	NV: Newark Valley
28		XL Spring tui chub	Gila bicolor oregonensis	OR: Abert Basin
29		Mohave tui chub	Gila bicolor mohavensis	CA: Mohave River
30		Owens tui chub	Gila bicolor snyderi	CA: Owens Valley
31		Railroad tui chub	Gila bicolor ssp.	NV: Railroad Valley, Little Fish Lake Valley, Hot Creek Valley

Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
CYPRINIDAE — MINNOW FAMILY (continued)				
32		Dixie Valley tui chub	Gila bicolor ssp.	NV: Dixie Valley
33		Big Smoky Valley tui chub	Gila bicolor ssp.	NV: Big Smoky Valley
34		Fish Lake Valley tui chub	Gila bicolor ssp.	NV: Fish Lake Valley
35		Charnock Spring tui chub	Gila bicolor ssp.	NV: Big Smoky Valley
36		Green Springs tui chub	Gila bicolor ssp.	NV: Railroad Valley
37		Kate Spring tui chub	Gila bicolor ssp.	NV: Railroad Valley
38		Blue Eagle Spring tui chub	Gila bicolor ssp.	NV: Railroad Valley
39		Butterfield Spring tui chub	Gila bicolor ssp.	NV: Railroad Valley
40		Bull Creek tui chub	Gila bicolor ssp.	NV: Railroad Valley
41		Hutton Spring tui chub	Gila bicolor ssp.	OR: Alkali Basin
42		Silver Lake/Ft. Rock tui chub	Gila bicolor ssp.	OR: Silver Lake/Ft. Rock
43		Summer Lake tui chub	Gila bicolor ssp.	OR: Summer Lake Basin
44		Catlow Valley tui chub	Gila bicolor ssp.	OR: Catlow Valley
45		Surprise Valley tui chub	Gila bicolor ssp.	CA: Surprise Valley
46		Cowhead Lake tui chub	Gila bicolor vaccaceps	CA: Cowhead Lake
47		P orax Lake chub	Gila boraxobius	OR: Alvord Basin
48		Humpback chub	Gila cypha	CO: Colorado River, Green River; UT: Colorado River, Green River; AZ: Colorado River, Little Colorado River
49		Sonora chub	Gila ditaenia	SON, AZ: Rio Magdalena
50		Bonytail	Gila elegans	CO: Colorado River (Ex), Green River (Ex), Yampa River (Ex); UT: Colorado River (Ex), Green River (Ex); NV, AZ, CA: Colorado River; NM, CO, UT: San Juan River (Ex); AZ: Gila River drainage (Ex)
51		Gila chub	Gila intermedia	AZ: Gila River drainage, Verde River, Salt River
52		Saltillo chub	Gila modesta	COA: Upper Rio Salinas
53		Chihuahua chub	Gila nigrescens	NM: Mimbres River; CHI: Laguna de Bustillos drainage, Laguna de Guzman drainage
54		Rio Grande chub	Gila pandora ssp.	TX: Little Aguja Creek
55		Yaqui chub	Gila purpurea	AZ, SON: Rio Yaqui; SON: Rio Matape, Rio Sonora, Rio Magdalena
56		Pahranagat roundtail chub	Gila robusta jordani	NV: Pahranagat Valley
57		Virgin River roundtail chub	Gila robusta seminuda	NV, AZ, UT: Virgin River
58		Moapa roundtail chub	Gila robusta ssp.	NV: Moapa River
59		unnamed chub	Gila sp.	CHI: Laguna de Bavicora drainage
60		unnamed chub	Gila sp.	DGO: Upper Rio Presido
61		Parras fatty chub	Gila sp.	COA: Parras Valley

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Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
CYPRINIDAE — MINNOW FAMILY (continued)				
62		Parras slender chub	Gila sp.	COA: Parras Valley
63		White River spinedace	Lepidomeda albivallis	NV: Upper White River
64	Ex	Pahranagat spinedace	Lepidomeda altivelis	NV: Pahranagat Valley
65	V	Virgin River spinedace	Lepidomeda m. mollispinis	NV, AZ, UT: Virgin River
66		Big Spring spinedace	Lepidomeda m. pratensis	NV: Meadow Valley Wash
67	V	Little Colorado spinedace	Lepidomeda vittata	AZ: Little Colorado River drainage
68		Moapa dace	Moapa coriacea	NV: Moapa River
69	V	Spikedace	Meda fulgida	NM, AZ: Gila River Basin; AZ: Salt River, Verde River
70		Pion shiner	Notropis aguirrepequenoi	TAM, NLE: Rio Soto La Marina
71		Largemouth shiner	Notropis bocagrande	CHI: Ojo Solo en Bolson de los Muertos
72	V	Yaqui beautiful shiner	Notropis formosus mearnsi	AZ, CHI, SON: Rio Yaqui
73	Ex	Phantom shiner	Notropis orca	NM, TX, CHI, TAM: Rio Grande
74	V	Conchos shiner	Notropis panarcys	CHI: Rio Conchos
75	V	Proserpine shiner	Notropis proserpinus	TX: Rio Grande drainage (Devil's River, Pecos River, Las Moras, Pinto and San Felipe Creeks)
76	Ex	Rio Grande bluntnose shiner	Notropis simus simus	NM, TX, CHI: Rio Grande
77	V	Pecos bluntnose shiner	Notropis s. pecosensis	NM: Pecos River
78		Cuatro Cienegas shiner	Notropis xanthicara	COA: Cuatro Cienegas
79		Woundfin	Plagopterus argentissimus	UT, AZ, NV: Virgin River; AZ: Gila River (Ex)
80		Colorado squawfish	Ptychocheilus lucius	CO: Colorado River, Gunnison River, Yampa River, Green River; UT: Colorado River, Green River; NV, CA, AZ: Colorado River; NM, CO, UT: San Juan River (Ex?); AZ: Gila River drainage (Ex)
81		Relict dace	Relictus solitarius	NV: Goshute Basin, Spring Basin, Steptoe Basin, Ruby Basin, Butte Basin
82		Big Smoky speckled dace	Rhinichthys osculus lariversi	NV: Big Smoky Valley
83	V	Independence Valley speckled dace	Rhinichthys o. lethoporus	NV: Independence Valley
84	V	Moapa speckled dace	Rhinichthys o. moapae	NV: Moapa River
85		Ash Meadows speckled dace	Rhinichthys o. nevadensis	NV: Ash Meadows
86		Clover Valley speckled dace	Rhinichthys o. oligoporus	NV: Clover Valley
87	Ex	Grass Valley speckled dace	Rhinichthys o. reliquus	NV: Grass Valley
88	V	Owens speckled dace	Rhinichthys osculus ssp.	CA: Owens Valley
89	V	Amargosa Canyon speckled dace	Rhinichthys osculus ssp.	CA: Middle Amargosa River drainage
90		Preston speckled dace	Rhinichthys osculus ssp.	NV: Upper White River
91		Amargosa speckled dace	Rhinichthys osculus ssp.	NV: Upper Amargosa River

Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
CYPRINIDAE — MINNOW FAMILY (continued)				
92	R	Meadow Valley speckled dace	Rhinichthys osculus ssp.	NV: Meadow Valley Wash
93	V	Foskett Spring speckled dace	Rhinichthys osculus ssp.	OR: Warner Basin
94	V	Kendall Warm Springs dace	Rhinichthys o. thermalis	WY: Green River Basin
95	V	Pahranagat speckled dace	Rhinichthys o. velifer	NV: Pahranagat Valley
96	Ex	Las Vegas dace	Rhinichthys deaconi	NV: Colorado River drainage (Las Vegas Creek)
97	Ex	Stumptooth minnow	Stypodon signifer	COA: Parras Valley
98	V	Loach minnow	Tiaroga cobitis	NM, AZ, SON: Gila River Basin; AZ: Salt River
CATOSTOMIDAE — SUCKER FAMILY				
99		White River desert sucker	Catostomus clarki intermedius	NV: Upper White River, Pahranagat Valley
100		Meadow Valley desert sucker	Catostomus clarki ssp.	NV: Meadow Valley Wash
101		Conchos sucker	Catostomus conchos	CHI: Rio Conchos
102	V	Zuni bluehead sucker	Catostomus dicobolus yarrowi	NM: Rio Nutria
103		Modoc sucker	Catostomus microps	CA: Pit River
104		Goose Lake sucker	Catostomus occidentalis lacusanserinus	OR, CA: Goose Lake
105		Jenny Creek sucker	Catostomus rimiculus ssp.	OR: Upper Klamath Basin
106		Klamath largescale sucker	Catostomus snyderi	OR, CA: Upper Klamath Basin
107	V	unnamed sucker	Catostomus sp.	CHI, SON: Rio Yaqui; CHI: Upper Rio Casas Grandes
108		Wall Canyon sucker	Catostomus sp.	NV: Surprise Basin
109	V	Warner sucker	Catostomus warnerensis	OR: Warner Basin
110		Shortnose sucker	Chasm istes brevirostris	OR, CA: Upper Klamath Basin
111	V	Cui-ui	Chasm istes cujus	NV: Lahontan Basin
112	Ex	June sucker	Chasm istes liorus liorus	UT: Utah Lake
113		June sucker	Chasmistes 1. mictus	UT: Utah Lake
114		Lost River sucker	Deltistes luxatus	OR, CA: Upper Klamath Basin
115	V	Razorback sucker	Xyrauchen texanus	CO: Colorado River, Green River; UT: Colorado River, Green River; NV, AZ, CA: Colorado River; AZ: Gila River drainage; NM, CO, UT: San Juan River
ICTALURIDAE — BULLHEAD CATFISH FAMILY				
116		Cuatro Cienegas headwater catfish	Ictalurus lupus ssp.	COA: Cuatro Cienegas
117		Yaqui catfish	Ictalurus pricei	AZ, CHI, SON: Rio Yaqui
118		Mexican blindcat	Priatella phreatophila	COA: Well near Muzquiz

Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
GOBIESOCIDAE — CLING FISH FAMILY				
119		Mexican freshwater clingfish	Gobiesox *fluviatilis*	SIN, DGO: Rio Fuerte, Rio Mezquital, Rio Grande de Santiago
CYPRINODONTIDAE — KILLIFISH FAMILY				
120	V	Preston White River springfish	Crenichthys baileyi albivallis	NV: Upper White River
121		White River springfish	Crenichthys b. • baileyi	NV: Pahranagat Valley
122		Hiko White River springfish	Crenichthys b. grandis	NV: Pahranagat Valley
123	V	Moapa White River springfish	*Crenichthys* b. moapae	NV: Moapa River
124		Moorman White River springfish	Crenichthys b. therm ophilus	NV: Upper White River
125	V	Railroad Valley springfish	Crenichthys nevadae	NV: Railroad Valley
126		Media Luna killie	Cualac tessellatus	SLP: La Media Luna
127		Potosí pupfish	Cyprinodon alvarezi	NLE: El Potosi
128		Bolson pupfish	Cyprinodon atrorus	COA: Cuatro Cienegas
129	V	Cuatro Cienegas pupfish	Cyprinodon bifasciatus	COA: Cuatro Cienegas
130		Leon Springs pupfish	Cyprinodon bovinus	TX: Pecos River drainage (Diamond-Y Springs, Leon Creek)
131		Devils Hole pupfish	Cyprinodon diabolis	NV: Ash Meadows
132		Comanche Springs pupfish	Cyprinodon elegans	TX: Pecos River drainage (Phantom Cave waters, San Solomon Springs)
133	V	Devils River pupfish	Cyprinodon eximius ssp.	TX: Rio Grande drainage (Devil's River)
134	Ex	Parras pupfish	Cyprinodon latifasciatus	COA: Parras Valley
135		Largescale pupfish	Cyprinodon m acrol epis	CHI: Ojo de Hacienda Dolores
136		Desert pupfish	Cyprinodon macularius	BCA, SON: Colorado River; AZ: Gila River (Ex), Quitobaquito Spring; CA: Salton Sea area; SON: Rio Sonoyta
137		Mezquital pupfish	Cyprinodon meeki	DGO: Upper Rio Mezquital
138	Ex	Tecopa pupfish	Cyprinodon nevadensis calidae	CA: Middle Amargosa River drainage
139	V	Ash Meadows Amargosa pupfish	Cyprinodon n. mionectes	NV: Ash Meadows
140		Amargosa pupfish	Cyprinodon n. nevadensis	CA: Death Valley
141		Warm springs Amargosa pupfish	Cyprinodon n. pectoralis	NV: Ash Meadows
142	Ex	Shoshone pupfish	Cyprinodon n. shoshone	CA: Middle Amargosa River drainage
143		Pecos River pupfish	Cyprinodon pecosensis	NM, TX: Pecos River
144		Owens pupfish	Cyprinodon radiosus	CA: Owens Valley
145		Cottonball Marsh pupfish	Cyprinodon salinus milleri	CA: Death Valley
146		Salt Creek pupfish	Cyprinodon salinus salinus	CA: Death Valley
147		Bighead pupfish	Cyprinodon sp.	CHI: Ojo de San Diego de Alcala
148		unnamed pupfish	Cyprinodon sp.	CHI: Guzman complex, Laguna de Bustillos drainage
149	Ex	Monkey Spring pup fish	Cyprinodon sp.	AZ: Gila River drainage
150		White Sands pupfish	Cyprinodon tularosa	NM: Tularosa Valley

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Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
CYPRINODONTIDAE – KILLIFISH FAMILY (continued)				
151	Ex	Raycraft Ranch poolfish	Empetrichthys latos concavus	NV: Pahrump Valley
152		Pahrump poolfish	Empetrichthys 1. latos	NV: Pahrump Valley
153	Ex	Pahrump Ranch poolfish	Empetrichthys 1. pahrump	NV: Pahrump Valley
154	Ex	Ash Meadows poolfish	Empetrichthys merriami	NV: Ash Meadows
155		Cuatro Cienegas sardinilla	Lucania interioris	COA: Cuatro Cienegas
156		Perrito Enano de Potosí	Megupsilon aporus	NLE: El Potosi
GOODEIDAE – MEXICAN LIVEBEARER FAMILY				
157	V	Striped goodeid	Ataeniobius toweri	SLP: La Media Luna, Upper Rio Verde
158	R	Rainbow goodeid	Characodon lateralis	DGO: Upper Rio Mezquital; COA: Parras Valley (Ex)
POECILIIDAE – LIVEBEARER FAMILY				
159	V	Guayacón de San Gregorio	Gambusia alvarezi	CHI: Ojo de San Gregorio
160	Ex	Amistad gambusia	Gambusia amistadensis	TX: Rio Grande drainage
161	E	Big Bend gambusia	Gambusia gaigei	TX: Rio Grande drainage
162	R	Guayacón de Hacienda Dolores	Gambusia hurtadoi	CHI: Ojo de Hacienda Dolores
163	V	Guayacón de Rio de Nava	Gambusia krumholzi	COA: Rio de Nava
164	V	Guayacón de Cuatro Cienegas	Gambusia *longispinis*	COA: Cuatro Cienegas
165	V	Pecos gambusia	Gambusia nobilis	TX, NM: Pecos River Basin
166	I	Guayacón de San Diego	Gambusia sp.	CHI: Ojo de San Diego
167	E	Gila topminnow	Poeciliopsis o. occidentalis	AZ: Gila River drainage
168	E	Monterrey platyfish	Xiphophorus couch ianus	NLE: Rio Grande drainage
169	R	Cuatro Cienegas platyfish	Xiphophorus gordoni	COA: Cuatro Cienegas
170	E	Muzquiz platyfish	Xiphophorus sp.	COA: Muzquiz
CENTRARCHIDAE – SUNFISH FAMILY				
171	R	Cuatro Cienegas longear sunfish	Lepomis megalotis ssp.	COA: Cuatro Cienegas
172	R	Cuatro Cienegas largemouth bass	Micropterus salmoides ssp.	COA: Cuatro Cienegas
PERCIDAE – PERCH FAMILY				
173		Conchos darter	Etheostoma australe	CHI: Rio Conchos
174	V	Rio Grande darter	Etheostoma grahami	TX: Rio Grande drainage (Devil's River, Pecos River, San Felipe Creek, Independence Creek); CHI, NLE: tributaries of Rio Grande
175	V	Mexican darter	Etheostoma pottsi	CHI: Rio Nazas, Rio Conchos; ZAC: Rio Aguanaval; DGO: Rio Mezquital
176		Cuatro Cienegas darter	Etheostoma sp.	COA: Cuatro Cienegas

Table 1.—List of fishes of concern from the North American deserts region. Fishes are noted as endangered (E), vulnerable (V), rare (R), or indeterminate (I). Extinct fishes (Ex) are also included.

Number	Status	Common Name	Scientific Name	Location
CICHLIDAE – CICHLID FAMILY				
177	E	Mojarra caracolera	*Cichlasoma* bartoni	SLP: La Media Luna
178	I	Cuatro Cienegas mojarra	*Cichlasoma* minckleyi	COA: Cuatro Ciénegas
179	E	Yellow mojarra	*Cichlasoma* sp.	SLP: La Media Luna
COTTIDAE – SCULPIN FAMILY				
180	R	Rough sculpin	Cottus asp errimus	CA: Pit River
181	R	Malheur mottled sculpin	Cottus bairdi ssp.	OR: Malheur Basin
182	Ex	Utah Lake sculpin	Cottus echinatus	UT: Utah Lake

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An endemic biota and a striking diversity of aquatic habitats have made the desert Bolson of Cuatro Cienegas de Carranza, Coahuila, Mexico (26° 59' N, 102° 04' W), an area of considerable biological interest. Much of the literature on fishes and aquatic habitats of the basin, as well as references to studies on other aspects of the region, have been reviewed by Minckley (1969, 1978, 1984). Limnology is described by Minckley and Cole (1968a) and vegetation is discussed by Pinkava (1984). The following description of the area is abstracted from these contributions.

Isolated on nearly all sides by mountains exceeding 1,800 m, the 740 m, low-relief valley floor is split into two sub-triangular lobes by the anticlinal tip of Sierra de San Marcos, which plunges into valley alluvium from the south. Hydrologically, the surface has been subdivided into seven endorheic systems (Minckley 1969) including a small area in the northeastern corner that now drains via artificial channels through Puerto Salado to the Rio Salado de los Nadadores, a Rio Grande (Bravo del Norte) tributary. Biological and geological evidence both indicate prehistoric consolidation of present hydrologic entities into two major sumps: one in the west-central region of the basin, the other the southeastern lobe. Relatively recent connection of the southeastern lobe to the Rio Grande system through Puerto Salado is indicated, while the central portion appears to have been long isolated.

Aquatic habitats are abundant and amazingly diverse. In the central region, an area of karst topography is riddled with cenote-like sinkholes called pozos, and lagunas that range to greater than 200 m in diameter and more than 10 m deep (e.g., Laguna El Mojarral, Juan Santos, Churince, Escobeda). These differ markedly amongst themselves in size, morphometry, and discharge. Most springs are thermal. Also in this region are large, ephemeral, saline playa lakes (e.g., Lagunas Grande and Salada), fed at least in part by springs. Lotic systems similarly vary in physical and chemical parameters. Most streams on the valley floor may have stable discharges over constant, low gradients, and they flow between intricate travertine banks (e.g., Ríos Mesquites and Puente Chiquito). There is typically little or no riparian vegetation differing from surrounding desert, but marsh communities occur along lotic systems and around many pozos and lagunas. Outside the karst region, where water quality permits, riparian zones support trees (e.g., Laguna Anteojo, Rio Canon, Laguna Santa Tecla), and streams may have varied gradients with pronounced pool-riffle development and temporal instability of discharge and temperature.

While this unique valley has a long history of human modification, the system has been changed little in the past 2.5 decades (Contreras-Balderas 1984, Minckley 1984). Many diversion canals were constructed long ago and abandoned after crops failed because of inadequate soils and water quality. Although artificially-induced hybridizations have sometimes resulted from past modifications that have dramatically altered some lagunas (Minckley 1969, 1978), species losses from these communities have been insignificant (Minckley 1984). Perhaps the most notable changes have occurred at Poza la Becerra, where a diversion channel has resulted in lowered water levels and slumped bottom sediments. Diminished populations of snails (Mexipyrgus churinceanus, Mexithauma quadripaludium, Nymphophilus minckleyi), a shrimp (Palaemonetes suttkusi), fishes (*Astyanax* mexicanus, Notropis xanthicara, *Cichlasoma* minckleyi) and reptiles (Terrapene coahuila, Pseudemys scripta *taylori*, Trionyx ater) have been recorded there (Contreras-Balderas 1984). Agriculture in the valley is localized and restricted from expansion by insufficient supplies of water of acceptable quality. Industrial impacts on fishes have been few. Gypsum is mined locally, which has disrupted plant communities, but fishes have not been affected. Water quality may be adequate, however, for some industrial uses. A large steel industry in Monclova, about 80 km east, exploits Cuatro Cienegas water.

SPECIES ACCOUNTS.—Cuatro Cienegas roundnose minnow, Dionda episcopa ssp.—Rare. — Minckley (1978) noted Cuatro Cienegas populations of this species as distinct and referred them to an undescribed subspecies, while noting a need for systematic review of this highly variable species. Minckley (1969) reported that the Cuatro Cienegas form occurs on or near bottom and in current rather than pools. He (1984) found it most abundant in canals. Elsewhere, D. episcopa usually is associated with springs in habitats with relatively stable temperatures (Hubbs and Brown 1956). While found at many localities within the central portion of the basin, it is rarely abundant. Its rarity appears natural rather than a result of habitat modifications (W. L. Minckley, pers. comm.).

Cuatro Cienegas shiner, Notropis xanthicara — Rare. — Notropis xanthicara has been commonly collected from Cuatro Cienegas since 1960. This endemic, open-water shiner is a sister species of Notropis rutilis, which was collected in the Cuatro Cienegas Basin at two localities in 1939, but never since. Other 1939 collections did not contain N. xanthicara in habitats where in now occurs. Reasons for such recent changes in distribution are unknown (Minckley 1969, Minckley and Lytle 1969). The species is found throughout the basin except in shallow marshes and larger terminal lakes. It often is abundant near limnocrene origins of streams. Minckley and Lytle (1969) noted that it appears to be sensitive to canalization and intensive water management.

Cuatro Cienegas headwater catfish, Ictalurus lupus ssp. — Rare. — This endemic form of Ictalurus lupus is undescribed. The fish is found most frequently in larger, cooler environments but occasionally occurs in outflows of warmer springs or marshes fed by warm springs (Minckley 1978).

Cuatro Cienegas pupfish, Cyprinodon atrorus — Rare. — Described by Miller (1968), this hardy Cuatro Cienegas endemic is characteristic of highly variable and often saline environments of the basin (Minckley 1969, Minckley and

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Itzkowitz 1967). It is ecologically allopatric from the other endemic pupfish, C. *bifasciatus,* but occasionally hybridizes with it in disturbed areas (Minckley 1969). In dry periods, when the large Laguna Salada becomes highly saline, C. *atrorus* may be the only fish present, often in great numbers (W. L. Minckley, pers. comm.). As an endemic in this small basin, we consider it "rare" although it can be abundant in certain habitats.

Cuatro Cienegas pupfish, *Cyprinodon bifasciatus* — Vulnerable. — Perhaps the most differentiated of the endemic fishes in the bolson, this open-water, schooling pupfish occurs in more stable limnocrenes and larger springs. It is notably stenothermic and restricted to the arc of thermal springs surrounding the tip of Sierra de San Marcos. It is thus clearly separated ecologically from the other pupfish, C. *atrorus,* in the basin. Hybridization with C. *atrorus* is rare in natural habitats, but hybrid swarms have been reported in disturbed areas (Minckley 1969, 1978). Most of the hybrid swarms, which occurred in artificial habitats, have disappeared with the drying of canals. Despite habitat alteration and hybridization in some areas, most large pozos still support substantial, apparently stable populations of this species.

Cuatro Cienegas sardinilla, *Lucania interioris* — Rare. — Hubbs and Miller (1965) discussed the ecology and morphological differentiation among populations of this endemic. Its apparent rarity may be an artifact of its habit of burrowing in soft sediments, where it is difficult to collect (Minckley, pers. comm.; Hubbs and Miller 1965). It is typical of small, extreme, temporally varying waters and occurs in such habitats throughout the central portion of the basin. It appears to be absent from the southeastern lobe (Minckley 1978).

Guayacen de Cuatro Cienegas, *Gambusia longispinis* — Vulnerable. — The apparent rarity of this diminutive endemic may be related to difficulties in collection because of its highly secretive habits. It lives in dense emergent vegetation at depths generally less than 10 cm (Minckley 1962). Water diversions from lagunas are far more devastating to this species' shallow marsh habitats than to laguna habitats (Minckley 1969), making it especially vulnerable to modifications that reduce groundwater levels.

Northern platyfish, *Xiphophorus gordoni* — Rare. — Also endemic to the basin, *Xiphophorus gordoni* is restricted to the southeastern lobe where it occurs in habitats equivalent to those of the allopatric *Gambusia longispinis* of the central basin. Behavioral or competitive interactions were hypothesized by Minckley (1978) as mechanisms maintaining this allopatry. The platyfish is known only from three adjacent lagunas and a few small pozos (Miller and Minckley 1963, Minckley 1968). This species probably is a near relative of X. *couchianus* of the Rio San Juan or X. *variatus xiphidium* of the Rio Soto La Marina to the south and east (Minckley 1978). Rosen and Bailey (1963), with no discussion, considered X. *gordoni* a junior synonym of X. *couchianus,* but Rosen (1979) recognized it as a separate species. Histocompatibility studies between and within populations of X. *gordoni* have been done by Kallman (1964) and Lysne (1967). Because of restricted distribution and occurrence as small populations in limited, vulnerable habitats, we classify this species as "rare".

Cuatro Cienegas largemouth bass, *Micropterus salmoides* ssp. — Rare. — Because it is a "top carnivore" in large pozos, lagunas and streams of the basin, population densities of this species are relatively low. It is widely distributed throughout the basin and omnipresent in the larger, more stable habitats, where is occupies open waters (Minckley 1969). It is in thermal as well as cool-water habitats. Minckley (1969, 1978) noted that it is darker and has a more pronounced lower jaw than conspecifics outside the basin. In some isolated habitats in the basin, the endemic form appears to have been replaced by phenotypes more typical for the species, possibly because of importation of exotic conspecifics (Minckley 1978).

Cuatro Cienegas longear sunfish, *Lepomis megalotis* spp. — Rare. — This second endemic centrarchid is also restricted to larger streams, pozos and lagunas where it lives always near undercut travertine or other cover. Not known from the southeastern lobe, it is restricted to the central portion where it feeds mostly on molluscs, and is much less common than the largemouth bass (Minckley 1969, 1978). Although undescribed, it differs dramatically in breeding coloration from conspecifics in the southeastern United States (W. L. Minckley, pers. comm.).

Cuatro Cienegas darter, *Etheostoma* sp. — Rare. — The Rio Mesquites and closely associated streams of the bolson are the only known habitats of this cryptic, undescribed species. Minckley (1969) discussed the uncertain systematic relationships of this species and expressed the need for revisionary study of *Etheostoma* in Mexico, some of which has been completed by Smith et al. (1984). This secretive species lives in the current over complex travertine bottoms at depths sometimes exceeding one meter. It is difficult to collect without the aid of mask and snorkel while searching for individuals. Although extremely restricted in distribution, it occurs in generally low, but apparently stable densities.

Cuatro Cienegas mojarra, *Cichlasoma minckleyi* — Indeterminate. — The cichlids of the Cuatro Cienegas Basin have posed a complex problem that has attracted considerable attention. Taylor and Minckley (1966) reported a "species flock" of cichlids from the basin composed of three species that differ in body form and trophic structures related to dietary differences—detritivory, molluscivory and piscivory. Later, LaBounty (1974) determined that relationships of this species flock are to the subgenus *Parapetenia,* particularly to species in the Rio Panuco. He also reported a fourth member of the flock, a piscivore distinguished by pharyngeal tooth morphology. Kornfield and Koehn (1975) conducted an electrophoretic survey of proteins of flock members and, failing to find variation among the forms or between localities, hypothesized that speciation had occurred without genetic differentiation. Sage and Selander (1975) suggested that such

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observations might be explained by conspecificity of the morphs. Kornfield et al. (1982) published subsequent studies designed to clarify the problem and in 1983, Kornfield and Taylor described the flock as a polymorphic species, C. *minckleyi*.

All four forms are restricted to the central portion of the basin. Most widely distributed and abundant is the detritivore (sensu Minckley 1978), which once occurred at 43 sites and has been extirpated at three of them. This group apparently corresponds to the herbivore trophic-morphotype of Sage and Selander (1975) and to the deep-bodied, papilliform morph of Kornfield et al. (1982) and Kornfield and Taylor (1983). The molluscivore form is less abundant. Minckley (1978) recorded it at 16 localities surrounding the tip of Sierra de San Marcos. The molluscivore is the deep-bodied, molariform morph as described by Kornfield et al. (1982) and Kornfield and Taylor (1983). Piscivores were found by Minckley (1978) in low numbers at only 6 of the localities occupied by the other two morphs, with the second, even more rare "unexpected" morph at only 3 of these. Piscivores analyzed by Kornfield and Koehn (1975), Sage and Selander (1975) and Kornfield et al. (1982) have not included the "unexpected" form reported by LaBounty (1974) and Minckley (1978), though Kornfield and Taylor (1983) published morphological data on it (slender-bodied, molariform morph). In some localities on the south and eastern edges of the range of the *Parapetenia* group, detritivore and molluscivore forms are found together with another cichlid of the subgenus *Herichthys* (LaBounty 1974, Minckley 1978), which also occupies the southeastern lobe, along with its apparent sister species C. (H.) *c. cyanoguttatum* (Minckley 1978). The latter apparently is a recent invader to the basin via artificial connections through Puerto Salado, from which it presently is expanding its range and evidently hybridizing with the native sister form (Minckley 1978).

Genetic evidence for conspecificity of the C. *minckleyi* morphs includes lack of departure of allelic frequencies from Hardy-Weinberg expectations for conspecificity and concordant variation among morphs between localities (Sage and Selander 1975). Furthermore, heteromorphic mating pairs have been observed and both morphs occur in individual wild-caught broods (Kornfield et al. 1983). Both morphs have developed in similar broods raised in aquaria (Kornfield et al. 1983). However, the species description is based largely on morphologies of specimens collected in the early 1960's for which no biochemical data are available. Biochemical evidence for conspecificity was derived from other specimens which apparently were not preserved. We thus relegate C. *minckleyi* to "indeterminate" status until further studies integrating detailed morphological data sets with genetic information derived from the same specimens clarify the taxonomic status.

As a whole, C. *minckleyi* is one of the more abundant species in the basin. However, the piscivore morphs are among the rarest forms. Regardless of taxonomic disagreements that may affect endangered status in classification schemes based on "endangered species", it is imperative that the resource represented by the entire *Parapetenia* complex and its environments receive thorough protection. This group provides unique, invaluable opportunities for study of evolutionary and ecological processes.

Cuatro Cienegas reptiles — Indeterminate. — Four semi-aquatic or aquatic reptiles are endemic to Cuatro Ciénegas. The Cuatro Cienegas aquatic box turtle, *Terrapene coahuila,* is the most divergent and unusual reptilian endemic and occurs in semi-aquatic habitats as well as streams and lagunas (Brown 1974, McCoy 1984). Two other aquatic turtles, *Pseudemys scripta taylori* and *Trionyx ater,* also are endemic (McCoy 1984). A semi-aquatic lizard, *Scincella lateralis* ssp., is also restricted to the bolson and like the aquatic turtles, exhibits close affinities to the Tamaulipan fauna (McCoy 1984). The current status of these species is uncertain.

Cuatro Cienegas snails — Indeterminate. — A remarkable fauna of hydrobiid snails is endemic to the bolson of Cuatro Ciénegas. At least ten described hydrobiids *(Cochliopina milleri, Coahuilix hubbsi,* C. *landyei, Durangonella coahuilae, Mexiostiobia manantiali, Mexipyrgus churinceanus, Mexithauma quadripaludium, Nymphophilus acarinatus,* N. *minckley* and *Paludiscala caramba)* are endemic to the basin and others probably exist, but are unknown to scientists (Hershler, in litt. comm. in Wells et al. 1983; Taylor 1966). Six of the genera *(Coahiilix, Mexiostiobia, Mexipyrgus, Mexithauma, Nymphophilus* and *Paludiscala)* are known only from Cuatro Cienegas. A more recent systematic revision (Hershler 1984) resulted in a classification that recognized nine genera (five endemic) of hydrobiids from the basin. Hershler (1984) collected snails from 103 localities in the basin, including 100 sites concentrated around the northern tip of the Sierra de San Marcos. Diversions of springs for agricultural purposes, canalization, and modification of spring pools for swimming have reduced certain habitats. If preserved intact, the snail fauna and their habitats will provide a wealth of information to scientists concerned with speciation, evolution and adaptation.

Cuatro Cienegas crustaceans — Indeterminate. — Four aquatic Isopoda are endemic to the Cuatro Cienegas Basin: *Speocirolana thermydronis, Sphaerolana interstitialis,* S. *affinis,* and *Mexistenasellus coahuila* (Cole 1984). *Mexistenasellus coahuila* (Cole and Minckley 1972) was the only member of the isopod family Stenasellidae known outside the Eastern Hemisphere at the time of its description. *Speocirolana thermydronis* is known from interstices of porous travertine at the margins of pozos and lagunas as well as spring outflow sediments and roots of aquatic and riparian plants (Cole and Minckley 1966, Minckley and Cole 1968b). *Speocirolana* therm *ydronis* was described by Minckley (1969) as relatively abundant. The bispecific genus *Sphaerolana* is known only from Cuatro Cienegas. At least two amphipods, *Mexiweckelia colei* and *Paramexiweckelia particeps,* are also endemic (Cole 1984). The only known locality for the monotypic genus *Paramexiweckelia*

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is Taylor's Spring (Cole 1984, Holsinger and Minckley 1971). Additionally, the local forms of Hyalella probably represent at least one endemic species (Cole 1984).

SUMMARY.—The native ichthyofauna of Cuatro Cienegas includes the 12 endemic fishes discussed above as well as the Cuatro Ciénegas sardina, Astyanax mexicanus ssp., which we believe to be too widespread and common to be included in our discussion of rare fishes. Another component of the native fauna, the flathead catfish, Pylodictis olivaris, is so rare in collections as to have been unstudied (see Table 2 for complete ichthyofauna list). Other aquatic organisms that are endemic to the bolson include four reptiles, at least six crustaceans and at least ten molluscs. As with other ecosystems, we see the need for protection and preservation of natural habitats and complete communities in Cuatro Ciénegas, rather than protection of individual species per se.

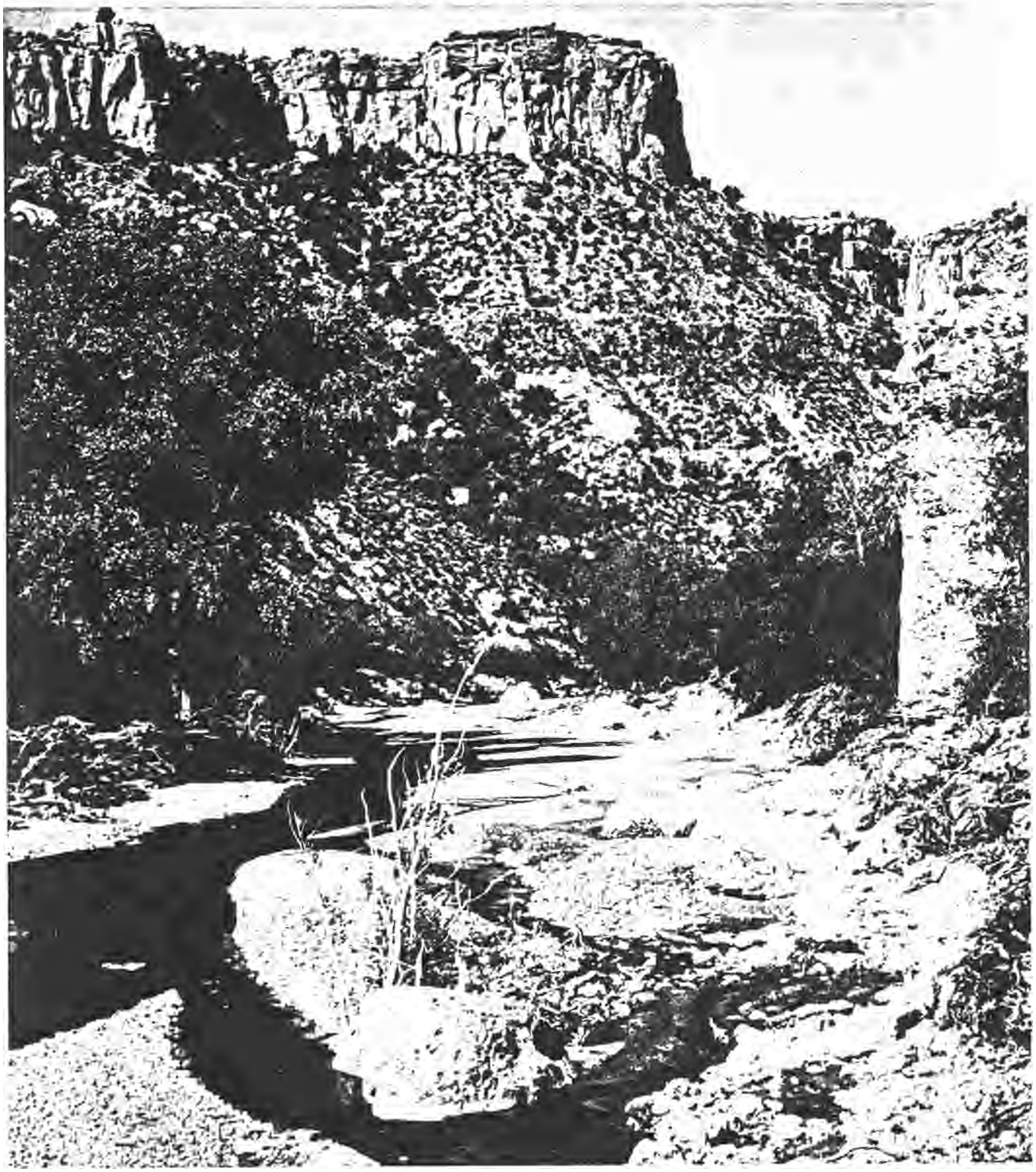
Because of its wealth of endemic aquatic organisms and myriad of aquatic habitats, Cuatro Cienegas is a natural, experimental laboratory, well-designed for studies in ecology, evolution and systematics. The ecosystem is little known despite considerable study and should be preserved unmodified for future examinations. The proposal of this valley as a national park (Almada-Villela and Contreras-Balderas 1984) should be heartily supported by the international scientific community.

Table 2.—Native ichthyofauna of the Cuatro Cienegas Basin.

Taxon	Endemic Status
Characidae	
Astyanax mexicanus ssp.	Comm on
Cyprinidae	
Dionda episcopa ssp.	
Notropis xanthicara	
Ictaluridae	
Ictalurus lupus ssp.	
Pylodictis olivaris	
Cyprinodontidae	
Cyprinodon atrorus	
Cyprinodon *bifasciatus*	V
Lucania interioris	
Poeciliidae	
Gambusia longispinis	V
Gambusia marshi	Common
Xiphophorus gordoni	
Centrarchidae	
Lepomis megalotis ssp.	
Micropterus salmoides ssp.	
Percidae	
Etheostoma sp.	
Cichlidae	
Cichlasoma minckleyi	

SRP11903

GILA RIVER, NEW MEXICO, ARIZONA AND SONORA



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The Gila River originates in southwestern New Mexico, continues through Arizona until joining the Colorado River near Yuma, having flowed for more than 800 km throughout its length. Major tributaries in Arizona include the Verde, Salt and San Francisco Rivers, which flow into the Gila River from mountainous areas to the north. The Santa Cruz and San Pedro Rivers are also tributary, but flow northward into the Gila from headwater areas in northeastern Sonora and southeastern Arizona. Habitats in the drainage range from high-elevation (above 3,000 m) streams dominated by salmonids to low-elevation Sonoran Desert streams dominated by cyprinids and catostomids. Numerous springs along the river and its tributaries add to the flow. Except during major floods, the Gila River has been largely dry in its lower course for the past 30 years (Miller 1961).

SPECIES ACCOUNTS.—Apache trout, Salmo apache — Vulnerable. — Apache trout historically occurred in the Blue River, a tributary of the San Francisco River, as well as in headwaters of the Little Colorado and Salt Rivers. By the 1950's, hybridization and competition with exotic trouts, S. gairdneri, S. trutta and Salvelinus fontinalis, had eliminated genetically pure Apache trout from all streams except a few headwater tributaries above 3,000 m elevation (Minckley 1973, Rinne 1985). Since that time, streams have been renovated to eliminate exotic salmonids and S. apache has been reestablished in several creeks (Minckley 1973, Rinne et al. 1981). Recently, at least two populations of S. apache have been maintained in reservoirs by repeated introductions.

Gila trout, *Salmo* gilae — Endangered. — Historically, this trout occurred in high-elevation streams tributary to the Verde River in Arizona and the Gila River in New Mexico (Miller 1972). Genetically pure Salmo gilae were collected from West Clear and Oak Creeks, tributaries of the Verde River, in the late 1800's (Miller 1972, Minckley 1973). By the early 1900's, however, hybridization with introduced S. gairdneri was eliminating S. gilae from the Verde system (Minckley 1973). Interactions with exotic fishes, particularly S. gairdneri, eventually extirpated S. gilae from the Verde River tributaries and many of the Gila River tributaries in New Mexico. Natural populations persist in Spruce, Iron and McKenna Creeks in the Gila Wilderness Area, and Main Diamond and South Diamond Creeks in the Blue Range Primitive Area. The species has been introduced into other southwestern New Mexico streams in an effort to improve its status.

Gila chub, Gila intermedia — Vulnerable. — Gila chubs formerly occupied smaller creeks and cienegas throughout the upper and middle Gila River drainages in Arizona and New Mexico and in similar habitats of the Santa Cruz and San Pedro drainages in adjacent areas of Sonora. However, loss or modification of habitat from diversions, desiccation, and overgrazing, and predation by exotic largemouth bass, Micropterus salmoides, as well as competition from other exotic fishes, have caused disappearance or decline of Gila chub populations throughout their range, including extirpation from New Mexico (Minckley 1973). The species persists in isolated drainages of the Gila River system in Arizona.

Spikedace, Meda fulgida — Vulnerable. — Historically, spikedace occurred in Arizona, New Mexico, and Sonora in the Verde, Salt, Agua Fria, San Francisco, and San Pedro Rivers and their tributaries, and the Gila River and its tributaries upstream of Phoenix (Miller and Winn 1951, Minckley 1973). Presently, spikedace inhabit the entire perennial flow of Aravaipa Creek (24 km), limited portions of the upper Gila River from the town of Red Rock, New Mexico, upstream to approximately the 1,850 m elevation on the East and Middle Forks (120 km), and in the Verde River near the town of Perkinsville and near the mouth of Sycamore Creek (8 km). The species inhabits shallow riffles with gravel and rubble substrates and moderate to swift currents, and swift-water pools over sand or gravel substrates in moderate-sized to large perennial streams. Recurrent flooding is an integral feature of its life history. Habitat destruction and loss, major dam construction, and predation and competitive interaction from exotic fishes have led to the diminished distribution of M. fulgida.

Woundfin, Plagopterus argentissimus — Endangered. — Presently, this species is restricted to the Virgin River from La Verkin, Utah, downstream to near Riverside, Nevada. Until the early 1900's, P. argentissimus also occurred in the Gila River from Tempe, Arizona, downstream to the Colorado River (Gilbert and Scofield 1898, Snyder 1915). Extirpation from the Gila River appears attributable to reduced stream flows and degradation of habitat.

Loach minnow, Tiaroga cobitis — Vulnerable. — The loach minnow is endemic to small and moderate-sized creeks and rivers in the Gila River system upstream of Phoenix (Minckley 1973). However, it now occurs only in five areas: (1) Aravaipa Creek, Graham and Pinal Counties, Arizona; (2) the San Francisco and Blue Rivers above their confluence, Greenlee County, Arizona, and Catron County, New Mexico; (3) the mainstream Gila River above the Middle Box, Grant and Catron Counties, New Mexico; (4) the Tularosa River below the town of Cruzville, Catron County, New Mexico; and (5) the lower reaches of Whitewater Creek, a tributary of the San Francisco River, Catron County, New Mexico. Distribution and abundance of Tiaroga cobitis has been reduced by habitat destruction, impoundment, channel downcutting, substrate sedimentation, and reduced flows from water diversion and groundwater pumping (Minckley 1973). The species continues to be threatened by proposed dam construction, water losses, habitat alteration, and by introduction and spread of exotic predatory and competitive species such as red shiner, Notropis lutrensis.

Colorado River fishes. — Historically, Gila elegans, Ptychocheilus lucius and Xyrauchen texanus were abundant in the Gila, Salt and Verde Rivers of Arizona (Minckley 1973). Although these species persist in the Colorado and Green Rivers (see those ecosystem accounts for a

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general treatment of these fishes), they have been extirpated from the entire Gila River drainage. Minckley (1973) reported that a commercial fishery existed for these big-river fishes in the Gila River system until 1910. The decline of these fishes during the early 1900's was precipitous. For example, the last adult P. lucius known from the Gila River drainage was collected in 1937 from the Salt River above Roosevelt Dam, where they had been "fairly common" in 1906 (Miller 1961). Reduced stream flows, impoundments and interactions with exotic fishes appear to be the major causal factors in declines of these species. Efforts are now underway to reintroduce X. texanus using propagated stock from Dexter National Fish Hatchery (J. E. Johnson, pers. comm.).

Desert pupfish, Cyprinodon macularius — Endangered. — This pupfish is native to backwaters, sloughs, springs and seeps of the Gila River drainage, the lower Colorado River downstream of its confluence with the Gila, the Rio Sonoyta drainage, and the Salton Sea region. Cyprinodon macularius was described from specimens collected from the San Pedro River, a tributary of the Gila, in Arizona (Baird and Girard 1853). At one time, this typical form of macularius was widespread in the Gila River system in Arizona, including the San Pedro and Santa Cruz Rivers to their headwaters in Sonora (R. R. Miller, pers. comm.), from where it also appears to be extirpated (Minckley 1973). Loss of habitat from water diversion and desiccation is the principal reason for the decline. Introductions of predatory and competitive fishes such as Poecilia latipinna, P. *mexicana*, Poeciliopsis gracilis, Notropis lutrensis, Tilapia spp., and Gambusia affinis have contributed to elimination of desert pupfish from remaining habitats throughout its range (Black 1980, Minckley 1973). As part of a proposal to reestablish desert pupfish in the Gila River Basin, C. macularius were introduced into Howard Well, Peoples Canyon and Mesquite Spring, all on public land in Arizona, during August 1982. The original source of these fish was Santa Clara Slough, Sonora.

Monkey Spring pupfish, Cyprinodon sp. — Extinct. — This undescribed pupfish was known only from Monkey Spring, an associated cienega and an artificial pond in the Sonoita Creek drainage, Santa Cruz County, Arizona (Minckley 1973). Attempts to deepen the cienega apparently "broke the seal" and drained the marsh area (Minckley 1973). The pupfish survived in the pond until largemouth bass, Micropterus salmoides, were introduced in 1968 and 1969. Predation by the bass appears to be the primary causal factor in extirpation of this pupfish.

Gila topminnow, Poeciliopsis o. occidentalis — Endangered. — The Gila topminnow once was abundant throughout the Gila River system except in mountain streams, and in the Santa Cruz and San Pedro River systems as far as northern Mexico, and north through the Salt and Verde Rivers of central Arizona (Minckley and Deacon 1968). The Gila topminnow now occurs naturally in only nine isolated localities in the United States. All but one of the remaining natural populations of P. o. occidentalis are in the Santa Cruz River system; these are: Redrock Canyon, Cottonwood Spring, Monkey Spring, Sonoita Creek, Cienega Creek, Sheehy Spring, Sharp Spring, and the upper Santa Cruz River (Meffe et al. 1983). Two additional populations are in immediate tributaries of the mainstream Gila River. One of these, Salt Creek, is a natural population, and the other, Bylas Springs, is a reclaimed population that was treated in March 1982 to eliminate mosquitofish, Gambusia affinis (Meffe 1983). Mosquitofish persist, however, despite the treatment.

Alteration of drainage basins, water development projects and artificial desiccation have caused extensive loss of Gila topminnow habitat. Introductions of exotic predatory and competitive fishes, particularly G. affinis, have caused the extirpation of P. o. occidentalis throughout much of its range. Meffe et al. (1983) attributed predation by mosquitofish as the primary causal factor in the decline of P. o. occidentalis and its sister taxon, P. o. sonoriensis in the Rio Yaqui system. Threats of habitat loss and mosquitofish introductions continue for the remaining populations.

Gila River snails — Indeterminate. — At least 14 hydrobioid snails are endemic to localized areas of the Gila River system. The following snails occur in the Verde River drainage of Arizona: Tavasci Spring springsnail (Fontelicella sp., endemic to Tavasci Spring, Yavapai County), Fossil Spring springsnail (*Fontelicella* sp., endemic to several springs feeding Fossil Creek, Gila and Yavapai Counties), Verde Rim springsnail (Fontelicella sp., endemic to Nelson Place Spring, Yavapai County), Page Springs springsnail (Fontelicella sp., endemic to Lo-Lo-Mai, Bubbling Pond and Page Springs, Yavapai County) and Montezuma Well springsnail (Fontelicella sp., endemic to Montezuma Well, Yavapai County) (Landye 1981). Four snails occur in springs along the Gila River: New Mexico hot spring springsnail (Fontelicella sp.) and Gila springsnail [Fontelicella sp., both endemic to springs along the Gila River just within the Gila Wilderness Area boundary, Grant County, New Mexico (Taylor 1983)] , Bylas springsnail (Fontelicella sp.) and Bylas tryonia [Tryonia sp., both snails endemic to springs near Bylas, Graham County, Arizona (Landye 1981)1. Four snails occur in isolated parts of the Santa Cruz or San Pedro River drainages in southern Arizona: Canelo Cienega springsnail (Fontelicella sp., endemic to springs of the Canelo Hills Cienega, Santa Cruz County), Monkey Spring springsnail (*Fontelicella* sp., endemic to Monkey and Cottonwood Springs, Santa Cruz County), Sheehy springsnail (*Fontelicella* sp., endemic to Sheehy Spring, Santa Cruz County) and Huachuca springsnail (*Fontelicella* sp., endemic to Peterson Ranch Springs, Cochise County) (Landye 1981). An undescribed genus and species, the Three Forks hydrobioid, is found in springs forming headwaters of the Black River, Apache County, Arizona. Its closest relationships are with desert spring snails, even though the habitat exceeds 2,400 meters in elevation (Landye 1981). The taxonomic status of all

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these snails is uncertain and in need of reevaluation. Several of the snails (i.e., Bylas springsnail, Bylas tryonia, Sheehy springsnail, Monkey Spring springsnail and Canelo Ciénega springsnail) occur with native fishes treated in this account.

SUMMARY.—Historically, the Gila River drainage provided habitat for twelve fishes of concern, including the monotypic fish genera Meda, Plagopterus, Tiaroga and Xyrauchen. When settlers first arrived in central Arizona, the Gila River was a large, perennial stream of clear to sea-green water throughout its course (Miller 1961). In the mid-1800's, large flatboats floated the river from near Phoenix to its confluence with the Colorado River (Miller 1961). Now, the river is usually dry west of Phoenix, tributary streams are incised and eroded, and formerly-extensive belts of riparian vegetation now exist only in small remnants.

Changes in habitats have closely paralleled declines in native fishes. Ptychocheilus lucius, which used to run up the San Pedro River as far as Fairbank, Cochise County (Miller 1961), has been eliminated from the entire Gila River system. All naturally-occurring populations of Gila elegans, Plagopterus argentissimus and Xyrauchen texanus also have been extirpated from the drainage. Cyprinodon macularius has been eliminated from the Gila River Basin but remains in a portion of the lower Colorado River. The Monkey Spring pupfish, Arizona's only fish endemic to a single spring, also has been extirpated. Competition and predation from exotic fishes and habitat loss from reduced stream flows are primary causes in reduction of the native ichthyofauna of the Gila River system.

Although much of the native fish habitat within the Gila River Basin has been lost, a number of natural refugia remain. One refugium for many native fishes is Aravaipa Creek, a small Sonoran Desert stream tributary to the San Pedro River. Seven native fishes, Catostomus insignis, C. clarki, Ago sia chrysogaster, Gila robusta, Meda fulgida, Rhinichthys osculus and Tiaroga cobitis still occur under natural conditions in the creek (Barber and Minckley 1966, Schreiber and Minckley 1981). Several spring systems, such as Bylas, Sheehy and Monkey, still provide good habitat for remaining native fishes and snails. Preservation of remaining refugia is essential to prevent further extinctions in the Gila River system.

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RIO GRANDE, NEW MEXICO, TEXAS, CHIHUAHUA, COAHUILA, NUEVO LEÓN AND TAMAULIPAS

PLATE III. Devil's River near Pafford's Crossing, Val Verde County, Texas. The Devil's River, a tributary of the Rio Grande, provides habitat for *Dionda diaboli, Notropis proserpinus, Cyprinodon eximius* ssp. and *Etheostoma grahami.* Photograph taken March 1979 by Robert J. Edwards.

One of the longest rivers of North America and the American Southwest, the Rio Grande begins in the San Juan Mountains of Colorado and flows in a southerly direction. It bisects the state of New Mexico and travels southeasterly as the boundary between the United States and Mexico, to its mouth, which empties into the Gulf of Mexico. Middle reaches of the Rio Grande pass through some of the most arid portions of the Chihuahuan Desert region and this greatly influences the character of the river. Because of its great length, the river passes through a number of biotic zones, including montane stream habitats in its upstream reaches, the New Mexico Highlands, the Chihuahan Desert and the steep canyon areas of the Big Bend region of Texas. Downstream, the river crosses the western edge of the Edwards Plateau near Del Rio/Ojinaga and emerges as a sluggish lowland coastal river meandering to the Gulf of Mexico.

Water withdrawals for irrigation in New Mexico and near El Paso remove nearly all of the water from the upper Rio Grande. The river remains dry or has minimal flow for nearly 300 km through the Chihuahuan Desert until the much more abundant waters from the Rio Conchos enter the Rio Grande above the Big Bend region near Presidio/ Ojinaga. Downstream from the Big Bend, water from a second major tributary, the Pecos River (discussed elsewhere in this monograph), enters the Rio Grande in the vicinity of Del Rio/Ciudad Acucia. Also in this area, other significant streams such as the Devil's River and San Felipe Creek also join with the Rio Grande. The Río Conchos, which originates on the eastern slopes of the Sierra Madre Occidental, has a major impoundment (Presa Luis L. León) that regulates its flow and essentially regulates the water flow in the Rio Grande in the Chihuahuan Desert region. The Río Conchos is herein considered a separate ecosystem because of its unique ichthyofauna and large size (Smith and Miller, in press).

SPECIES ACCOUNTS.—Rio Grande cutthroat trout, *Salmo clarki virginalis* — Rare. — This subspecies of cutthroat trout maintains a number of viable populations in the upper

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Rio Grande drainage in Colorado and New Mexico (Wallace and Behnke 1974). Two major threats exist for this form: (1) siltation, erosion and other habitat alterations resulting from effects of timber removal and (2) competition and introgressive hybridization by introduced salmonids. At present, numbers of Rio Grande cutthroat trout seem stable and conservation agencies in both Colorado and New Mexico appear to be recognizing and adequately managing this resource (J. E. Johnson, pers. comm.).

Devils River minnow, *Dionda diaboli* — Vulnerable. — The range of this species is limited to springfed flowing portions of the Devil's River, San Felipe and Las Moras Creeks near Del Rio, Val Verde County, Texas, and also the Rio San Carlos, Coahuila, Mexico (Hubbs and Brown 1956). Each of these systems was dramatically affected when Amistad Reservoir was filled. Not all impacts were related to inundation of formerly flowing-water environments from the filling of this reservoir. Greater water head pressures in the portion of the aquifer downstream from Amistad caused increases in spring and stream flows in nearby San Felipe Creek. Much of the range of the Devils River minnow, however, was lost during the initial filling of the reservoir. This species apparently requires springfed stream environments. Loss of habitat resulting from the construction of Amistad Reservoir, inappropriate land and water management activities for flood control in the Las Moras Creek, San Felipe Creek and Del Rio areas, as well as only limited amounts of suitable habitats in San Carlos Creek, comprise the major threats to this species. Largely because of political, rather than biological considerations, the U.S. Department of the Interior has withdrawn the Devils River minnow from consideration of listing as a threatened species.

Phantom shiner, *Notropis orca* — Extinct. — This species, part of the *Notropis simus* complex (Chernoff et al. 1982), originally occupied the Rio Grande from central New Mexico (Bernalillo County) to the mouth of the river (Cameron County, Texas). During the last several decades, this species has been rare and not often collected (e.g., see Treviño-Robinson 1959). The last known specimen was taken in a series of collections in the Lower Rio Grande near Ciudad Diaz Ordaz/Los Ebanos in 1975 (Olmos 1976). Since then, no individuals have been found despite considerable collection efforts (Hubbs et al. 1977a; Edwards and Contreras-Balderas, ms.). Decreases in stream flows, habitat modification and degradation of water quality appear to have caused extinction of this species.

Proserpine shiner, *Notropis proserpinus* — Vulnerable. — This species was recently confirmed to represent a taxon distinct from the closely related *N. panarcys* (Hubbs and Miller 1978). *Notropis proserpinus* is restricted to the lower portions of the Pecos River, Devil's River, and San Felipe, Las Moras and Pinto Creeks, in Texas, and the Rio San Carlos, south of Ciudad Acuña, Coahuila, Mexico. In these springfed stream habitats, proserpine shiners commonly inhabit areas with moderate to little current; however, they appear intolerant of the lentic conditions provided by Amistad Reservoir, which inundated lower portions of the Pecos and Devil's Rivers and extirpated this species from these areas. Like the Devils River minnow, proserpine shiners are facing a number of threats including loss of habitat and changes in water flow characteristics resulting from Amistad Reservoir, inappropriate land and water management practices in the San Felipe Creek area and limited suitable habitat in other small creeks where the species occurs.

Rio Grande bluntnose shiner, *Notropis simus simus* – Extinct. — This subspecies originally occured in the Rio Grande from Rio Arriba County, New Mexico, downstream to El Paso/Juarez (Chernoff et al. 1982). Decreases in stream flows, habitat modification and degradation of water quality are presumed to have caused a similar fate for this subspecies as for the phantom shiner. The last collection of this taxon was in 1964 from Sandoval County, New Mexico (Chernoff et al. 1982).

Devils River pupfish, *Cyprinodon eximius* ssp. — Vulnerable. — The Conchos River pupfish *(Cyprinodon eximius)* complex is native to the Rio Conchos, Rio Sauz, Alamito Creek, Rio Alamo, Tornillo Creek and the Devil's River. Because of this relatively large range and the disjunct nature of many populations, Miller (1976a) considered the group to be composed of a series of subspecies, one of which is the Devil's River population. In these environments, this pupfish inhabits river-edge and shallow-water habitats, often close to springs, spring runs or seeps. Inundation of the lower Devil's River by Amistad Reservoir drastically reduced the range of this form and the subspecies was considered extinct. None was taken in a large series of collections during 1974 and 1975 (Harrell 1978). However, a small population was found in 1977 in the Pafford's Crossing area, immediately upstream from the lentic waters of the impoundment (Davis 1980). Individuals that once inhabited upstream environments (near the Dolan Creek and Dolan Falls areas) apparently were exterminated by combined effects of major floods, reduced spring flows, an alleged rotenone "renovation" and perhaps development of a campground in the Dolan Creek area (Davis 1980, Garrett 1980). In 1979, a small sample of pupfish from the Pafford's Crossing area was transported upstream to Dolan Creek, where they subsequently reproduced and appear to have reestablished a population. Declining springflows, in combination with tremendous loss of habitat because of Amistad Reservoir, apparently represent the greatest threat to this pupfish.

Amistad gambusia, *Gambusia amistadensis* — Extinict. – This gambusia was endemic to Goodenough Springs, once the third-largest spring system in Texas (Brune 1975). In 1969, waters impounded by the newly constructed Amistad Reservoir inundated these springs and created a recharge zone where a springs system formerly had been present. This exterminated the spring habitat and subsequently caused extinction of the natural population (Peden 1973). Specimens of Amistad gambusia were collected from among the cacti and other desert vegetation in the flooded coun-

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tryside near the immersed springs and were maintained in artificial cultures at the University of Texas in Austin. A portion of those stocks was transferred to Dexter National Fish Hatchery in New Mexico. Genetic contamination of both stocks by mosquitofish (G. affinis) was discovered in 1982, and no G. amistadensis were found alive in any of the cultures (Hubbs and Jensen 1984).

Big Bend gambusia, Gambusia gaigei — Endangered. — This species is restricted to the small Boquillas Springs and runs in the Rio Grande Village campground area of Big Bend National Park (Hubbs and Brodrick 1963). Although extirpated from its type locality within the park and at three different times extinct in nature, a laboratory culture of this species at the University of Texas at Austin was used to reestablish this rare gambusia into a number of suitable spring areas and a manmade refugium in Big Bend National Park. Threats have included predation from repeated introductions of green sunfish (Lepomis cyanellus) that have been removed each time (Hubbs and Brodrick 1963, Hubbs and Echelle 1972); competition from mosquitofish (Gambusia affinis) that enter the spring system from the Rio Grande (Hubbs and Springer 1957, Hubbs et al. 1977b); declining spring flows because of human demands for a limited water supply within the National Park; deaths related to cold shock in the refugium area (Hubbs and Williams 1979); and periodic flood events in the Rio Grande Village area, which scour the springs (Hubbs et al. 1977b).

Rio Grande darter, Etheostoma grahami — Vulnerable. — This species is native to Devil's River, lower Pecos River, Independence Creek and San Felipe Creek, Val Verde County, Texas. It also occurs in the Rio Salado and Río San Juan, Nuevo Leon, and presumably in nearby streams and springs in Coahuila, such as the Rio San Carlos south of Ciudad Acuña (Harrell 1980; Kuehne and Barbour 1983; R. R. Miller, pers. comm.). This species is adapted to the clear, springfed, flowing streams of these tributaries of the Rio Grande. Much of its range was inundated by Amistad Reservoir, which caused extinction of the type population (Hubbs and Echelle 1972). Controversial land and water management practices within the San Felipe watershed, including channelization and other stream modifications, could further reduce the limited amount of suitable habitat to an even greater degree.

Socorro springsnail, Fontelicella neomexicana — Endangered. — Fontelicella neomexicana was historically known from only Sedillo Springs, Socorro County, New Mexico, where it has been eliminated (Landye 1981, Pilsbry 1916). Landye (1981) discovered a population of this species in nearby Torreon Springs, where it has been restricted to less than three meters of spring outflow because of impoundments (Taylor 1983).

Chupadera springsnail, Fontelicella sp. — Rare. — This snail is known only from Willow Spring, Socorro County, New Mexico, where it is abundant (Taylor 1983). However, any modification of the spring could easily reduce or eliminate the species.

Alamosa tryonia, Try onia sp. — Rare. — Distribution of this snail is restricted to a group of thermal springs near the head of perennial flow in Alamosa Creek, Socorro County, New Mexico (Taylor 1983). Taylor (1983) found the species at two localities, Ojo Caliente and a spring about 1 km to the west, where they are abundant. Present ownership and land use (grazing) are not detrimental to the snail populations, but development of the springs for pumping or other major modification would quickly render the snail endangered.

Boquillas isopod, Therm osphaeroma subequalum — Endangered. — Cole and Bane (1978) described this close relative of the Socorro isopod from thermal springs in Boquillas Canyon and the Rio Grande Village nature trail, Brewster County, Texas. It is protected by its location in Big Bend National Park, but because of reasons summarized for the Big Bend gambusia, this species should be considered endangered.

Socorro isopod, Thermosphaeroma therm ophilum — Endangered. — The historic distribution of Therm osphaeroma therm ophilum included Sedillo, Socorro and Cook Springs near Socorro, Socorro County, New Mexico, but it is now restricted to an approximately 30 m stretch of habitat between Sedillo Springs and a bathhouse (Hubbard et al. 1978). The near extinction of this species was caused by diversion and capping of its thermal springs habitat.

Mussel, Disconaias salinasensis — Indeterminate. — This species is restricted to the Rio Grande drainage, where it occurs in the Rio Grande proper, lower Conchos, Pecos and Devil's Rivers, and certain tributaries of these streams (R. W. Neck, pers. comm.). Impoundments, water pollution and reduced water flows appear to have caused declines in distribution and abundance during recent years.

Pope's mussel, Popenaias popei — Indeterminate. — Distribution of this species includes the lower Pecos River, the lower Rio Grande and certain tributaries in Texas and Mexico (Taylor 1983). Declines in its distribution and abundance have been noted (R. W. Neck, pers. comm.; Taylor 1983) because of decreasing water flows and quality.

SUMMARY.—The Rio Grande is the largest stream system passing through the Chihuahuan Desert. Many fishes and invertebrates unique to this drainage appear in danger of extinction or are now extinct. Water withdrawals, modifications to the stream course and reduced water quality because of human-cultural activities apparently have caused the extinction of three fishes.

The general decline of water flows and quality in the Rio Grande is exhibited in the loss of certain big-river fishes from the river. Although present in many of the larger rivers in the eastern and southern United States, the shovelnose sturgeon, Scaphirhynchus platorynchus, longnose gar, Lepisosteus osseus, and blue sucker, Cycleptus elongatus, have been eliminated or greatly reduced in the Rio Grande system.

Reductions in recharge to aquifers feeding the spring

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systems in the lower Pecos River and the Devil's River have been caused by overgrazing, along with water withdrawals and loss of habitat caused by reservoir construction. As a result, much of the free-flowing portions of these streams have been destroyed. With these losses, many habitats suitable for native species have been lost. A number of non-native fishes have been introduced into Amistad Reservoir for sportfishing purposes, including walleye *(Stizostedion vitreum),* striped bass *(Morone saxatilis),* white bass *(Morone chrysops),* various hybrid combinations of the latter two species, smallmouth bass *(Micropterus dolomieui)* and blue tilapia *(Oreochromis aureus).* These species can enter the free-flowing portions of the Devil's and Pecos Rivers and represent potential, but uncertain threats for the native fauna. Smallmouth bass have been taken in close proximity to pupfish habitat near the Pafford's Crossing area of the Devil's River in 1979, and would likely consume pupfish as part of their diet. Because of their unique faunas, the Devil's River and San Felipe Creek areas are especially in need of preservation as biotic refugia.

PECOS RIVER, NEW MEXICO AND TEXAS

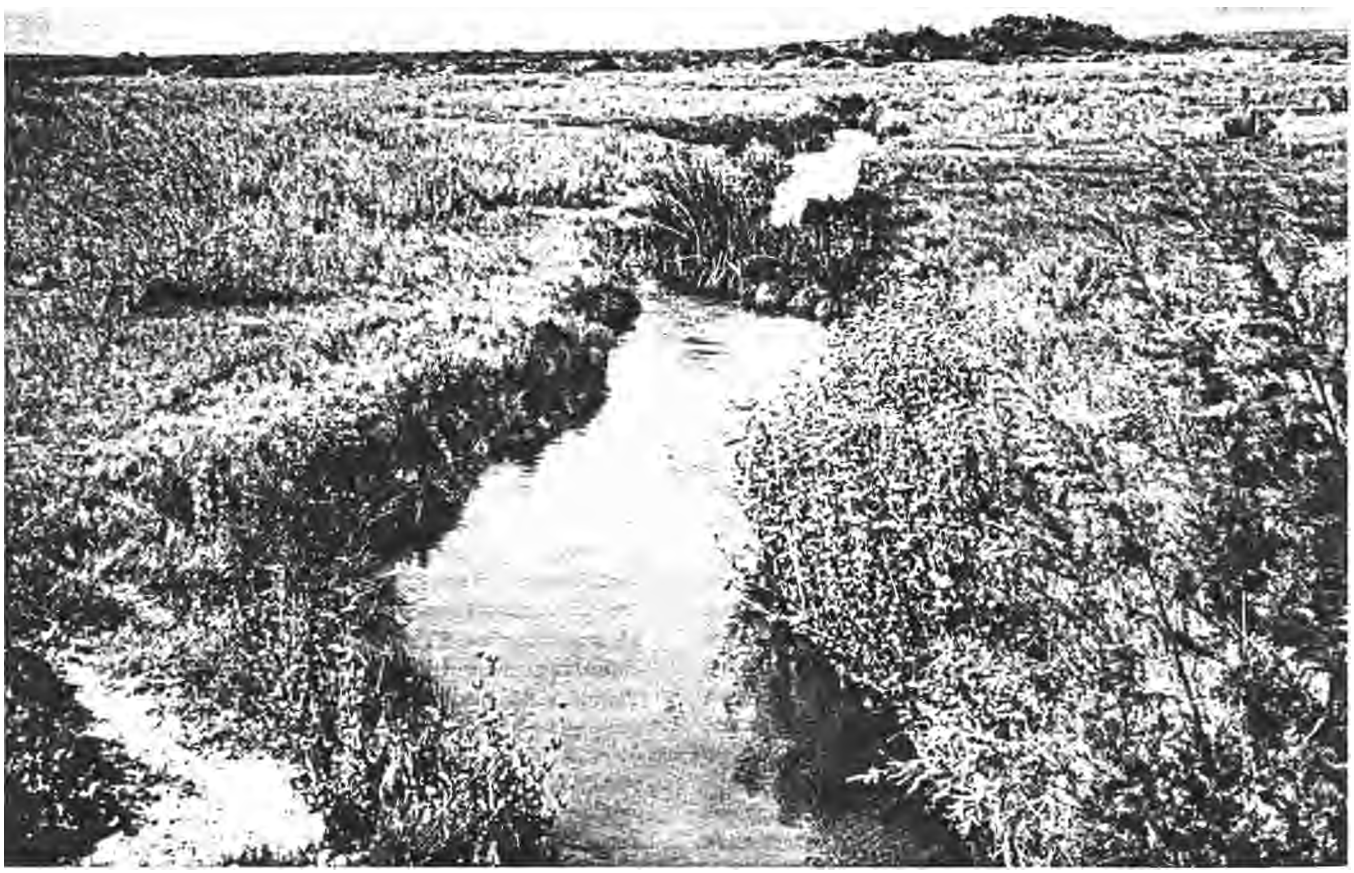

PLATE IV. Upper segment of Blue Spring, Eddy County, New Mexico. *Dionda episcopa, Gambusia nobilis, G. affinis, Etheostoma lepidum* and the *introducedAmbloplites ruprestris* occur at this site. Photograph taken April 1972 by Anthony A. Echelle.

The Pecos River extends 920 km south-southeast from Mora County, north-central New Mexico, to its confluence with the Rio Grande in Val Verde County, southwestern Texas. The Pecos Valley is bounded on the east primarily by a steep escarpment defining the western edges of the Staked Plains (Llano Estacado) and the Edwards Plateau, and on the west by foothills of a series of mountain ranges. Nearly all major tributaries arise in mountains at the northern end or on the western side of the drainage. The one exception is Howard's Creek, a tributary, which arises on the Edwards Plateau. Average annual discharge near the mouth of the river is about 2.6 x 10^{9} m^{3}, but can fluctuate as much as an order of magnitude depending on precipitation (Stout et al. 1961).

A great diversity of aquatic habitats occurs in the Pecos River ecosystem (herein defined as the Pecos River proper and associated waters on the floodplain). Originating in the Sangre de Cristo Mountains as a coldwater trout stream, the headwater one-fifth of the river is a rocky-bottomed, relatively **high-gradient (4.8 to 21.9 m/km)** stream; the

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middle three-fifths, from below Fort Sumner, DeBaca County, New Mexico, to Sheffield, Pecos County, Texas, is a sluggish (ca. 1 m/km), soft-bottomed, meandering stream with occasional rocky riffles; the remaining downstream section has moderate gradient (1.9 to 2.3 m/km) and frequent rocky riffles. Because of water storage upstream, a lack of freshwater input, and oil field pollution, a 300-km section of stream from Malaga, New Mexico, to Sheffield, Texas, often has salinities in excess of 10 ppt and locally as high as 25.1 ppt (Hubbs 1957, Hubbs and Echelle 1972).

Human activities have drastically altered normal flow regimes of the Pecos River. Extensive irrigation diversion canals occur in the Artesia-Carlsbad, New Mexico area. Five major reservoirs have been constructed on the Pecos River (in New Mexico: Los Esteros Reservoir, Lake Sumner, Lake McMillan, Avalon Reservoir; in Texas: Red Bluff Lake), and one, Amistad Reservoir, an impoundment of the Rio Grande, inundates 10 to 20 km of the lower Pecos. Also, there are several minor impoundments in the Carlsbad area. Because of extensive groundwater pumpage between Fort Sumner and Carlsbad, the water table has been lowered to the extent that groundwater seepage flows are drastically reduced. This, coupled with a controlled release of water from Lake Sumner, significantly reduces flow and often desiccates the river in the Roswell area.

SPECIES ACCOUNTS.—Rio Grande cutthroat trout, *Salmo clarki virginalis* — Rare. — This subspecies occupies headwater tributaries of the Pecos River above the town of Pecos, San Miguel County, New Mexico. Primary threats include hybridization and/or competition with introduced congeners (rainbow trout and stocks of the Yellowstone cutthroat) and competition with introduced populations of brown and brook trout (Hatch 1977). Apparently because of competition with introduced trouts, the distribution of this subspecies has diminished within the Pecos as well as in other portions of its range, i.e., the upper Rio Grande and Canadian River.

Proserpine shiner, *Notropis proserpinus* — Vulnerable. — This species is known only from "the lower Pecos River basin, the nearby Devil's River... and a few smaller creeks . . . , all in Texas," and a single locality in the Rio San Carlos, Coahuila, Mexico (Hubbs and Miller 1978). Although locally common in collections (e.g., Harrell 1978), much of the Texas range was inundated by Amistad Reservoir (Hubbs and Echelle 1972) and the present spotty and restricted distribution cause concern for its future survival.

Pecos bluntnose shiner, *Notropis simus pecosensis* — Vulnerable. — This apparently is the only extant form of *Notropis simus*. The nominate subspecies is extinct (Chernoff et al. 1982; M. D. Hatch, pers. obs.). *Notropis s. pecosensis* is known with certainty only from the mainstream of the Pecos River in New Mexico where it now occurs regularly, but in low abundance, from Fort Sumner to the Artesia area and occasionally below Lake McMillan at Major Johnson Springs. Seasonal abundance fluctuates markedly. Preferred habitat seems to be areas with low velocity flows and moderate depths over shifting sandy bottoms (M.D. Hatch, pers. obs.). Survival may be dependent on groundwater seepage. The previously mentioned altered and reduced flow of the river because of human activity is a major factor in the reduced range of this subspecies.

Leon Springs pupfish, *Cyprinodon bovinus* — Endangered. — *Cyprinodon bovinus* originally was known and described only from specimens collected in 1851 from "Leon's Springs" (Echelle and Miller 1974, Girard 1859). Subsequent collection efforts failed and the species was considered extinct (Miller 1961) until W. L. Minckley and W. E. Barber collected the pupfish in 1965 from Diamond Y Spring, a tributary spring of Leon Creek. *Cyprinodon bovinus* now survives in a short section of Leon Creek and in Diamond Y Spring, Pecos County, Texas, but has been extirpated from the type locality (Echelle and Miller 1974). The remaining population is threatened by pollution from a nearby oil refinery, competition from exotic fishes and habitat alteration.

Comanche Springs pupfish, *Cyprinodon elegans* — Endangered. — The native range of this species is restricted to two isolated spring systems in the Pecos River drainage of southwestern Texas. *Cyprinodon elegans* was initially described from specimens collected in Comanche Springs, Pecos County. Because of excessive overdraft of the groundwater supply, Comanche Springs failed in 1955 (Brune 1975) and the typical population was extirpated. The remaining population persists in a series of interconnected springs in the Balmorhea area of Reeves and Jeff Davis Counties. Within the Balmorhea area, the outflows of Phantom Lake Spring, San Solomon Springs and Giffin Springs provide the primary habitats, which consist of concrete and earthern irrigation canals (U.S. Fish and Wildlife Service 1981). Excessive groundwater pumping, channelization and diversion of outflows as well as introgressive hybridization with introduced *C. variegatus* threaten the remaining population (Davis 1979, Ono et al. 1983).

Pecos River pupfish, *Cyprinodon pecosensis* — Vulnerable. — This pupfish is endemic to the Pecos River (Echelle and Echelle 1978). It occurs abundantly in saline oxbows near Roswell and in nearby isolated springs and gypsum sinkholes, but seems uncommon in riverine habitat above Carlsbad. Below Carlsbad, it occurs in local abundance in more saline portions of the river. Available habitat in the Roswell area has declined with the previously mentioned lowering of the water table and the resulting loss of spring/sinkhole habitat.

Pecos gambusia, *Gambusia nobilis* — Vulnerable. — Except for introduced populations in a sinkhole on the Salt Creek Wilderness area near Roswell and another at the Living Desert State Park near Carlsbad, this species occurs only in four small springfed systems in the Pecos River Basin. In New Mexico, it occurs in semi-isolated springs and gypsum sinkholes on the Pecos River floodplain at the Bitter Lake National Wildlife Refuge, Chaves County, and

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in Blue Spring, Eddy County. In Texas, it occurs in Diamond Y Spring and associated waters of lower Leon Creek, Pecos County, and in the Balmorhea area, Reeves and Jeff Davis Counties (U.S. Fish and Wildlife Service 1982). Survival of this species is totally dependent on springflows. Because of the lowering of the water table by groundwater pumping, available habitat has declined throughout the range of the species. This includes extinction of once-large populations when Comanche Springs and Tunis Spring dried in the 1950's. On the Bitter Lake Wildlife Refuge, sinkholes were once interconnected by surface waters, but present water level is 2 to 3 m below the interconnecting system of canals. A number of sinkholes once having relatively permanent water are now dry for most of the year (D. Boggs, pers. comm.). Decline of the Balmorhea population may be attributable to competition with an introduced congener, G. geiseri (Echelle and Echelle 1980).

Rio Grande darter, Etheostoma grahami — Vulnerable. — This species occurs in the lower Pecos River proper and two tributaries, Howard's Creek and Independence Creek (Echelle et al. 1984). Elsewhere, it occurs at undetermined levels of abundance in certain Mexican tributaries of the Rio Grande and is locally common in Devil's River and associated tributaries of the Rio Grande in Texas (Harrell 1978, Hubbs and Echelle 1972). A significant portion of its presumed native range in the lower Pecos was inundated by Amistad Reservoir.

Pecos assiminea, Assiminea sp. — Vulnerable. — This undescribed snail is native to the Diamond Y Spring complex, Pecos County, Texas, but possibly is present in other suitable spring areas of the Leon Creek drainage (Landye 1973). Threats are primarily from reduced spring flows and pollution from nearby oil fields. Taylor (1983) also referred two Chaves County, New Mexico, populations to this species. One population at Roswell Country Club Spring has been extirpated, and the second, at Bitter Lake National Wildlife Refuge, is restricted to an area of less than 18 square meters.

Phantom Spring cochliopa, Cochliopa texana — Endangered. — This snail is native to Phantom Lake Spring and associated outflows in Reeves County, Texas (Dundee and Dundee 1969, Landye 1973). Reduced spring flow as well as channelization and diversion activities have reduced known populations (Landye 1973).

Roswell springsnail, Fontelicella sp. — Vulnerable. — This snail is endemic to a series of springs in the Roswell area of Chaves County, New Mexico, but is now restricted to Roswell Country Club Spring and three small springs on Bitter Lake National Wildlife Refuge (Landye 1981, Taylor 1983). The major threat to this species has been spring failure caused by excessive pumping of groundwater.

Blue Spring springsnail, Fontelicella sp. — Rare. — This undescribed snail is known from Blue and Castle Springs, Eddy County, New Mexico (Landye 1981). Population levels apparently have remained stable during recent years, with the snail occurring in densities of $2/cm^2$ in optimal habitats of Blue Spring (Landye 1981).

Diamond Y pondsnail, Physa virgata bottomeri — Vulnerable. — This subspecies is known from the Diamond Y Spring complex and Leon Creek, Pecos County, Texas (Clench 1924). Reduced spring flows and pollution are the primary threats to this taxon. Excessive groundwater pumping and the resultant failure of Comanche Springs eliminated P. v. bottomeri from that locality.

Phantom Lake tryonia, Tryonia cheatumi — Endangered. — The distribution of this snail and threats to its continued existence are the same as Cochliopa texana discussed above. Landye (1973) attributed the draining of Phantom Lake as the causal factor in a major decline in range and number of Tryonia cheatumi.

Roswell tryonia, Tryonia sp. — Vulnerable. — Formally occurring in South Spring and other springs in the Roswell area, this species is now restricted to Roswell Country Club Spring and four springs on the Bitter Lake National Wildlife Refuge (Landye 1981, Taylor 1983). Like the Roswell springsnail discussed above, the range of the Roswell tryonia has been greatly reduced by spring failures. Landye (1981) reported declines of both native snail populations in Roswell Country Club Spring following alterations of the spring in the mid-1970's.

Diamond Y tryonia, Tryonia sp. — Vulnerable. — This undescribed snail is known only from Diamond Y Spring and its outflows, Pecos County, Texas (Landye 1973). As with the Diamond Y assiminea, threats are primarily from reduced spring flows and pollution.

New Mexico ramshorn snail — Vulnerable. — This undescribed genus and species of snail is restricted to the New Mexico portion of the Pecos River drainage, where it occurs in seasonal pools (Taylor 1983). At least one population was eliminated by construction of Interstate Highway 40 just northwest of Santa Rosa, Guadalupe County. Only two extant populations, in the Guadalupe Mountains of Eddy County, are known (Taylor 1983).

Horn mussel, Popenaias popei — Indeterminate. — Within the Pecos system, P. popei is known from lower portions of artesian springfed streams adjacent to the Pecos River in Chaves and Eddy Counties, New Mexico, and from the mainstream Pecos (Taylor 1983). During the early 1900's, shells from recently-living animals were collected in the North Spring River at Roswell and in the lower Black River near Carlsbad (Taylor 1983). Remnant populations may persist in the Pecos River drainage but are unknown. Impoundments, pollution and overdraft of groundwater are causal factors in the decline. Rarity of essential native fish host(s) for the parasitic larval stage may contribute to the decline of this and other freshwater mussels in the American Southwest.

Phantom Spring amphipod, Gammarus hyalello ides — Endangered. — This species, and perhaps a second undescribed species of Gammarus, is endemic to Phantom Lake Spring, Reeves County, Texas (Cole 1976, pers. comm.). It is threatened by channelization and reduced water flows.

Pecos amphipod, Gammarus pecos — Vulnerable. — This

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species is native to Leon Creek and Diamond Y Spring, Pecos County, Texas (Cole and Bousfield 1970). Threats are primarily from reduced spring flows and pollution.

San Solomon amphipod, Gammarus sp. — Endangered. — Gammarus sp. is native to the San Solomon Springs, Reeves County, Texas (G. A. Cole, pers. comm.). This crustacean is threatened by groundwater pumping as well as channelization and diversion of spring flows. Its taxonomy is uncertain and in need of study.

Noel's amphipod, *Gammarus* desperatus — Endangered. — This undescribed member of the G. pecos species complex is endemic to springs along the Pecos River, but presently is known only from Roswell Country Club Spring (Cole 1981). Cole (1981) reported that, possibly, the species was extirpated from Landers Spring Brook in the Roswell area of Chaves County by reduced spring flows. Further distribution of this species, either historical or present, is unknown.

SUMMARY.—Three species and one subspecies of fishes are endemic to the Pecos River. The Pecos River system also harbors five other rare fishes and at least 12 invertebrates of highly restricted distribution. Reservoir construction, irrigation diversion canals and lowering of the water table by groundwater pumpage are major factors contributing to loss of habitat for most of these species, while hybridization and/or competition with congeners has adversely affected Salmo clarki *virginalis*, Gambusia nobilis and Cyprinodon elegans.

Pumping of groundwater and the resulting reduction of springflows is especially critical for Gambusia nobilis, Cyprinodon bovinus, C. elegans and associated aquatic species that inhabit springs, their outflow creeks and adjacent marshes. Maintenance of spring flows is critical for the survival of five taxa (Cyprinodon bovinus, *Gambusia* nobilis, Assiminea sp., Tryonia sp. and Physa virgata bottermeri) in the Diamond Y Spring/Leon Creek system and five taxa (Cyprinodon elegans, Gambusia nobilis, Cochliopa texana, Tryonia cheatumi and amphipods of the Gammarus pecos complex) in the Balmorhea area. Overdraft of the groundwater supply has already caused failure of Tunis Spring, Comanche Springs, Leon Springs and others in the region. In the early 1900's Comanche Springs discharged approximately 102,000 liters per minute, and Leon Springs discharged about 34,000 1/min, but by 1962, neither spring produced a measurable flow (Armstrong and McMillion 1961, Brune 1975, Echelle and Miller 1974).

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RAILROAD VALLEY, NEVADA

PLATE V. Little Warm Spring, Nye County, Nevada. Crenichthys nevadae and two undescribed snails are native to this small spring. No exotic fish are present. Photograph taken 17 October 1981 by Jack E. Williams.

Railroad Valley is an endorheic drainage basin in Nye and White Pine Counties of central Nevada. The valley encompasses approximately 9,233 km^2, and is dominated by the playa of pluvial Lake Railroad in its southern one-half (Snyder et al. 1964).

Aquatic habitats are sparse but include a series of coolwater springs (Kate, Butterfield, Blue Eagle and others) near the eastern margin of the Lake Railroad playa. Additional coolwater springs, Green Springs and the headwater springs of Bull Creek occur in the northern end of the valley. Primary thermal springs are located in the Lockes Ranch area near the western edge of the playa and farther north at Duckwater. Several of the springs are extensive with large spring pools and lengthy outflow creeks. Two of the largest springs, Big Warm Spring in Duckwater and Big Spring at Lockes Ranches, discharge approximately 22,059 and 1,900 liters per minute, respectively (Garside and Schilling 1979).

SPECIES ACCOUNTS.–Kate Spring tui chub, *Gila bicolor* ssp. — Vulnerable. — The Kate Spring tui chub, one of six undescribed subspecies of *Gila bicolor* in Railroad Valley, is confined to Kate Spring and its outflow (Deacon and Williams 1984). Channelization and the presence of exotic goldfish, Carassius auratus, threaten the existence of the native fish (Williams and Williams 1981).

Butterfield Spring tui chub, *Gila bicolor* ssp. — Indeterminate. — This undescribed subspecies is endemic to Butterfield Spring (Deacon and Williams 1984). Its current status is uncertain.

Blue Eagle Spring tui chub, *Gila bicolor* ssp. — Vulnerable. — This undescribed tui chub is restricted to Blue Eagle Spring and its outflow (Deacon and Williams 1984). Carp and goldfish have been introduced into the spring and have eliminated tui chub from the spring pool, but the tui chub remains in the outflow creek (Williams and Williams 1981).

Bull Creek tui chub, *Gila bicolor* ssp. — Rare. — This subspecies is confined to Bull Creek and its unnamed headwater springs (Deacon and Williams 1984). The tui chub is common throughout the length of Bull Creek despite some channelization and overgrazing of the riparian area. No exotic fishes are present.

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Green Springs tui chub, Gila bicolor ssp. — Rare. — This tui chub is endemic to Green Springs near the northern most extent of Railroad Valley in White Pine County (Deacon and Williams 1984). It is rare within the Green Springs system although no exotic fishes are present.

Railroad tui chub, Gila bicolor ssp. — Indeterminate. — Within Railroad Valley, this subspecies is known from Duckwater Creek. It is also known from the nearby Little Fish Lake and Hot Creek Valleys (Deacon and Williams 1984). Overgrazing, channelization and diversions have disrupted Duckwater Creek and reduced suitable habitat. Channel catfish, Ictalurus punctatus, have been introduced into the outflows of Big Warm Spring, which supply water for Duckwater Creek. Tui chubs can be expected to be further reduced by predation as the channel catfish spread into Duckwater Creek. The status of the Railroad tui chub in Little Fish Lake is unknown although the population in Twin Springs Slough, Hot Creek Valley, appears to be in good condition.

Railroad Valley springfish, Crenichthys nevadae — Vulnerable. — This type species of the genus Crenichthys was described from a warm spring (most likely Big Warm Spring) at Duckwater (Hubbs 1932). The species is also known from nearby Little Warm Spring and five springs further south in Railroad Valley at Lockes Ranch: Big, Hay Corral, North, Reynolds 1 and Reynolds 2 (Hubbs et al. 1974; Williams 1985). Introduced populations exist near the southern end of Railroad Valley at Chimney Hot Springs as well as springs at Sodaville in Mineral County (Williams and Williams 1981). Habitats at most springs have been altered by channelization and diversion. No exotic fishes occur in the springs except at Big Warm Spring, where there are guppies, Poe cilia reticulata, and channel catfish. Much of the Big Warm Spring system has been recently altered to establish an aquaculture project for channel catfish. Spring habitat has been adversely affected by construction of raceways in spring outflows and creation of adjacent rearing ponds. These changes have increased favorable habitat for the exotic guppy and have allowed it to become abundant throughout Big Warm Spring and its outflows. Channel catfish from the aquaculture project have escaped and now occur throughout the spring and its outflows. Further threats to C. nevadae are posed by uncertain spring flows in the southern portion of the valley. Failure of the Chimney Hot Springs complex during 1981 eliminated the introduced springfish population at that site (Williams 1985). Springfish have since been reintroduced into Chimney Hot Springs where springflows now have returned.

Lockes Ranch snail — Rare. — An undescribed genus and species of hydrobioid snail is endemic to Big, Hay Corral, Reynolds 1, Reynolds 2 and presumably, North Springs in the Lockes Ranch area (Deacon et al. 1980). Although highly restricted in distribution, the Lockes Ranch snail is abundant in the springs. In Big Spring it occurs in *Utricularia* and algal-sedge mats at densities as high as 30,000 to 40,000 per square meter (Deacon et al. 1980).

Currant springsnail, Fontelicella sp. — Indeterminate. — Fontelicella sp. is known only from three springs in the eastern part of Railroad Valley near Currant (Deacon et al. 1980). Preferred habitat is fast-flowing waters near headsprings and Nasturtium mats (Deacon et al. 1980).

Warm springs snail — Indeterminate. — This is an undescribed genus and species of hydrobioid snail restricted to Big Warm and Little Warm Springs in the Duckwater area (Deacon et al. 1980). Its current status is unknown.

Little Warm Spring tryonia, Tryonia sp. — Indeterminate. — Although no living specimens of this snail were found during 1980 surveys, shells of an undescribed species of Tryonia were found in Little Warm Spring (Deacon et al. 1980). This species also may occur in Big Warm Spring, but its current status in both springs is unknown.

Duckwater Springs snail — Indeterminate. — This undescribed genus and species of hydrobioid snail is known only from Duckwater Springs (Deacon et al. 1980). Its status is unknown and like other Railroad Valley molluscs, is in need of study.

SUMMARY.—Six fishes, five tui chub subspecies and the Railroad Valley springfish, are restricted to isolated springs and creeks in Railroad Valley. A sixth tui chub subspecies occurs in Railroad and two other nearby valleys. At least five hydrobioid snails, all of which are undescribed, are also known from the isolated waters of Railroad Valley. A red-legged frog inhabits Little Warm Spring, Big Warm Spring and Duckwater Creek. Kay and Emmerson (ms.) considered this frog to be an undescribed species endemic to the Duckwater area. However, recent karyological analyses indicate that the Duckwater frog probably is an introduced population of Rana aurora from the Sierra Nevada of California (D. M. Green, pers. comm.). Moreover, no such frog was noted by C. L. Hubbs and party at these localities in September 1934 and August 1938 (R. R. Miller, pers. comm.).

In the northern portion of Railroad Valley, Little Warm Spring provides an important and, until recently, a virtually undisturbed refugium for the Railroad Valley springfish and two undescribed snails. Williams (1985) reported that Little Warm Spring was channelized and its adjacent marsh burned in the spring of 1984. At this time, we are uncertain of the extent of damage to this system. Most springs in the southern portion of the valley have been channelized and/or diverted for agricultural purposes. Hay Corral and the Reynolds Springs are the least disturbed springs in the Lockes Ranch area and are free of exotic species. The effects of further groundwater withdrawal on surface flows of springs in the valley should be determined prior to expansion of petroleum development or extensive agricultural development.

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COLORADO RIVER, COLORADO, UTAH, NEW MEXICO, ARIZONA, NEVADA, CALIFORNIA, BAJA CALIFORNIA DEL NORTE AND SONORA

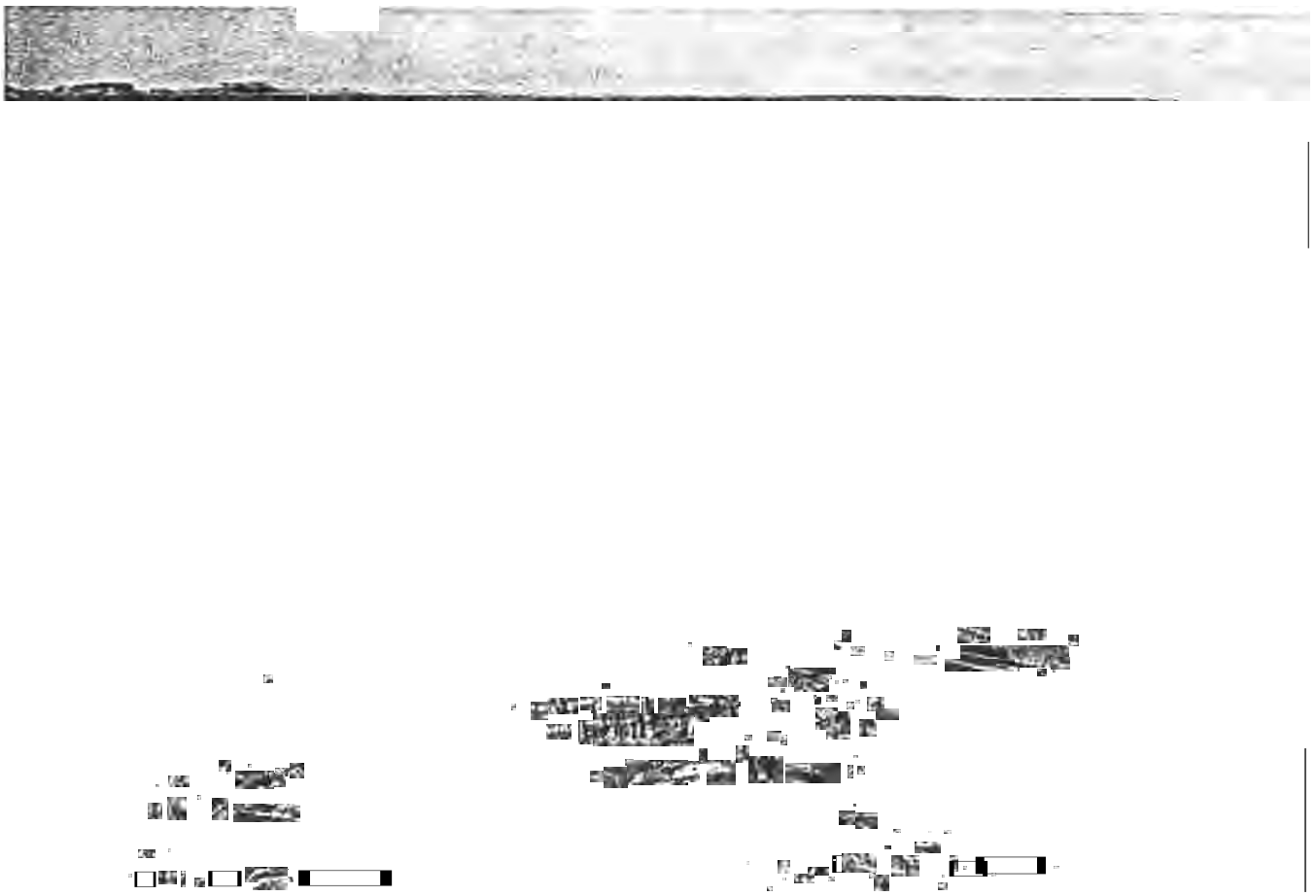

PLATE VI. Colorado River near Indian Creek, Canyonlands National Park, Utah. Natural, free-flowing stretches such as this provide refugia for the native big-river fishes, *Gila cypha, G. elegans, Ptychocheilus lucius* and *Xyrauchen texanus.* Photograph taken November 1981 by Richard A. Valdez.

The Colorado River mainstream originates in the Rocky Mountains of Colorado and flows 2,282 kilometers (excluding the Green River) through Colorado, Utah, Arizona and northern Mexico into the Gulf of California. The basin has a drainage area of 631,936 square kilometers (Anon. 1946, Anon. 1976, LaRue 1916). The Green, Gunnison, Dolores, and San Juan Rivers comprise its major upper-basin tributaries. In the lower basin, the Little Colorado, Virgin, Bill Williams, and Gila Rivers add to the flow of the Colorado.

Flows in the Colorado River are highly variable and fluctuate widely within various parts of the drainage. Prior to construction of dams, flows varied with the seasons and amount of precipitation within the drainage. Recorded flows at Yuma, Arizona, have ranged from approximately 3.0 to 7,000 cubic meters per second (U.S. Fish and Wildlife Service 1983a, b). Presently, flows are stabilized and fluctuate unseasonally because of water diversions and the presence of dams along the mainstream and tributaries. Dams also significantly alter water temperatures by releasing cold, hypolimnetic waters into downstream reaches.

Because water depletion from the Colorado River has increased yearly, flows now reach the Gulf of California only rarely during extremely wet years when large-volume releases from the reservoirs are necessary. Annual depletions at Lee's Ferry, Arizona, have increased from 0.3 to 4.7 billion cubic meters from 1896 to 1975 (Joseph et al. 1977). The average annual undepleted flow for the same period was estimated at 18.3 billion cubic meters.

SPECIES ACCOUNTS.—Colorado cutthroat trout, *Salmo clarki pleuriticus* — Rare. — This endemic to the Colorado River drainage is restricted to the upper basin (Behnke and Benson 1980). Historically, this cutthroat occurred throughout the colder headwaters of Colorado and Green Rivers (Behnke and Benson 1980). Present distribution is restricted to high mountain lakes where the fish are stocked for sport fishing purposes. Minckley (1973) indicated that

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infrequent collections from the lower basin probably resulted from incidental movement down the Colorado River. Introduction of exotic trout species and subsequent hybridization are major reasons for the decline of this subspecies (Behnke and Benson 1980, Behnke and Zarn 1976).

Humpback chub, Gila cypha — Endangered. — This bizarre-looking fish has a flattened head followed by a large, pronounced dorsal hump that tapers abruptly to a deeply-forked caudal fin. These characteristics represent adaptations for life in the turbulent Colorado River. Historic distribution of the humpback chub was concentrated in whitewater canyons of the Colorado River system as far downstream as the present site of Hoover Dam (Miller 1955, Smith et al. 1979). Included in this range were the Green, Yampa, White and Little Colorado Rivers (Holden and Stalnaker 1975, Sigler and Miller 1963, Vanicek et al. 1970). Present distribution includes Black Rocks, Debeque, Westwater, Cataract, Gray, Desolation, Marble and Grand Canyons as well as the lower Yampa River and the Little Colorado River from its mouth 14.5 km upstream (Kaeding and Zimmerman 1983, Tyus et al. 1982a, U.S. Fish and Wildlife Service 1983a). Threats to the humpback chub include dam construction, water diversion, exotic fish introductions, pollution, and hybridization with Gila elegans and G. robusta (Holden and Stalnaker 1970, Minckley 1973, Seethaler et al. 1979).

Bonytail, Gila elegans — Endangered. — A streamlined body with a smoothly arching nuchal hump typify the bonytail as a fish adapted to the turbulent flow of the Colorado River. Other morphological adaptations include a narrow caudal peduncle, falcate fins, and small, embedded scales on the nuchal hump (Minckley 1973). Historically, this endemic of the Colorado River system occurred throughout the upper and lower basins and most major tributaries (Smith et al. 1979). Now it is known to exist in pure (nonhybridized) form only in Lakes Havasu and Mohave. These populations consist of large, old adults (U.S. Fish and Wildlife Service 1983b), with individual fish estimated to be as old as 32 to 39 years of age (B. Taubert, pers. comm.). No bonytails have been collected in the mainstream Colorado River or in any of its tributaries in Utah or Colorado during the last five years (Miller et al. 1982; Wick et al. 1979, 1981). In the lower basin, the bonytail has been reduced to its present distribution by dam construction, interactions with exotic fishes, and habitat alteration (Miller 1961, Minckley 1973). Loss of the bonytail in the upper basin is a result of dam construction, water diversion and pollution as well as hybridization with other Gila species. Habitat alteration may have promoted hybridization through a loss of niche separation between the species (Holden and Stalnaker 1970, U.S. Fish and Wildlife Service 1983b).

Colorado squawfish, Ptychocheilus lucius — Endangered. — The Colorado squawfish is the largest fish endemic to the Colorado River system and is considered to be a top carnivore (Minckley 1973). It is the largest cyprinid in North America (Miller 1961). Its historic distribution included the Colorado River and its tributaries throughout the upper and lower basins into Mexico (Behnke and Benson 1980). Present distribution consists of the upper basin of the Colorado River from Grand Junction to Lake Powell (Miller et al. 1982, Minckley 1973, Persons et al. 1981) as well as those areas of the Green River system mentioned in the Green River ecosystem account of this paper. Surveys of the upper Colorado River system for larval squawfish were conducted from 1979 to 1981 to document spawning success (Haynes et al. 1984). These extensive surveys documented spawning only in a 31-km stretch of the Colorado River in Mesa County, Colorado, and the lowermost 29 km of the Yampa River in Dinosaur National Monument (Haynes et al. 1984). The decline in distribution and abundance of the squawfish is attributed to dam construction, the resultant loss of habitat and blockage of spawning and seasonal migration routes, lowered water temperatures and introductions of exotic fish species (Behnke and Benson 1980).

Las Vegas dace, Rhinichthys deaconi — Extinct. — This species was endemic to Las Vegas Creek, a small tributary to the Colorado River in Clark County, Nevada (Hubbs and Miller 1948b, Miller 1984). The Las Vegas dace, probably the most distinctive of the many forms of Rhinichthys in Nevada, was extirpated during the 1950's because of increased water use and development in the Las Vegas metropolitan area (Miller 1984).

Razorback sucker, Xyrauchen texanus — Vulnerable. — The razorback sucker, like the humpback chub and bonytail, exhibits morphological adaptations for a turbulent, riverine environment. A sharp keel behind the head rather than a round hump is, however, characteristic of the razorback sucker. Historically, this endemic of the Colorado River system occurred throughout the upper and lower basins (Minckley 1983). Present distribution in the upper basin is restricted to segments of the river not directly affected by dams (Behnke and Benson 1980, Joseph et al. 1977). In the lower basin, remnant populations of razorbacks occur in Lakes Mohave and Havasu and Senator Wash Reservoir, California. Hatchery-reared fry and fingerling razorbacks are being reintroduced into the Gila River drainage (J. E. Johnson, pers. comm.; Minckley 1983). Behnke and Benson (1980) defined the major reasons for decline of the razorback sucker as habitat alteration because of damming and the introduction of exotic fishes. Reduced water temperatures below Hoover and Davis Dams are also detrimental to the remaining populations in Lakes Mohave and Havasu.

Desert pupfish, Cyprinodon macularius — Endangered. — This species is endemic to the lower Colorado River drainage in Arizona, California and Mexico, and the Rio Sonoyta drainage. Minckley (1973) described desert pupfish habitat as springs, marshes, slow-flowing streams, and backwater areas along large rivers. Historically, the desert pupfish occurred in all these habitat types of the lower Colorado downstream to the Gulf of California. Distribution in the Colorado River drainage now is restricted to three introduced populations in Arizona and one native stock in

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Mexico's Santa Clara Slough. Reasons for decline include desiccation of habitat and introduction of exotic fishes that prey on or compete with the pupfish. Portions of the Mexican population appear to have been replaced by large numbers of *Tilapia.*

Las Vegas frog, *Rana fisher* — Extinct. — At one time a common inhabitant of springs, marshes and creeks in the Vegas Valley area of Clark County, Nevada, the Las Vegas frog is now extinct (Bradley and Deacon 1967). The University of Michigan Museum of Zoology collections indicate that the species occurred in the Las Vegas Creek area and Tule Springs, northwest of Las Vegas. Like the Las Vegas dace, extinction of the species is attributable to increased water use and development in the Las Vegas metropolitan area.

Overton assiminea, *Assiminea* sp. — Rare. — Restricted to Blue Spring, Lake Mead National Recreation Area, Clark County, Nevada, this snail lives on moist substrate a few centimeters from the spring outflow. Undescribed *Fontelicella* and *Tryonia* species are associated with it in the spring outflow. However, few live samples of these taxa have been found to make positive identification.

Grand Wash springsnail, *Fontelicella* sp. — Rare. — Discovered in 1980 by Landye (1981), this snail is found in a series of springs that include Grapevine and Whiskey in Grand Wash, north of Lake Mead, Mohave County, Arizona. Even though the water source previously had been used in mining operations, present grazing practices do not appear detrimental to snail populations.

SUMMARY.—The Colorado River has been altered from a highly variable river to one impounded at many sites throughout the drainage with resulting loss of suitable habitat for native fishes. Major habitat degradation began with construction of mainstream Colorado River dams, including Hoover Dam in 1936 and Glen Canyon Dam in 1963. While "wild" riverine habitat and its endemic fishes have been reduced, modified river conditions have proven favorable for exotic species. Native fishes have responded negatively to this change and may eventually succumb to the new environmental conditions as well as increased competition and predation from exotic fishes.

Three of the seven fishes discussed herein, the Colorado squawfish, humpback chub and bonytail, are listed as endangered by U.S. Fish and Wildlife Service. The razorback sucker is not officially recognized by the U.S. Fish and Wildlife Service as threatened or endangered, but its continued existence is, nonetheless, also in jeopardy. The Colorado cutthroat trout faces potential elimination primarily from hybridization with other trouts. The desert pupfish in the lower basin is also endangered by exotic fish introductions, loss of habitat and man's continually increasing water needs. The Las Vegas dace and Las Vegas frog, former inhabitants of a small tributary of the Colorado River, are now extinct.

With increasing energy and water demands, the continued modification of the Colorado River drainage is a certainty. The decline in native fish populations will most likely continue as it has in the past when subjected to man-caused habitat modification (Minckley and Deacon 1968). Maintenance of remaining free-flowing riverine areas, and management of exotic species are necessary to maintain any viable populations of native Colorado River fishes.

Man's inability to recognize the value of the Colorado River in its pristine condition is typified by the Bureau of Reclamation's 1946 monograph (Anon. 1946) on the river:

> "Yesterday the Colorado River was a natural menace . . .
>
> Today this mighty river is recognized as a national resource . . .
>
> Tomorrow the Colorado River will be utilized to the very drop."

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GREEN RIVER, WYOMING, COLORADO AND UTAH

PLATE VII. Green River from Harper's Corner, Dinosaur National Monument, Colorado. This stretch of the Green River provides habitat for *Gila cypha*, *Ptychocheilus lucius* and *Xyrauchen texanus*. Prior to completion of Flaming Gorge *Dam*, *Gila elegans* also occurred here. Photograph taken July 1966 by C. David Vanicek.

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The Green River is the largest tributary to the Colorado River and is located in the upper Colorado River Basin. Originating in the Wind River Mountain Range of Wyoming, the Green River flows approximately 850 km before entering the Colorado River. Total area of the Green River drainage basin is 115,773 square kilometers (Carlson and Carlson 1982). Major tributaries include the Duchesne, White and Yampa Rivers.

The Green River is impounded by Fontenelle Dam in Wyoming and Flaming Gorge Dam in Utah. In addition to inundating significant portions of the river, these impoundments have significant affects on downstream river stretches and water quality. Lowered water temperatures in the summer and unseasonal flows now occur. Because of these changes, downstream habitat has been altered to the extent that introduced exotic fishes are now favored over native species (Holden and Twedt 1980, Joseph et al. 1977).

SPECIES ACCOUNTS.—Colorado cutthroat trout, Salmo clarki pleuriticus — Rare. — Historic distribution of this subspecies in the Green River included most headwater streams. At present, the Colorado cutthroat trout is thought to occur only in small tributary streams in southwestern Wyoming (Behnke and Benson 1980, Tyus et al. 1982b). Introduction of non-native trouts and resultant hybridization is the major reason for the decline (Behnke and Benson 1980, Behnke and Zarn 1976).

Humpback chub, Gila cypha — Endangered. — Historically, this species occurred abundantly in the Green River drainage (Vanicek et al. 1970). Present distribution in this drainage is restricted to Desolation, Gray and Labyrinth Canyons, and the Green and Yampa Rivers in Dinosaur National Monument (Holden and Stalnaker 1975, Miller et al. 1982). Continued existence of this species is threatened by habitat alteration (dams, diversions, channelization), competition with and predation by exotic fish species, pollution, and hybridization with Gila robusta and G. elegans (Minckley 1973, Seethaler et al. 1979).

Bonytail, Gila elegans — Endangered. — The bonytail may be extinct in the Green River system as few specimens have been collected since 1967 (Holden 1978, Holden and Crist 1981, Holden and Stalnaker 1975, Vanicek 1967). Current distribution as indicated by these collections includes Desolation Canyon and the Yampa River. Reasons for decline of this species in the Green River appear to be directly related to alterations of flow caused by Flaming Gorge Dam (P. B. Holden, pers. comm.; Holden and Stalnaker 1975; Vanicek et al. 1970).

Colorado squawfish, Ptychocheilus lucius — Endangered. — Historically, the Colorado squawfish inhabited much of the Green River drainage, including the Yampa and White Rivers (Holden 1973). Current distribution in the Green River is similar to historic distribution except the species no longer occurs upstream of the mouth of the Yampa River (Miller et al. 1982). As with the humpback chub and bonytail, decline of the Colorado squawfish is related to several factors including dam construction with resultant loss of habitat and blockage of spawning and seasonal migration routes, and competition with exotic fish species.

Kendall Warm Springs dace, Rhinichthys osculus thermalis — Vulnerable. — This subspecies of speckled dace occurs only in Kendall Warm Springs, a small tributary to the Green River (Hubbs and Kuhne 1937). Habitat for this small fish consists of a 300 m length of creek formed by flows from thermal springs with a source temperature of about 29° to 30°C (Binns 1978). Man's activities, including bathing, livestock grazing and pollution from cleansing agents have adversely affected the creek. Many of these activities were banned by 1975, resulting in improved habitat conditions (Binns 1978).

Razorback sucker, Xyrauchen texanus — Vulnerable. — Historic distribution of the razorback sucker included most of the Green River drainage. Recently it has been found, in small numbers, only between Split Mountain Gorge and Desolation Canyon. Reasons for this decline undoubtedly parallel those of the humpback chub, bonytail and Colorado squawfish, including damming and resulting loss of habitat as well as competition with and predation by exotic fish species (Behnke and Benson 1980).

SUMMARY.—Modification of the Green River from construction of dams and water diversions has reduced suitable habitat available to the native fish fauna. In addition, introduction of non-native fishes has resulted in competition with and predation on the native fishes, and has combined with habitat alterations to further threaten their existence. Increasing energy development and its associated activities will lead to further changes in availability and quality of water for native fishes. By 1965, 581 reservoirs had been constructed in the upper Colorado River Basin, depleting Colorado River flows by 4,765 cubic feet per second (Jacobsen 1982). Between 1965 and 1980, additional projects had depleted 707 cfs (Jacobsen 1982). Thus, total water losses by 1980 were 5,472 cfs, which is approximately 27% of average flow at Lee's Ferry, Arizona.

The resulting synergistic effect of changes in the Green River system have made it difficult to identify precise reasons for the decline of native fishes. Recent and ongoing studies by the U.S. Fish and Wildlife Service (Miller et al. 1982) and others are adding to our knowledge of the Colorado River drainage and its fishes. However, recovery efforts must be pursued immediately to insure survival of these native fishes.

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PAHRANAGAT VALLEY, NEVADA

PLATE VIII. Ash Springs, Lincoln County, Nevada. Rhinichthys osculus velifer, Crenichthys *b. baileyi* and two rare snails occur here. The outflow of these springs provide the only remaining habitat for *Gila* robusta jordani. Photograph taken 17 October 1980 by Walter R. Courtenay, Jr.

Pahranagat Valley is situated along the course of the intermittent White River in Lincoln County, Nevada. Within the narrow valley, several springs create a variety of aquatic habitats that contrast sharply with the normally dry bed of the White River both upstream and downstream of Pahranagat Valley. Principal aquatic habitats are Hiko, Crystal and Ash Springs and their outflow creeks. Water temperature and discharge are approximately 26.3°C and 13,957 liters per minute (Hiko), 26.5°C and 20,333 l/min (Crystal) and 35.9°C and 31,988 l/min (Ash) (Garside and Schilling 1979, Williams and Wilde 1981). Discharge from Ash Springs creates a perennial flow for a short distance in the White River channel.

SPECIES ACCOUNTS.—Pahranagat roundtail chub, *Gila* robusta jordani — Endangered. — This fish was native to the outflows of Hiko, Crystal and Ash Springs (Tanner 1950), but now is restricted to a short reach of the Ash Springs outflow (Deacon and Williams 1984). During 1979 to 1981, the total population of Pahranagat roundtail chub varied from approximately 37 to 250 individuals (Hardy 1982), making this one of our rarest desert fishes. Water diversions, channelization and competition and predation by exotic species appear to have been the causal factors in the decline of the Pahranagat roundtail chub. Hardy (1982) attributed competition and predation by the exotic carp, Cyprinus carpio, shortfin molly, Poecilia *mexicana,* mosquitofish, Gambusia affinis, convict cichlid, *Cichlasoma* nigrofasciatum, and Oriental snail, Melano*ides* tuberculatus, *as* the major factors now limiting the roundtail chub in the outflow of Ash Springs.

Pahranagat spinedace, Lepidomeda altivelis — Extinct. — This species was known from only Upper Pahranagat Lake and the outflow of Ash Springs in Pahranagat Valley and was extinct when described by Miller and Hubbs in 1960. Extinction of this species appears to be attributable to establishment of carp and mosquitofish (Miller and Hubbs 1960).

Pahranagat speckled dace, Rhinichthys osculus velifer — Rare. — This subspecies of speckled dace is native to

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Hiko, Crystal, and Ash Springs as well as smaller springfed ditches in Pahranagat Valley. The Pahranagat speckled dace has fared relatively well compared with the other native fishes in the valley. Although less abundant than in historic times, this dace still occurs in the outflows of Crystal and Ash Springs, where it is the most abundant native species. It also occurs commonly below Lower Pahranagat Lake. It was eliminated from the Hiko Spring system.

White River desert sucker, Catostomus clarki intermedius — Endangered. — This subspecies is native to the outflows of Crystal and Ash Springs in Pahranagat Valley and to spring outflows of the upper White River near the towns of Preston and Lund, White Pine County. The White River desert sucker was eliminated from Pahranagat Valley and survives only in Lund Town Spring and springs near Preston. Extirpation of this fish from Pahranagat Valley evidently resulted from competition and/or predation by the exotic carp and mosquitofish.

White River springfish, Crenichthys b. baileyi — Endangered. — The typical form of Crenichthys baileyi is endemic to Ash Springs. It also occurs in the outflow of Ash Springs but occurrence there is very rare (Hardy 1982) and may be C. b. grandis washed down from upstream or hybrids between the two forms (Reider 1971, Williams and Wilde 1981). White River springfish are reduced in number because of competition and predation by exotic fishes, namely mosquitofish, shortfin mollies and convict cichlids.

Hiko White River springfish, Crenichthys b. grandis — Endangered. — This subspecies is endemic to Hiko and Crystal Springs (Williams and Wilde 1981). The Hiko White River springfish has been extirpated from Hiko Spring because of predation by largemouth bass, Micropterus salmoides, and competition with shortfin mollies and mosquitofish. An exotic parasite, Lernaea, which apparently was introduced along with the exotic fishes, also may have contributed to the decline. The Hiko White River springfish is extremely rare in Crystal Springs, apparently because of the presence of large numbers of exotic convict cichlids. A stock of springfish from Crystal were introduced into Hiko Spring in 1985, but the success of this transplant remains uncertain (J. E. Deacon, pers. comm.).

Pahranagat pebblesnail, Fluminicola merriami — Rare. — This species is native to Hiko, Crystal and Ash Springs, where it survived in surprisingly large numbers up to at least 1973 (Landye 1973). However, some decline in numbers occurred coincidentally with establishment of the exotic Oriental snail, Melanoides tuberculatus. The Oriental snail now is the dominant species in the benthos of Ash Springs (Hardy 1982) and the status of the native species should be reexamined.

White River tryonia, Tryonia clathrata — Vulnerable. — The range of this White River endemic includes springs in Pahranagat Valley. Since its introduction sometime prior to 1969, Melanoides tuberculatus has largely replaced Tryonia clathrata in Ash Springs (Deacon et al. 1980). Status of the White River tryonia in other Pahranagat Valley springs is uncertain, but a general pattern of dramatic population reductions in native molluscs is evident following establishment of the widely introduced Melanoides tuberculatus.

SUMMARY.—Five fishes and two aquatic invertebrates are endemic to the springs of Pahranagat Valley. A sixth fish is known only from Pahranagat Valley and springs just to the north. Two of the fishes have been extirpated from the valley and three more have been reduced to critically low numbers. Introductions of exotic fishes and molluscs, which now far outnumber native species in all habitats, apparently were the primary cause for decline of the native animals. Diversion and channelization of outflows also may have contributed to the decline of the native fishes. Physical alteration of the springs may have provided favorable habitat for the exotic species, allowing them to greatly increase in numbers.

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PARRAS BASIN, COAHUILA

PLATE IX. "East Water Supply" stream, Parras Basin, Coahuila, Mexico. Jerry J. Landye and Ed Meyer collected *Gila* from this section of stream on 30 July 1970. Photograph taken on that date by Jerry J. Landye.

This small, springfed, desert valley oasis in southern Coahuila formerly harbored a small, highly endemic ichthyofauna, much of which is now extinct or locally extirpated. Its abundant springs of relatively high water quality and fertile valley soils were exploited early for extensive agriculture, particularly for vineyards. Aquifer modifications, designed to augment water yields, caused drying of some natural habitats; others have been impounded and diverted. The fish fauna now consists predominantly of exotics *(Cyprinus carpio, Xiphophorus maculatus, Gambusia affinis,* and others). Of the five or six native species, the one or two remaining are restricted to minimal habitat and small populations in peripheral headwater areas. Miller et al. (ms.) discussed two extinct endemics *(Cyprinodon latifasciatus* and *Stypodon signifer)* and the history of their discovery and extinction. Subfossil hydrobioid snail shells have been found in the basin that appear to represent extinctions of additional aquatic organisms.

SPECIES ACCOUNTS.—Parras chubs, *Gila* spp. — Endangered. — At least one, and probably two distinct, undescribed species or forms of *Gila,* the Parras fatty chub and Parras slender chub, still inhabit this extensively modified system. One of these was collected by one of the authors (DAH) in 1980 from a small, apparently perennial reach of a rocky, erosive arroyo on the edge of the valley and nearby canals that carry water diverted from the same source. It is not abundant, and occurs sympatrically with *Xiphophorus maculatus* in very restricted habitats. While *Xiphophorus* is widespread and highly localized in these systems, *Gila* is decidedly habitat specific, being associated only with pools and/or substantial cover in the form of undercut banks, fallen trees or tree roots. Other bodies of water in the valley also were sampled in 1980. All were either unnatural or highly modified and inhabited only by exotic fishes. However, Salvador Contreras-Balderas (pers. comm.) has collected *Gila* sp. from the other side of the valley. Specimens from that locality differ markedly in fin length and may be a distinct species (S. Contreras-Balderas, pers. comm.). Relationships of both forms appear to be with *G. modesta* of the Rio San Juan (Smith and Miller, in press).

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Both populations are highly restricted and in immediate danger of extinction because of further habitat modifications or impacts of exotic species. Essentially nothing is known of their biology. Measures to protect them are urgently needed.

Stumptooth minnow, *Stypodon signifer* — Extinct. — The monotypic genus *Stypodon* is endemic to Parras Basin. The stumptooth minnow is very poorly known, having been collected only in 1880 (2 specimens) and in 1903 (4 specimens) (Miller et al., ms.). Subsequent attempts to collect the species, including an extensive survey in 1953, have failed, and *Stypodon signifer* is regarded as extinct (Miller 1961; Miller et al., ins.). Beginning about 1930, establishment of various factories and industrial facilities resulted in depletion and pollution of surface springs and overdraft of groundwater supplies. Disruption of water supplies was sufficient to exterminate the species sometime prior to 1953 (Miller et al., ins.). Because of its early extinction, the habitat, biology and relationships of *Stypodon* are, unfortunately, largely speculative. The uniquely modified ("stump-like") pharyngeal teeth and arch indicate a molluscivorous diet.

Parras pupfish, *Cyprinodon latifasciatus* — Extinct. — This Parras Basin endemic also is known from only two collections, made in 1880 and 1903, from a spring or spring complex near Parras (Miller et al., ms.). As described above for *Stypodon,* extensive development of springs resulted in extinction of *C. latifasciatus* sometime prior to 1953. The biology of *C. latifasciatus* is unknown, but Miller (1976a) determined the species to be most closely related to the C. *eximius* complex of the Chihuahuan Desert region.

SUMMARY.—There are only two surviving members of the highly endemic Parras Basin ichthyofauna. Two endemics, *Stypodon signifer* and *Cyprinodon latifasciatus,* were extinct by 1953. Two other species, although extirpated from the Parras system, still occur elsewhere. The goodeid, *Characodon lateralis,* is found in the Rio Mezquital, although the Parras form may have been significantly differentiated (Miller 1976b). Smith and Miller (in press) suggest that Jordan and Evermann (1896-1900) perhaps validly renamed this species *C. garmani. Characodon lateralis* is designated as rare throughout its range (Table 1). The record of roundnose minnow, *Dionda episcopa punchier,* in the basin may be erroneous (Smith and Miller, in press), although it is provisionally included in Table 3. *Hybognathus (Dionda) punchier* was described by Garman (1881) on the basis of specimens from "Parras, and spring near Saltillo". Miller (in press) also questioned whether the reference to Parras may have been in error. He further determined that the name *punctifer* was preoccupied, and synonymized it with *Dionda melanops* (Girard 1857). If *Dionda episcopa melanops* occurred in the Parras Valley, it is now extinct.

The *Gila* are in imminent danger of extinction. If they are to survive, it will only be under some form of protection, which is urgently needed.

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LA MEDIA LUNA, SAN LUIS POTOSI

PLATE X. La Media Luna, San Luis Potosi, Mexico. This spring and lagoon system provide habitat for Dionda mandibularis, D. dichroma, Cualac tessellatus, Ataeniobius toweri, *Cichlasoma bartoni*, C. sp. and three endemic crustaceans. Photograph taken 6 February 1974 by Robert R. Miller.

The following description is modified from an unpublished report by R. R. Miller (see also, Miller 1956, 1974): La Media Luna is the name given to an extensive series of warm-spring aquifers, marshes and outflows that lie in a broad meadow about 10 airline km south-southwest of the town of Ríoverde, San Luis Potosi, at an elevation just above 1000 m. A large, constant volume of exceptionally clear, blue water rises from six spring holes (one of them very deep, perhaps 40 m) in a crescent-shaped (half-moon) laguna that provides all the water for three municipios. According to SCUBA divers, the flow from the laguna is at least 36,000 liters per minute. The water has a noticeable sulfurous odor, with temperatures varying from 29.5°C to 30.3°C; pH values have ranged from 6.9 to 7.3 and hardness was 92 ppm of $CaCO_3$ (μmhos 1,930; salinity 1.3 ppt). Dissolved oxygen is relatively high, 4.0 to 6.4 ppm.

Miller (pers. comm.) detected no obvious changes in habitat or species composition from 1955 to 1971. In 1972, however, he observed the first exotic fishes, Oreochromis aureus and Gambusia panuco. By 1978, two more exotic fishes, Poecilia mexicana and *Cichlasoma* cyanoguttatum, were established (Hubbs and Miller 1977; R. R. Miller, pers. comm.). A more recently introduced species, *Poecilia* latipunctata, was observed to be common by one of the authors (JEW) in a 1984 visit. Further human perturbations include construction of canals and (temporarily) a large pumping facility on the edge of the main laguna (Miller 1974, pers. comm.). Miller (1974) noted that "Such perturbations by man have already affected the aquatic biota of the area which, . . . is biologically unique and is urgently in need of preservation as a national scientific heritage."

SPECIES ACCOUNTS.—Flatjaw minnow, Dionda mandibularis — Endangered. — This species is known only from two springfed locations, a stream and, 60 km away in another restricted area of the upper intermontane portion of the Rio Verde (Hubbs and Miller 1977). Miller (1956) noted that "Dionda is probably quite scarce . . . " in La

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Media Luna. In fact, no species of Dionda has been observed in the main laguna of La Media Luna. These observations, taken with the restricted distribution, suggest that this species deserves close attention. Structural habitat modifications and competition and/or predation by introduced fishes apparently represent the major threats to this species in La Media Luna.

Bicolor minnow, Dionda dichroma — Rare. — This species is restricted primarily to headwaters ("intermontane valley") of the Rio Verde (Hubbs and Miller 1977). Although not inhabiting La Media Luna itself (Miller 1956), the species is abundant in closely associated streams and springs in that area of the Rio Verde drainage (Hubbs and Miller 1977). It was also taken, but less commonly, in other areas of the Rio Verde system. Although this species is less threatened than D. mandibularis, maintenance of springfed waters in the Rio Verde area is essential for its well-being.

Media Luna killie, Cualac tessellatus — Endangered. — This species represents a monotypic genus entirely restricted to the La Media Luna ecosystem (Miller 1956). The species was never known to be very abundant. Miller (1956) postulated that it is "a relict that is able to survive in an isolated habitat under limited competition." Thus, the recently introduced fishes (especially poeciliids) are of special concern and could, presumably, eliminate the Media Luna killie by competition or predation.

Striped goodeid, Ataeniobius toweri — Vulnerable. — This form represents a monotypic genus endemic to the upper Rio Verde where it is known only from La Media Luna and associated waters of the Rio Verde and another springfed locality 60 km away. This restricted species is relatively uncommon in La Media Luna (Miller 1956). Its major threats probably are as described above for Dionda mandibularis.

Mojarra caracolera, *Cichlasoma* bartoni — Endangered. — This cichlid is endemic to the upper Rio Verde where it is restricted to springfed locations including La Media Luna (Taylor and Miller 1983). At La Media Luna, the species occurs at low levels of abundance and primarily in small streams and ditches draining the laguna. It is uncommon in the laguna itself. The introduced cichlids, Oreochromis aureus and *Cichlasoma* cyanoguttatum, particularly the former, have undergone a population explosion in the main laguna and may have partially excluded C. bartoni from that habitat (I. L. Komfield, pers. comm.).

Yellow mojarra, *Cichlasoma* sp. — Endangered. — This undescribed, bright yellow species has been seen in the laguna of La Media Luna by both R. R. Miller and I. L. Komfield, and a free-living specimen was photographed by the latter. So far as known, the species was never abundant, but none was seen in a recent (June 1983) intensive search by Dr. Komfield. The introduced cichlids are of major concern regarding survival of this species.

La Media Luna crayfish, Procambarus roberti — Rare. — This species is known only from the La Media Luna region, where it appears to be uncommon (Villalobos and Hobbs 1974). The species is of special zoogeographic interest, as it is a highly disjunct member of its subgenus and may represent a relict crayfish stock that migrated southward into Mexico during the Pliocene (Villalobos and Hobbs 1974).

La Media Luna ostracod, Ankylocythere barbouri — Rare. — The survival of this species depends on survival of the above-named crayfish, upon which it is an obligatory parasite (Villalobos and Hobbs 1974).

La Media Luna shrimp, Palaemonetes lindsayi — Rare. — This is a third crustacean species that is known only from La Media Luna (Villalobos and Hobbs 1974). Like Procambarus roberti, its status should be periodically monitored to detect changes in abundance and any introduction of exotic predators or competitors.

SUMMARY.—La Media Luna harbors five fishes and three crustaceans that are endemic to the intermontane portion of the Rio Verde drainage where they are restricted to 13 springfed locations. These endemics include two monotypic genera of fishes, one of which is entirely restricted to the La Media Luna ecosystem. The abundance of native fishes has declined since introduction of exotic fishes into the area. Manmade constructions also have had adverse effects.

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ASH MEADOWS, NEVADA

PLATE XI. Big Spring, Nye County, Nevada. Cyprinodon nevadensis mionectes, Rhinichthys osculus nevadensis and an undescribed snail, Tryonia sp., occur here. Several exotics, Gambusia affinis, Poe cilia latipinna, Procambarus clarkii and Rana catesbeiana, are also present. Historically, this spring provided habitat for a large population of the now-extinct Ash Meadows poolfish, Empetrichthys *merriami*. Photograph taken September 1975 by James E. Deacon.

Ash Meadows occupies about 756 km^2 of Mohave Desert in southwestern Nevada. More than 30 springs and seeps discharge about 40 m^3/sec of water (17,100 acre-feet annually) in the area (Winograd and Doty 1980). These waters create an oasis that supports a diverse flora, including several endemic species and the velvet ash, Fraxinus velutina var. coriacea, for which Ash Meadows was named (Beatley 1977).

Elevation of Ash Meadows decreases from approximately 850 m in the northeast to less than 670 m in the southwest. Springs occur throughout much of Ash Meadows, but can be divided into three groups: 1) Devil's Hole at 732 m elevation, 2) a series of small springs at approximately 710 m, and 3) many larger springs between 680 and 707 m. The period of isolation for these springs increases with increasing elevation. Thus, different fishes and other aquatic organisms occupy each of the three spring groups, with the Devils Hole pupfish more divergent than pupfishes at lower elevations (Miller 1948, Soltz and Naiman 1978). Springs only one or two kilometers distant may have been isolated from each other for thousands of years.

In pluvial times, surface waters of Ash Meadows dischared into the Amargosa River system. Presently, flows from larger springs discharge into the remnants of Carson Slough and sink into desert soils or evaporate before leaving the meadows.

SPECIES ACCOUNTS.—Ash Meadows speckled dace, Rhinichthys osculus nevadensis — Endangered. — Historically, Rhinichthys o. nevadensis occurred with Cyprinodon nevadensis mionectes and Empetrichthys merriami in many of the larger, lower-elevation springs in Ash Meadows. The dace occurred in spring pools, outflow creeks and marsh areas, but typically in much fewer numbers than the pupfish. Diversion, channelization and dredging of spring systems have greatly reduced favorable habitat. Predation and/or competition from the exotic sailfin molly, Poecilia latipinna, m osquitofish , Gambusia affinis, bullfrogs, Rana

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catesbeiana, and crayfish, *Procambarus clarkii,* also adversely affect dace populations (Deacon and Williams 1984, Soltz and Naiman 1978). Largest remaining populations of dace are in Big and Jack Rabbit Springs (Williams and Sada 1985). A very small population persists in the Bradford Springs and a single specimen was taken in recent years from Point-of-Rocks Springs. Otherwise, all populations appear to have been eliminated.

Devils Hole pupfish, *Cyprinodon diabolis* — Endangered. — The native range of this species is restricted to Devil's Hole, a springfed limestone cavern in Ash Meadows (Wales 1930). This dwarf pupfish, rarely exceeding 20 mm SL, is the most distinctive member of its genus in the United States (Miller 1948). Because little sunlight reaches the water in Devil's Hole, productivity is low and the pupfish population is small. The population varies seasonally between about 150 and 400 individuals (Deacon 1979). The primary threat to the Devils Hole pupfish is lowering water levels caused by excessive groundwater pumping. Reduced water levels expose a small shelf area where virtually all pupfish reproductive and feeding activity occurs (James 1969). During the 1960's, groundwater withdrawal for agricultural developments in Ash Meadows began lowering the water level in Devil's Hole. This overdraft of groundwater supplies continued until a 1976 U.S. Supreme Court decision upheld a lower court ruling that mandated maintenance of water levels sufficient for pupfish survival and reproduction. Since then, water levels have been maintained, but status of the species remains of concern because of naturally low population levels, restricted distribution and threats from vandalism.

Since 1970, two populations of *C. diabolis* have been established in artificial refugia. One is located below Hoover Dam in Clark County, Nevada, and the other is in Ash Meadows. Although both populations appear to be self-sustaining, the Hoover Dam Refugium stock has changed in appearance and morphometry (Williams 1977). Such changes indicate the importance of maintaining Devil's Hole if *C. diabolis is* to be preserved in its natural condition.

Ash Meadows Amargosa pupfish, *Cyprinodon nevadensis mionectes* — Vulnerable. — *Cyprinodon n. mionectes* is one of three pupfishes endemic to Ash Meadows. Historically, it occurred in at least 13 of the larger, lower-elevation springs. Many of these habitats have spring pools of ten to 15 m in diameter and discharges that vary from 2,220 to 6,500 liters per minute (Garside and Schilling 1979). Pupfish occurred in spring pools, outflow creeks and marshes created by the large flows. Of particular interest was Carson Slough, formed by the outflows of Fairbanks, Rogers and Longstreet Springs and others in the northwestern part of Ash Meadows. Carson Slough was approximately 7 km long and provided habitat for many thousands of *C. n. mionectes* and ***R.*** *o. nevadensis.* All habitats have been altered by reduction of spring flows, diversion, channelization, dredging and/or elimination of riparian vegetation. Carson Slough was drained in the early 1960's for peat mining. Fishes were eliminated from Jack Rabbit Spring in the early 1970's, when a pump was suspended in the spring boil and the habitat was pumped dry. Fortunately, the spring again flows and native fishes were reintroduced. Exotic species also have been introduced into all spring systems inhabited by *C. n. mionectes* and are abundant in many habitats. Exotics typically found in these habitats include sailfin mollies, mosquitofish, bullfrogs and crayfish (Deacon and Williams 1984, Soltz and Naiman 1978). Two exotic predators, largemouth bass, *Micropterus salmoides,* and arawana, *Osteoglossum bicirrho sum,* were temporarily present in Crystal and Forest Springs, respectively (Soltz and Naiman 1978). Physical and biological habitat alteration has eliminated *C. n. mionectes* from some habitats and reduced the species in the remainder. Despite these abuses, the pupfish persists in some springs in large numbers. Longstreet, Rogers, Big and Jack Rabbit contain the largest populations.

Warm springs Amargosa pupfish, *Cyprinodon nevadensis pectoralis* — Endangered. — *Cyprinodon n. pectoralis* is known from only a series of six warm springs [School (= Lovell's), Scruggs 1, Scruggs 2, Indian, Mexican and Marsh] about 2 km northwest of Devil's Hole in Ash Meadows (Miller 1948, Miller and Deacon 1973). All of the springs are small, with spring pools typically one to two meters in diameter. These springs occur along the western slope of a hill at approximately 710 m elevation, slightly less than the 732 m elevation at Devil's Hole. Nearly all spring habitats have been altered by ditching, diverting or impounding. The Mexican Spring population was extirpated in 1973 following habitat alterations (Soltz and Naiman 1978). Remaining populations, except School Spring, also have been negatively affected by large numbers of exotic mosquitofish. Habitat at School Spring was greatly disturbed by recent "improvements," which included lining of pools and interconnected channels with concrete. Bullfrogs also were introduced in most habitats and may prey on the pupfish. Because *C. n. pectoralis* inhabitats such small springs, their populations are especially vulnerable to decreases in spring flows.

Ash Meadows poolfish, *Empetrichthys merriami* — Extinct. — Historically, *Empetrichthys merriami* occurred with *Rhinichthys osculus nevadensis* and *Cyprinodon nevadensis mionectes* in many of the larger lower-elevation springs in Ash Meadows. From 1936 to 1942, Miller (1948) collected *E. merriami* from Big, Jack Rabbit, Point-of-Rocks, Forest and Rogers Springs. Although very rare at all localities during the early 1900's, Miller (1948) collected most specimens from Big Spring (= Deep Spring of Miller 1948). Efforts to collect the species in 1953 and thereafter were unsuccessful and it is now considered to be extinct (Miller 1961; Miller et al., ms.). Predation from exotic bullfrogs and crayfish as well as habitat alterations appear to have caused the decline (Miller et al., ms.).

Point-of-Rocks Springs naucorid, *Ambrysus amargosus* — Endangered. — *Ambrysus amargosus* is known only from the type locality, Point-of-Rocks Springs (La Rivers 1953).

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When collected from the springs in 1951, the insect was found in loose rock bottoms of the outflow creek "in large quantities" (La Rivers 1953). A few specimens were also collected from the pool, where they were rare. Channelization of outflow creeks, dredging of pools and cementing of creeks and pools have reduced the species to precariously low population levels.

Devils Hole riffle beetle, *Stenelmis calida calida* – Endangered. — When described from Devil's Hole by Chandler (1949), *calida* was the only member of the genus *Stenelmis* known west of the Rocky Mountains. Since that time, various forms of *S. calida* have been described from southern Nevada (La Rivers 1949, 1962). However, the typical form is herein considered restricted to Devil's Hole. Like the Devils Hole pupfish, *S. c. calida* is dependent upon maintenance of adequate water levels in Devil's Hole for its survival.

Ash Meadows snails — Indeterminate. — Springs of Ash Meadows harbor a rich molluscan fauna that includes at least nine undescribed, endemic species (Taylor 1980). The endemic snails comprise two species flocks: four species of an undescribed genus ("Nevada spring snails") and five species of *Tryonia* (Taylor 1980). A sixth species of *Tryonia* found in Ash Meadows occurs elsewhere in the Amargosa River drainage. Additional species of these genera undoubtedly exist in Ash Meadows. For example, Taylor (1980) identified seven localities of "Nevada spring snails" in Ash Meadows that are known only from empty shells. These snails cannot be identified to species and are presumed extinct. The four known but undescribed species of "Nevada spring snails" are the Longstreet Spring snail (endemic to Longstreet Spring, but now extinct), large-gland Nevada spring snail (known from three springs), median-gland Nevada spring snail (endemic to Scruggs Springs) and Point-of-Rocks Springs snail (endemic to Point-of-Rocks Springs) (Taylor 1980). Undescribed species of *Tryonia* consist of the Amargosa tryonia (numerous localities in Ash Meadows and southward into the Amargosa River drainage), Sportinggoods tryonia (restricted to Big and Fairbanks Springs), small solid tryonia (endemic and possibly extinct from a small spring southeast of Longstreet Spring), minute slender tryonia (endemic to Scruggs Springs), small slender tryonia (endemic to Point-of-Rocks Springs) and Point-of-Rocks tryonia (also endemic to Point-of-Rocks Springs) (Taylor 1980).

Threats to the remaining Ash Meadows snails primarily are modifications of spring habitats for irrigation purposes and interactions with the exotic Oriental snail, *Melano ides tuberculatus*. In lamenting the poorly-studied nature of the native Ash Meadows snails, Taylor (1980) noted that the fauna "exceeds in diversity and narrow localization the cyprinodont fishes that have received so much attention." It is desirable that these snails are adequately surveyed and protected before any more are extirpated.

SUMMARY.—Five fishes and at least 11 invertebrates are endemic to springs in Ash Meadows. The invertebrate fauna has not been adequately surveyed and additional endemics are undoubtedly present. Physical and biological habitat alteration has been pervasive. And in recent times, reduced flows from groundwater pumping has been of increasing concern. The Ash Meadows poolfish and at least one snail are extinct. Only a few habitats, such as Devil's Hole and Jack Rabbit and Big Springs, are in natural or near-natural condition.

A major breakthrough in the protection of remaining biota and their habitats was made in 1983 when The Nature Conservancy acquired the vast majority of private land in Ash Meadows. Intensive residential and commercial developments were planned for these areas. Ownership of the land has been transferred to U.S. Fish and Wildlife Service for management as a wildlife refuge. Several major management needs still exist: 1) ecological and taxonomic studies of the invertebrate fauna, 2) restoration of damaged spring and marsh areas, 3) control of existing exotic species and 4) prevention of additional exotic species introductions.

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UPPER WHITE RIVER, NEVADA

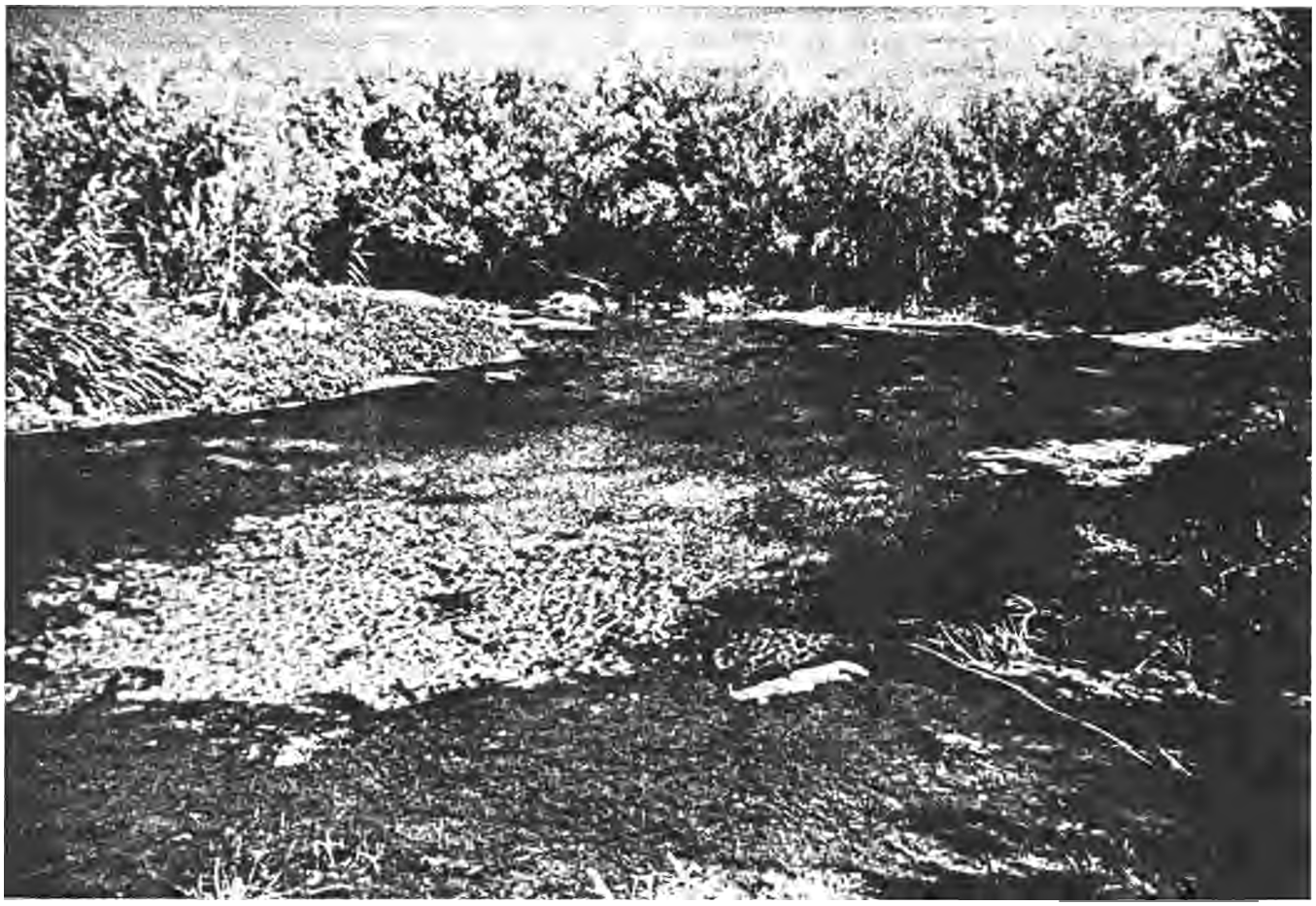

PLATE XII. Lund Town Spring, White Pine County, Nevada. Lepidomeda albivallis, Rhinichthys osculus ssp., Catastomus clarki intermedius and possibly Crenichthys baileyi albivallis occur here. Photograph taken August 1983 by Walter R. Courtenay, Jr.

The Upper White River ecosystem consists of the isolated remnants of the desiccated Upper White River Basin in eastern Nevada. The White River once was tributary to the Colorado River when greater stream flows occurred during pluvial times. Now the river typically is dry except for a small section northwest of Preston. The remaining aquatic habitats are primarily limited to a series of springs and their outflow creeks located along the streamcourse of the White River in White Pine and Nye Counties, Nevada (Hubbs and Miller 1948b, Williams and Wilde 1981). Each of these springs exhibit relatively constant temperatures and physiochemical parameters such as dissolved oxygen concentrations; however, these characteristics vary considerably among springs. For example, some springs such as the ones near Preston are relatively cool (ca. 20°C) with moderate amounts of dissolved oxygen (3.3 ppm) while others such as Moorman Spring are much warmer (ca. 37°C) with extremely low dissolved oxygen concentrations (0.7 ppm) (Hubbs and Hettler 1964, Sumner and Sargent 1940, Williams and Wilde 1981).

The principal spring systems include those near Preston (Preston Big, Preston Town (= Nicholas?), Arnoldsen, and Cold Springs] , the spring in the vicinity of Lund (Lund Town Spring) and various springs farther south in Nye County (Moorman, Moon River, and Hot Creek Springs and the springs at Sunnyside).

SPECIES ACCOUNTS.—White River spinedace, Lepidomeda albivallis — Endangered. — This species is endemic to springs and their outflows in the Preston, Lund and Sunnyside areas. Within these clear, relatively small spring systems, White River spinedace are mostly found in the cool, shallower waters over sand and gravel substrate, often associated with the spring runs or shaded areas (Miller and Hubbs 1960, Rinne 1980). At present, the only known populations of this species are in Flag Springs in the Sunnyside area and in Lund Town Spring. The population at Sunnyside always has been small, because of the small size of the spring habitat. Habitat alteration has recently extirpated the species from Preston Big Spring and Preston

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Town Spring. Much of the flowing water habitat at Preston Big Spring was eliminated by installation of an irrigation pipe beginning about 1.6 km below the springhead. Chemical vegetation control practices in the remaining free-flowing waters may have been responsible for eliminating the remaining population of White River spinedace from the area (J. E. Deacon, pers. comm.). Two exotic fishes have been documented in the Preston and Lund areas, guppies (Poecilia reticulata) and goldfish (Carassius auratus), and competitive inhibition by exotics may have had a negative effect on the spinedace (Deacon et al. 1964, Williams and Wilde 1981). However, habitat modification, including alteration of spring runs and channels for irrigation practices, appears to be a primary factor in the decline of this species (Miller 1977). White River spinedace also have been collected from the White River near the mouth of Ellison Creek, about 8 km northwest of Preston (Miller and Hubbs 1960), but their present status there is uncertain.

Preston speckled dace, Rhinichthys osculus ssp. — Rare. — The Preston speckled dace occurs only in the cool waters and their outflows of Preston Big, Preston Town, Lund Town Springs and springs near Sunnyside (Williams 1978, Williams and Wilde 1981). Similar to other speckled dace, this subspecies prefers moving-water habitats such as those found near the spring runs. As described for Lepidomeda, exotic fish introductions and habitat alterations appear to have negatively affected Preston speckled dace populations.

White River desert sucker, Catostomus clarki intermedius — Endangered. — This subspecies of desert sucker is native to springs and their outflows in the Upper White River area and to the Pahranagat Valley area to the south. It has, however, been extirpated from the springs in Pahranagat Valley and presently is restricted to Preston Big, Preston Town, Arnoldsen and Lund Town Springs (Williams and Wilde 1981). Two exotic species, guppies (found in most of the springs) and goldfish (found in Lund Town Spring), and habitat degradation threaten survival of this form. No desert suckers were found in Preston Big Spring during a summer 1983 survey (J. E. Deacon, pers. comm.). Chemical vegetation control may have eliminated the species from that habitat.

Preston White River springfish, Crenichthys baileyi albivallis — Vulnerable. — This subspecies of White River springfish is native to Preston Big, Preston Town, Arnoldsen, Cold and Lund Town Springs (Williams and Wilde 1981). It appears to prefer the cool, moderately oxygenated spring water near Preston and Lund and seems incapable of surviving in warmer and less oxygenated waters in the nearby Moorman area (Hubbs and Hettler 1964). Exotic guppies and goldfish, and habitat alterations are major threats to the continued existence of this fish.

Moorman White River springfish, Crenichthys baileyi thermophilus — Rare. — This subspecies is native to Moorman, Hot Creek and Moon River Springs, but has been collected downstream from these spring habitats as far as Adams-McGill Reservoir (Williams and Wilde 1981). These downstream individuals, however, appear to have been strays or were washed downstream to the reservoir following infrequent heavy rains. A breeding population has not been found in the reservoir itself (Williams and Wilde 1981). The largest population inhabits Moorman Spring. This taxon is remarkable in its ability to survive in the relatively warm waters of these springs with their extremely low dissolved oxygen levels and these fishes often abound in and around the spring boils (Hubbs and Hettler 1964, Hubbs et al. 1967). Large populations now occur in all three springs although the Hot Creek Spring population was nearly extirpated when largemouth bass, Micropterus salmoides, entered the spring during the 1970's (Williams and Wilde 1981). The bass were removed, but their proximity in an adjacent reservoir makes reintroduction probable.

Hot Creek pebblesnail, Fluminicola sp. — Rare. — This undescribed species of hydrobioid snail is restricted to the thermal waters of Moorman and Hot Creek 'Springs (Landye 1973), Preston Big Spring (Deacon et al. 1980) and possibly other springs in the Upper White River system. It was abundant in Moorman Spring, but uncommon in Hot Creek Spring (Landye 1973). During 1980 surveys, Fluminicola sp. was abundant in Nasturtium mats and rocky bottoms of fast-flowing areas of Preston Big Spring (Deacon et al. 1980). Another Fluminicola sp. may exist in Flag and Emigrant Springs.

Unnamed springsnail, Fontelicella sp. — Rare. — This undescribed mollusc is restricted to Hardy, Emigrant, Flag and Butterfield Springs in the Sunnyside area. Its status is uncertain.

White River tryonia, Try onia clathrata — Vulnerable. — This species is endemic to springs of the pluvial White River, including certain springs in Pahranagat Valley and the headwaters of the Moapa River. In the Upper White River, T. clathrata inhabits Moorman and Hot Creek Springs.

SUMMARY.—Four fishes and at least two molluscs are endemic to springs situated along the course of the pluvial Upper White River in eastern Nevada. A fifth fish also was known from springs in the Pahranagat Valley to the south, although this taxon is now extinct in the Pahranagat springs and is found only in portions of the Upper White River ecosystem. Because of negative effects of exotic species introductions, and diversions and modification of the spring runs, the abundance of each of these fishes appears to be declining substantially. Within the Preston and Lund areas, only the spring pool of Lund Town Spring remains relatively unaltered. Lund Town Spring provides a critical refugium for the White River spinedace, Preston speckled dace and White River desert sucker. The Preston White River springfish also may occur at Lund Town Spring but if so, they are very scarce. The cool water temperature (20°C) and relatively pristine habitat conditions at Lund Town Spring appear to have precluded domination by exotic fishes (Courtenay et al. 1985).

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MOAPA RIVER, NEVADA

PLATE XIII. Outflow creek from springs on Fredric Apcar property in the Warm Springs are of the Moapa River, Clark County, Nevada. Largest remaining populations of the endangered Moapa dace, Moapa coriacea, occur on this property. The Apcar property is adjacent to the Moapa National Wildlife Refuge and is slated for future acquisition by the U.S. Fish and Wildlife Service. Photograph taken 19 March 1981 by Donald W. Sada.

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The 40 km-long Moapa (= Muddy) River in Clark County, Nevada, flows from more than 20 warm springs (27 to 32.2°C) with a combined average discharge of approximately 84,000 liters per minute. Prior to filling of Lake Mead, the Moapa River flowed into the Virgin River, a tributary of the Colorado. The Moapa River has no perennial tributaries, and discharges from headwater springs are augmented only during flashfloods and snowmelt (Cross 1976). The river is a remnant of the pluvial White River system (Hubbs and Miller 1948b) and this relictual character is demonstrated by the isolated spring and springrun habitats of the headwaters, the physiochemical qualities of the water, and the sedimentary composition of the streambed. The native Moapa River ichthyofauna, with its high incidence of endemism, restricted distribution, and low diversity, also reflects the relictual character of the stream. For example, all native Moapa fishes, *Gila robusta* ssp., *Rhinichthys osculus moapae, Moapa coriacea* and *Crenichthys baileyi moapae,* are endemic.

As the Moapa River flows from its warm-spring source to Lake Mead, it passes through two zones of the Mohave Desert: the blackbrush and creosote communities. The river channel supports riparian and desert riparian transzonal communities along its course. The riparian communities contain species not found in the surrounding nonriparian areas, but representatives from the zonal communities are found mixed along the floodplains or stream banks (C. 0. Minckley, pers. comm.).

SPECIES ACCOUNTS.—Moapa roundtail chub, *Gila robusta* ssp. — Vulnerable. — Moapa roundtail chubs historically occupied a variety of habitats throughout the Moapa River. However, inundation of the lower reaches by Lake Mead, stream alterations for irrigation diversion, and introductions of exotic fishes and parasites apparently have eliminated *G. robusta* ssp. from the lower Moapa River. Abundance of this fish in the middle section of the river has decreased since 1942, probably as a result of competitive interactions with exotic fishes, particularly *Poecilia mexicana,* parasitism by organisms introduced on the exotic fishes and decreases in water quality caused by a dairy and other agricultural activities. Moapa roundtail chubs have always occupied headwater areas, but their low abundance in these areas are indicative of less suitable habitat. Remaining *Gila robusta* ssp. in the Moapa River appear primarily threatened by exotic species (Cross 1976, Deacon and Bradley 1972). The taxonomic separation of the Moapa roundtail chub from *G. robusta seminuda* of the Virgin River has not been demonstrated, but it is provisionally included herein pending a formal analysis.

Moapa dace, *Moapa coriacea* — Endangered. —*Moapa coriacea,* the monotypic representative of its genus, is endemic to headwater springs, their outflow creeks and the Moapa River downstream to the low head dam (Cross 1976, Hubbs and Miller 1948a). Even though abundance was historically much higher, the species probably always has been limited to the warm (27 to 32°C) and very low turbidity habitats characteristic of the headwaters. At most, this area comprised 25 springs and 16 km of rheocrenes. Presently, M. *coiacea* occurs in low numbers at only 3 springs and 3 km of rheocrenes locally referred to as the Warm Springs area of Clark County. A 1984-85 U.S. Fish and Wildlife survey (G. G. Scoppettone, pers. comm.) estimated that approximately 3,000 Moapa dace remain.

The decrease in abundance and distribution of *M. coriacea* apparently resulted from destruction or alteration of former habitat, including development of the springs for landscaping, recreation, tourism and water diversion for domestic and agricultural uses. Also, decreased abundance of *M. coriacea* coincided with establishment of the exotics, *Gambusia affinis* and *Poecilia mexicana,* in the headwater areas (Cross 1976, Deacon and Bradley 1972).

Moapa speckled dace, *Rhinichthys osculus moapae* — Vulnerable. — Historically, this Moapa River endemic probably occurred throughout the Moapa River, except the headwater springs. Presently, the dace is found in marginal, moderate to fast-current habitats of only the middle and upper reaches of the river (Williams 1978).

Loss or alteration of habitat from channelization, siltation, removal of riparian vegetation, and pollution has reduced the amount of habitat suitable for *R. o. moapae.* Competitive interactions with introduced exotics, such as *P. mexicana, G. affinis, Cyprinus carpio* and *Notropis lutrensis,* have further reduced the abundance and distribution of *R. osculus moapae* by forcing it to occupy only marginal habitats (Cross 1976, Deacon and Bradley 1972).

Moapa White River springfish, *Crenichthys baileyi moapae* — Vulnerable. — As its common name suggests, *C. baileyi moapae is* a Moapa River endemic that inhabits spring pools in headwaters of the river. Unlike *R. o. moapae,* the swift-water springruns are not preferred by *C. b. moapae.* Historical distribution of the springfish probably was similar to its present distribution in headwater springs of the Moapa River. *Crenichthys b. moapae* remains common in certain headwater springs, although exotic fishes, *Gambusia affinis, Poecilia mexicana* and *Pimephales promelas,* also occur in the area (Cross 1976, Deacon and Bradley 1972, Williams and Wilde 1981). Wilson et al. (1966) implicated exotic fishes as the source of a copepod and a nematode that parasitize *C. b. moapae* and add an additional cause for concern.

Moapa riffle beetle, *Stenelmis calida moapa* — Indeterminate. — *Stenelmis calida moapa* was described from warm, headwater springs of the Moapa River (La Rivers 1949). The status of this beetle is uncertain but can be expected to have declined from historic levels because of channelization, cementing and chlorination of springs.

Moapa naucorid, *Usingerina moapensis* — Indeterminate. — As described by La Rivers (1950), the monotypic genus *Usingerina* is confined to the "Warm Springs" area in headwaters of the Moapa River. It was taken in gravel beds of a stream where water temperature was 24 to 32°C (La Rivers 1950, Usinger 1956). Like other aquatic inverte-

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brates in the Moapa River system, *U. moapensis* is in need of a status survey.

Moapa pebblesnail, *Fluminicola avernalis* — Vulnerable. — This small hydrobioid snail is endemic to various headwater springs of the Moapa River (Landye 1973). Although its current status is not well known, the Moapa pebblesnail has suffered declines in numbers because of habitat alteration as described in the above discussion of *Moapa coriacea,* with which the snail is typically sympatric. The Moapa pebblesnail is also threatened by competition with the exotic snail, *Melanoides tuberculatus,* which is locally abundant.

White River tryonia, *Try onia clathrata* — Vulnerable. — The range of this pluvial White River endemic includes headwater springs of the Moapa River, where it is being replaced by the exotic *Melano ides tuberculatus.*

SUMMARY.—The headwater springs, rheocrenes, and lower reaches of the Moapa River have been modified extensively for tourism, recreation, and irrigation. Nine exotic fishes, *Salmo gairdneri, Cyprinus carpio, Carassius auratus, Notropis lutrensis, Notemigonus crysoleucas, Ictalurus melas, Gambusia affinis, Poecilia mexicana, Micropterus salmoides* and *Lepomis cyanellus,* have been introduced into the river system (Cross 1976; Deacon and Bradley 1972;J. E. Williams, pers. obs.). Construction of Hoover Dam and filling of Lake Mead inundated the confluence of the Moapa and Virgin Rivers, eliminated natural habitat in the lowest portions of both rivers and effectively eliminated the potential exchange of fishes between these two streams. Native fishes presently are restricted to the headwaters and middle reaches of the Moapa River.

In 1979, the Moapa National Wildlife Refuge was established on 19 ha of headwater spring habitat. The refuge was enlarged in 1983 by the purchase of the upper Plummer Springs area. Although the refuge was established for the endangered Moapa dace, it also provides habitat for the Moapa White River springfish and the Moapa pebblesnail. Protected habitat also needs to be obligated for the speckled dace and roundtail chub. Any endemic aquatic insects in the refuge should be identified so that management activities can incorporate requirements of these species.

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RIO YAQUI, ARIZONA, CHIHUAHUA AND SONORA

PLATE XIV. Unnamed spring near North Pond Cienega, San Bernardino National Wildlife Refuge, Arizona. *Poeciliopsis occidentalis* son*oriensis* is native to the spring and Gila *purpurea* has been reintroduced into the system. The adjacent North Pond is also an introduction site for the Yaqui catfish, *Ictalurus pricei*. Photograph taken October 1982 by Gerald L. Burton.

Headwaters of the Rio Yaqui system include the Rio de Bavispe in southeastern Arizona and northeastern Sonora, Rio Moctezuma in northeastern Sonora and Rios Papigóchic, Sirupa and Aros in western Chihuahua and eastern Sonora. These rivers form the Rio Yaqui, which flows southwesterly and eventually empties into the Gulf of California near Ciudad Obregón, Sonora. The entire basin comprises approximately 73,000 km^2, much of which is rugged and poorly accessible mountain and canyon areas (Blasquez 1959, Hendrickson et al. 1981).

Because of its high topographic relief and inaccessibility, much of the upper part of the Rio Yaqui system is is relatively undisturbed. However, several major reservoirs, such as those created behind Presas Angostura, Novillo and Alvaro Obregón, inundate major river areas. Much of the lower portion of the Rio Yaqui near Ciudad Obregón has been altered for irrigation purposes.

SPECIES ACCOUNTS.—Yaqui chub, *Gila purpurea* — Indeterminate. — The Yaqui chub was first described from San Bernardino Creek just south of the Arizona-Sonora border (Girard 1857). Since 1940, the species has been collected in the Rio Yaqui Basin only from the Rio Moctezuma at Cumpas, Sonora, a tributary of the upper Rio de Bavispe near Cabullonas, Sonora, and springs on the San Bernardino Ranch in Arizona (Branson et al. 1960, Hendrickson et al. 1981). The Yaqui chub is absent from most remaining portions of the Rio Yaqui system and is very rare in the few places where it is known. A small, introduced population exists in Leslie Creek, Cochise County, Arizona (Minckley 1973), and the species is locally abundant in the neighboring Rios Matape and Sonora of Mexico, but these populations appear to be at least somewhat differentiated from the Rio Yaqui form (Hendrickson et al. 1981). A possibly introduced population was discovered recently in the Rio de la Concepcion system (Hendrickson 1984). Primary threats to the Yaqui chub are habitat alteration, especially depletion of spring flows because of excessive groundwater pumping, stream diversion, reservoir construction and erosion of streambanks.

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Yaqui beautiful shiner, Notropis form osus mearnsi — Vulnerable. — Notropis *f.* mearnsi is restricted to the Rio Yaqui and that portion of the basin on the western side of the Sierra Madre Occidental (Hendrickson et al. 1981). This subspecies is provisionally included although the genus Notropis in northern Mexico is in need of taxonomic reevaluation. Minckley (pers. comm.) and Chernoff and Miller (1982) questioned the validity of mearnsi. Another beautiful shiner of uncertain status occurs in the Rio Papigóchic subbasin in Chihuahua (Contreras-Balderas 1978). During a 1978 survey of the Rio Yaqui system, N. f. mearnsi was found to be relatively scarce although wide-ranging (Hendrickson et al. 1981). Most populations occur in smaller streams and appear susceptible to the same threats as listed for the Yaqui chub except that N. *f.* mearnsi would be particularly vulnerable to introductions of red shiners, N. lutrensis. The Yaqui beautiful shiner has been extirpated from waters in the United States because of reductions in stream flows (McNatt 1974), and was not collected by Hendrickson et al. (1981) in Cajon Bonito in northern Sonora, where it had been taken in the 1950's.

Unnamed sucker, Catostomus sp. — Vulnerable. — This undescribed species is known from the Rio Gavilán system, a tributary of the Rio de Bavispe near the Chihuahua-Sonora border (Hendrickson et al. 1981). Historically, the species was known from headwater areas to the Rio Yaqui Delta. It may have occurred historically in Arizona but is now not found there. Nor has it recently been taken from the upper Rio Papigóchic in Chihuahua, the type locality of the probably synonymous I. meeki (Hendrickson et al. 1981, McNatt 1974). Parts of its historic range have been adversely affected by depletion of stream flows, diversions and erosion. Reservoir construction also appears to have eliminated suitable habitat; as the species was absent from impoundments although present in riverine areas upstream and downstream of the reservoirs (Hendrickson et al. 1981). Blue catfish, I. furcatus, and channel catfish, *I.* punctatus, have been introduced into the Rio Yaqui and may pose a problem through interaction with I. pricei. Although I. pricei obviously has declined in certain areas, part of the apparent rareness of the species may be an artifact of sampling difficulty in the large-river habitat preferred by this species.

San Bernardino springsnail, Fontelicella sp. — Vulnerable. — This snail is restricted to springs near the San Bernardino Ranch headquarters, Cochise County, Arizona (Landye 1981). It occurs in springs that supply water for the ranch headquarters and in springs feeding the nearby pond. The ranch was acquired recently by the U.S. Fish and Wildlife Service and should be managed to preserve all native aquatic species.

Yepomera springsnail, Fontelicella sp. — Rare. — This snail is restricted to the thermal springs of Yepomera, Chihuahua, Mexico. These springs are utilized by the local community and could be completely captured at a future date as the village expands.

Yepomera tryonia, Tryonia sp. — Rare. — This hydrobioid snail is associated in the same thermal springs as the Yepomera springsnail.

SUMMARY.—The Rio Yaqui systems provides the vast majority of sole habitat for two vulnerable, one indeterminate and one rare desert fishes. Although the precise distributions of these fishes are not well-known, recent surveys (Hendrickson et al. 1981) have clarified their status. The central portion of the drainage, however, remains largely unstudied. Although listed by the Fish and Wildlife Service as endangered, the Yaqui topminnow, Poeciliopsis occidentalis sonoriensis, is excluded from our list of rare fishes because of its wide distribution and abundance in Mexico (Hendrickson et al. 1981). Its status should be reexamined, however, if mosquitofish expand their range significantly in the Rio Yaqui system. Another fish of local abundance in the Rio Yaqui is the Yaqui trout, Salmo sp. Although not included in Table 1, the species is of uncertain taxonomic status and quite worthy of future study (Hendrickson et al. 1981, Smith 1984).

The Rio Yaqui form of Gila purpurea appears to be particularly vulnerable to extinction. If essential spring flows can be maintained, habitats on the recently dedicated San Bernardino National Wildlife Refuge in Cochise County, Arizona, may provide refugia for the Yaqui chub, Yaqui beautiful shiner and Yaqui catfish in the United States. Representative streams in Mexico, many of which are relatively undisturbed, need to be protected from increasing agricultural, logging, dam construction and mining pressures.

UPPER KLAMATH BASIN, OREGON AND CALIFORNIA

PLATE XV. Crooked Creek, Klamath County, Oregon. This small tributary of the Wood River provides spawning habitat for Deltistes luxatus. Photograph taken 20 April 1982 by Jack E. Williams.

The Upper Klamath Basin is defined herein as that part of the Klamath Basin from Iron Gate Reservoir on the Klamath River in Siskiyou County, California, upstream to the headwater of the Sycan, Sprague and Williamson Rivers in Oregon. Also included within this basin are the Lost River, Lower Klamath Lake, Upper Klamath Lake, Sheepy Lake and their tributary streams. Historically, marshes connected Lost River, Sheepy Lake and Lower Klamath Lake to the Klamath River system. Today, canal systems replace the marshes, which have been mostly drained. The Upper Klamath Basin contains a surprising diversity of suckers (family Catostomidae). Three species of Klamath Basin suckers exhibit a similar life history pattern of inhabiting large shallow lakes except during the spring when they ascend tributary streams to spawn. Upper Klamath Lake with its primary tributaries, the Williamson and Sprague Rivers, and Tule Lake with its primary tributary, the Lost River, provided habitat for hundreds of thousands or perhaps millions of suckers as recently as the late-1890's.

SPECIES ACCOUNTS.—Jenny Creek sucker, Catostomus rimiculus ssp. — Rare. — This undescribed dwarf subspecies of Catostomus *rimiculus* is isolated above high falls in Jenny Creek, Jackson County, Oregon, and its tributaries, Keene, Johnson, Beaver and Corral Creeks (Hohler 1981). Prior to the filling of Iron Gate Reservoir, Jenny Creek flowed into the Klamath River in Siskiyou County, California. Despite some habitat degradation caused by cattle grazing and construction of Hyatt Reservoir on Keene Creek, numbers and distribution of the Jenny Creek sucker appear little changed in recent times. However, the naturally restricted range of this fish calls for careful management.

Klamath largescale sucker, Catostomus snyderi — Rare. — The Klamath largescale sucker occurs in Upper Klamath Lake and its tributaries, the Sprague, Sycan and Williamson Rivers, as well as the Lost River system and and occasionally in the Klamath Lake just downstream of the Oregon border (Andreasen 1975, Moyle 1976). Lentic and lotic populations of the species are known,

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including a population of large individuals in Upper Klamath Lake that ascend the Williamson and Sprague Rivers to spawn. The status of the various populations is largely unknown, although water diversions and construction of dams on spawning streams have degraded habitats. Chiloquin Dam also facilitated some hybridization between C. snyderi and Chasmistes brevirostris, although pure populations of snyderi still exist.

Shortnose sucker, Chasmistes brevirostris — Indeterminate. — Chasmistes brevirostris is native to Upper Klamath Lake, Klamath County, Oregon, and its principal tributaries. Although three species of Chasmistes have been described from Upper Klamath Lake, *brevirostris* appears to be the only valid one (Miller and Smith 1981). The shortnose sucker has been collected from Clear Lake Reservoir, an impoundment on the Lost River in Modoc County, California, and its tributaries (Coots 1965, Koch et al. 1975). Their presence would seem to indicate that the shortnose sucker is native to Tule Lake and Lost River, although C. E. Bond (pers. comm. in Miller and Smith 1981) hypothesized that the species gained access to the Lost River from the Klamath system via the "A" Canal. None of the early ichthyological explorers collected Chasmistes from the Lost River system. Shortnose suckers have been taken from Lake of the Woods, Oregon (Andreasen 1975), but Miller and Smith (1981) also regarded this population as introduced. In recent years, the species also has been taken from Copco Reservoir on the Klamath River in Siskiyou County, California (Moyle 1976).

Like the Lost River sucker and certain populations of the Klamath largescale sucker, the shortnose is a lacustrine species that ascends tributary streams during spring spawning runs. Unfortunately, all specimens of shortnose suckers recently collected from Copco Reservoir, Upper Klamath Lake and Clear Lake Reservoir possessed characteristics of Catostomus snyderi or C. *rimiculus*, which indicates hybridization and subsequent introgression of Catostomus genes into the Chasmistes genome (Miller and Smith 1981). Concentrated spawning below dams appears to have been the primary cause of hybridization. The Chiloquin Dam on the Sprague River was constructed originally without fish ladders and apparently promoted hybridization between *Catostomus* snyderi and Chasmistes brevirostris as they ascended the Sprague River during spawning runs from Upper Klamath Lake. Despite some introgression of Catostomus genes, populations of shortnose suckers in Upper Klamath Lake and Copco Reservoir are relatively intact, true-breeding and worthy of protection and further study. The population of "Chasmistes" in Clear Lake Reservoir, however, shows evidence of hybridization and repeated backcrossing with Catostomus snyderi and seems not to be indicative of a true-breeding population (Andreasen 1975; C. E. Bond, pers. comm.). The population of Chasmistes in Lake of the Woods was destroyed by fish control operations in 1952 (Andreasen 1975).

Lost River sucker, Deltistes luxatus — Indeterminate. — The Lost River sucker is native to Upper Klamath Lake and its tributaries, the Lost River system, Lower Klamath Lake and Sheepy Lake (Andreasen 1975, Coots 1965, Koch et al. 1975). In recent years, the species also has been taken from Copco Reservoir on the Klamath River in California (Moyle 1976). Lost River suckers, commonly referred to as mullet, still support a sport fishery by snagging as they ascend the Williamson and Sprague Rivers in Oregon from Upper Klamath Lake. Adults commonly achieve 3 to 5 kg in weight. During the late-1800's, Lost River suckers were profuse and provided one of the staple foods of the Modoc and Klamath Indians (Cope 1879, Gilbert 1898). Construction of dams has reduced population sizes by eliminating habitat and blocking spawning runs. The species currently is listed as endangered by the State of California.

Topaz juga, Juga (Calibasis) *acutifilosa* — Rare. — This large gastropod is known from eight populations in Jackson County, Oregon, and Siskiyou, Lassen and Shasta Counties, California (Taylor 1981). These include Shoat Springs, Jackson County, Oregon, a tributary to Jenny Creek.

Archimedes pyrg, Pyrgulopsis arch imedis — Endangered. — This small hydrobioid snail was found in Tule Lake, Modoc County, California, and perhaps Lower Klamath Lake, Siskiyou County, California, but is presumed extinct in that state (Taylor 1981). Present distribution appears to be limited to Upper Klamath Lake, Klamath County, Oregon.

SUMMARY.—Three species and one subspecies of suckers, including the monotypic genus Deltistes, are endemic to the Upper Klamath Basin. With the exception of the Jenny Creek sucker, these species are mostly or entirely lacustrine and ascend tributary streams during spring spawning runs. Upper Klamath Lake is the primary refuge for the Lost River, shortnose and lacustrine populations of Klamath largescale suckers. The Sprague River is the primary tributary of Upper Klamath Lake that is utilized as a spawning stream for all three species. Chiloquin Dam on the Sprague River remains a major hindrance to spawning runs despite the presence of fish ladders. Passage over Chiloquin Dam needs to be improved if these large fishes are to persist. Survival of larvae as they drift back towards Upper Klamath Lake may be adversely affected by summer water diversions on the Sprague River. This potentially serious problem needs evaluation. Crooked Creek, a tributary of the Wood River, is also utilized as a spawning stream for the Upper Klamath Lake population of Lost River suck s and should be protected.

Habitat for suckers in the Lost River system has largely been destroyed by dams, water diversions and draining of wetlands. The only viable habitat remaining in the Lost River system is Clear Lake Reservoir, which harbors remnant populations of Lost River and hybrid Chasmistes brevirostris X Catostomus snyderi suckers. Willow and Boles Creeks are tributaries of Clear Lake Reservoir that are used as spawning streams (Coots 1965, Koch et al.

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1975). Instream flows and water quality must be preserved if these remnant Lost River populations are to persist. Survival of the sucker populations in Copco Reservoir is largely dependent on maintaining the free-flowing section of the Klamath River upstream of the reservoir.

DISCUSSION

Traditionally, biologists interested in endangered species have been concerned with preservation at the species level. Fewer efforts have been directed towards preservation of endangered habitats or communities. However, preservation of natural communities allows continued evolution of species, opportunities for future studies of species and natural community processes, and ultimately, provides the best chances for continued survival of the endangered species.

Recently, increased emphasis has been placed on artificial propagation of endangered species and relocation of rare organisms in artificial refugia to promote survival and recovery. Such efforts are appropriate for temporary survival or storage of critically endangered species, but are seldom suitable to allow natural evolutionary processes and long-term survival of the taxon. For example, Cross and King (1983) have shown that significant differences in gene frequencies developed between wild and hatchery-reared stocks of Atlantic salmon, Salmo salar, in five generations. Such unintentional selection under artificial conditions has been shown to result in genetically based behavioral changes in species (Bush et al. 1976). A number of Devils Hole pupfish, Cyprinodon diabolis, that were transplanted into an artificial refugium subsequently underwent a dramatic change in several mensural characters and overall body color (Williams 1977). These findings argue strongly for preservation of natural habitats and entire communities rather than concentrating efforts on preservation of species, per se.

Endangered species, and more appropriately, entire communities that are imperiled, are important indicators of endangered habitats. And for aquatic ecosystems of desert regions, fishes are key indicators of the health of these ecosystems. Herein, we identify 15 ecosystems that harbor large numbers of rare fishes and other aquatic organisms. These ecosystems range in size from approximately 1 to more than 600,000 km^2 and provide habitat for 4 to 12 rare fishes each (Table 3). Eighty-five of the 182 fishes of concern listed in Table 1 are included in these ecosystems. Endemism typically is high, and except for the Colorado and Green Rivers, little overlaps occurs among the distribution of the fishes discussed herein.

Table 3. Endangered aquatic ecosystems in the North American desert region. Approximate size includes the entire valley, basin or river drainage. E = endangered, V = vulnerable, R = rare, I = indeterminate, Ex = extinct.

Ecosystem	Location	Approximate size (km^2)	Number of fishes of concern					
				V	R	I	Ex	Total
Cuatro Cienegas	COA	1,200	0	2	9	1	0	12
Gila River	NM, AZ, SON	139,860	6	5	0	0	1	12
Rio Grande	NM, TX, CHI, COA, NLE, TAM	301,373	1	3	1	1	3	9
Pecos River	NM, TX	65,450	2	4	1	1	0	8
Railroad Valley	NV	9,233	0	3	2	2	0	7
Colorado River	CO, UT, NM, AZ, NV, CA, BCA, SON	631,936	4	1	1	0	1	7
Green River	WY, CO, UT	116,000	3	2	1	0	0	6
Pahranagat Valley	NV	2,600	4	0	1	0	1	6
Parras Valley	COA	2,231	3	0	1	0	2	6
La Media Luna	SLP	1	4	1	1	0	0	6
Ash Meadows	NV	756	3	1	0	0	1	5
Upper White River	NV	1,248	2	1	2	0	0	5
Moapa River	NV	405	1	3	0	0	0	4
Rio Yaqui	AZ, CHI, SON	73,000	0	2	1	1	0	4
Upper Klamath Basin	OR, CA	21,528	0	0	2	2	0	4

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Cuatro Ciénegas in Coahuila is remarkable for the large number of rare and/or endemic fishes, reptiles and molluscs inhabiting the 1,200 km^2 bolson. Pahranagat Valley, Ash Meadows, Moapa River and La Media Luna are also notable in numbers of endemic organisms per surface area. Despite its approximately 1 km^2 size, La Media Luna in San Luis Potosí provides habitat for three endemic crustaceans and five rare fishes, including two monotypic fish genera, Cualac and A taeniobius.

Three of the 15 ecosystems (Cuatro Cienegas, Parras and La Media Luna) are wholly within Mexico. Another four (Rio Grande, Colorado River, Gila River and Río Yaqui) are in both the United States and Mexico. Eight ecosystems (Pecos River, Railroad Valley, Pahranagat Valley, Green River, Ash Meadows, Upper White River, Moapa River and Upper Klamath Basin) are totally within United States boundaries. Our relatively poor knowledge of the Mexican ichthyofauna, especially as it pertains to identification of subspecies, may have resulted in fewer Mexican ecosystems meeting the criterion of providing habitat for at least four rare fishes.

Although many of the aquatic habitats in the 15 ecosystems have been degraded by man's activities, some still provide suitable habitat for a variety of rare organisms. Other habitats are yet pristine. In highly degraded ecosystems, protection of remaining natural habitats is critical to survival of a myriad of aquatic species. An account of certain remaining natural refugia in each ecosystem is provided below.

Most aquatic habitats in Cuatro Cienegas are in natural or near-natural condition. Natural water quality and quantity should be retained. On the other hand, flows in the Gila River have decreased to the point that much of the middle and lower portions are intermittent. Remaining tributaries and springs in their natural or near-natural condition should be preserved. The most important remaining habitat in the Gila River ecosystem is, perhaps, Aravaipa Creek, which provides habitat for seven native fishes. Much of the Rio Grande has been diverted, impounded or otherwise rendered unsuitable for many native fishes. Certain tributaries, such as the Devil's River and San Felipe Creek, provide natural refugia for the Rio Grande ichthyofauna. Within the Pecos River ecosystem, maintenance of aquifers is essential for springflows in the Diamond Y Spring/Leon Creek, Balmorhea, Blue Spring, and Bitter Lake National Wildlife Refuge habitats, which provide important natural refugia. Many springs in Railroad Valley still provide habitat for rare aquatic organisms, but unfortunately, the last remaining relatively undisturbed habitat (Little Warm Spring) was recently channelized and partially drained. In the Lockes Ranch area, Hay Corral and the Reynolds Springs do not harbor any exotic fishes and probably retain the least disturbed habitats. The Colorado and Green Rivers have been greatly altered by dams and water diversions. Remaining native fish habitats are restricted to large canyon areas, such as those in national parks and monuments, but water temperature, turbidity and flows have changed even in these areas because of upstream impoundments. Agricultural activities have greatly altered most Pahranagat Valley habitats, but preservation of headwater and outflow areas of Ash Springs is especially critical to survival of the dwindling native ichthyofauna. The entire native ichthyofauna of the Parras Basin has been nearly extirpated by habitat destruction and desiccation. Remaining habitat for the undescribed Gila is in immediate need of protection. The main laguna and associated springs of La Media Luna should receive immediate protection also. Within Ash Meadows, Devil's Hole and several middle-elevation springs still provide relatively unaltered habitat for the endemic fishes. Many lower-elevation springs have been modified, with Jack Rabbit and Big Springs providing the most favorable native fish habitats of this lower series. Many springs of the Upper White River have been severely modified, but Lund Town Spring is nearly pristine and harbors three or possibly four of the rare fishes from that region. The establishment of the Moapa National Wildlife Refuge offers new hope for preservation of the native Moapa River fishes. This refuge should be expanded to include both spring and riverine areas. Many Río Yaqui habitats in Mexico are undisturbed. The small portion of the Rio Yaqui drainage in Arizona, however, has been highly modified. Development of the San Bernardino National Wildlife Refuge in southeastern Arizona provides an excellent opportunity for restoring favorable habitat for the Rio Yaqui fishes in the United States. In the Upper Klamath Basin, maintenance of unimpeded flows in the Sprague River is essential to perpetuation of the endemic assemblage of catostomids from the basin. Although small, Crooked Creek provides a pristine spawing stream for the Lost River sucker in the Upper Klamath Basin.

Maintenance of remaining natural habitats is essential to survival of the many rare fishes known from North American deserts. Preservation of the native big-river fishes of the Colorado and Green Rivers poses special problems. Remaining populations are genetically isolated and subject to increased probability of extinction because of greatly reduced population sizes. Restoration of historic water temperature, flow and turbidity regimes along with the elimination of exotic fishes may be necessary for long stretches of these rivers and/or their tributaries in order to insure survival of the bonytail, humpback chub, Colorado squawfish and razorback sucker.

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