ENDANGERED AND THREATENED FISHES OF THE WEST

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ABSTRACT.— The endangered and threatened fish fauna of the United States exhibits problems resulting primarily from habitat modification by man. The evolutionary history of the fauna has left it especially sensitive to biotic interactions. In addition, many forms are of such restricted distribution that the entire taxon can be destroyed by very minor perturbations. The effects of habitat modification on woundfin and roundtail chub in the Virgin River of Utah, Arizona, and Nevada are discussed. Parasitism by *Lernea* on White River springfish is shown to coincide with population decline in some, but not all, cases. Population declines of Pahrump killifish are related to biotic interactions with both goldfish and mosquitofish. Population size of Devils Hole pupfish are shown to be quite responsive to small changes in habitat availability.

Fishes of the West are affected by the same general kinds of ecological problems that are causing extinctions throughout the world. The interplay of economics with perceived value in society has led us into the numerous ecological problems facing us today. There is some evidence to suggest that society is making some preliminary effort to slow the rate of extermination. Perhaps this is happening because the conclusions of ecologists, philosophers, and theologians regarding the relationship of man and environment are to some extent being translated into legislation as well as into conventional wisdom.

The fish fauna of the western United States has frequently been characterized as one having a relatively low diversity and containing an unusually high percentage of endemic taxa exhibiting limited distributions (Miller 1959, Smith 1978). These appear also to be the primary features contributing to the fact that much of the fauna is threatened to some degree.

Recently, the Endangered Species Committee of the American Fisheries Society compiled a listing of threatened fishes of North America (Deacon et al. 1979). The fishes on that list from the western United States are presented here as a data base for the general discussion (Tables 5 and 6). The predominant threats to all taxa listed were generalized into five broad categories and each taxon was assigned one or more of these categories. Threat categories were as follows: (1) The present or threatened destruction, modification, or curtailment of the habitat or range. (2) Overutilization for commercial, sporting, scientific, or educational purposes. (3) Disease or parasitism. (4) Other natural or manmade factors affecting continued existence (hybridization, introduction of exotic or translocated species, predation, competition). (5) Restricted range of the taxon. A comparison of threats to western fishes north of Mexico with those to eastern fishes is of general interest and illustrates significant differences between the two faunas (Table 1).

Habitat modification (Category 1) is clearly the most prevalent threat to native fishes throughout the world, and this is certainly true in North America. There are a few species in the West, however, that are not now so threatened. No eastern species, however, has escaped problems raised by physical alteration of the habitat.

No western species has been or is threatened by overexploitation (Category 2), but about 7 percent of the eastern fishes on the list are or were so threatened. Six species of ciscoes occurring in the Great Lakes were subjected to overfishing by commercial fishermen, changes resulting from the introduction of the sea lamprey, and general environmental degradation (Scott and Crossman 1973). In addition, the Atlantic whitefish has been subjected to overfishing as well as habitat alteration. They represent the only fish taxa in the United States or Canada to be on the American Fisheries Society list of threatened species, in part, because of overexploitation.

Disease and parasitism (Category 3) have

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apparently not been involved in threats to any eastern species on the list but have been factors for about 4 percent of the western fishes. It is probable that this difference results from the fact that information regarding incidence of disease and parasitism in native fishes is relatively sparse. In addition, though the initial major decline in abundance and distribution of eastern fishes probably occurred prior to 1850 (Trautman 1957), in the West the similar event occurred subsequent to 1850 (Miller 1961). Because increased incidence of disease and/or parasitism as an important factor in a population decline becomes most apparent during the major decline, it must be detected at that time to be recognized. The generally earlier decline of eastern fishes during a time when increased incidence of disease or parasitism would have been less likely to have either been detected or associated with the decline probably explains its absence from association with the eastern fauna. This factor doubtless has been a more important contributor to decline of both eastern and western fish populations than is apparent. It has specifically been identified by Wilson et al. (1966) and Seethaler (1978) as a factor in the decline of western fishes.

Biological interactions of various kinds (Category 4) contribute to the problems faced by 54 percent of the threatened western fauna but only 9 percent of the threatened eastern fauna. The marked differences in Category 4 point to distinctions of the western fish fauna that have been repeatedly discussed. Physical barriers to dispersal have resulted in relatively low colonization rates throughout the West, with the consequence that western fish faunas are not especially speciose (Smith 1978). Because their evolutionary experiences have been with relatively depauperate faunas, western fishes have relatively low tolerances to biological interactions (Smith 1978, Deacon and Minckley 1974, Hubbs et al. 1974).

A restricted range (occurring in only a single spring, a single group of springs, or a short stretch of stream [Category 5]) is a factor involved in giving a threatened status to 21 percent of the western fishes listed, but only about 7 percent of the eastern fishes. Category 5 illustrates the fact that one group of western fishes appears to have a high degree of "extinction resistance" (Smith 1978). The consequence is that many western taxa exist as relict populations in single habitats. They found their way onto the AFS list of threatened fishes because of that fact. They, like many western fishes, generally have high tolerances to physical extremes but low tolerances to biological interactions (Deacon and Minckley 1974).

Physical Modification of Habitats

While western fishes have in general developed considerable resistance to the physical extremes imposed upon them by climatic factors, they have also been most strongly affected by general and specific alterations of physical habitats imposed upon them by man. Miller (1961), Hastings and Turner (1965), and Cottam (1961) have dramatically shown the impact of slight climatic shifts superimposed on removal of vegetative cover by overgrazing between about 1880 and 1900. The arroyo cutting, siltation, and dewatering that occurred during this period were probably the most detrimental 20 years

Table 1. Comparison of general kinds of threats to the threatened freshwater fish fauna of western and eastern North America, north of Mexico.

General threat category	Western Fishes: Number of taxa (N = 112)	Western Fishes: Percent of fauna affected	Eastern Fishes: Number of taxa (N = 90)	Eastern Fishes: Percent of fauna affected
1. Habitat modification	109	97.3	90	100
2. Overexploitation	0	0	6	6.7
3. Parasitism and disease	5	4.4	0	0
4. Biotic interactions	60	54	8	8.9
5. Restricted range	24	21	6	6.7

of all time to fishes and aquatic habitats in the western United States. This period was followed closely by a very active period of dam building, with concomitant increases in irrigated agriculture, especially since about 1930, when large reclamation projects began providing water to irrigate what is now some 10 million acres of land in the West. The decline in abundance of the native fishes of the mainstream Colorado River is associated closely with construction of these mainstream dams (Minckley and Deacon 1968, Holden and Stalnaker 1975 a, b, Seethaler 1978). Declines in fishes of tributary streams are also occurring and are similarly associated with water manipulations of various kinds that result in dewatering portions of fish habitats. Recently, McNatt (1978) has described the process along the San Pedro River of Arizona. I present some documentation here for similar problems along the Virgin River of Utah, Arizona, and Nevada.

The Virgin River drains southwestern Utah and flows through the northwestern corner of Arizona before joining the Colorado River in Lake Mead, Nevada. A salt spring, LaVerkin Springs, enters the river 180 km upstream from its confluence with Lake Mead, forming the upstream limit of distribution for both the Virgin River roundtail chub, *Gila robusta seminuda,* and the woundfin, *Plagopterus argentissimus.* Both are here listed as endangered and both are presently restricted to the mainstream of the Virgin River below LaVerkin Spring. In addition, the Virgin spinedace, a threatened species, occurs both below and above the springs.

Irrigation diversions have been established along the river since the 1860s. Since at least the early 1900s, the Hurricane Diversion, Washington Diversion, and Mesquite Diversions (Fig. 1) have been capable of diverting essentially the total summer flow of the river at each of these three diversion points. La-

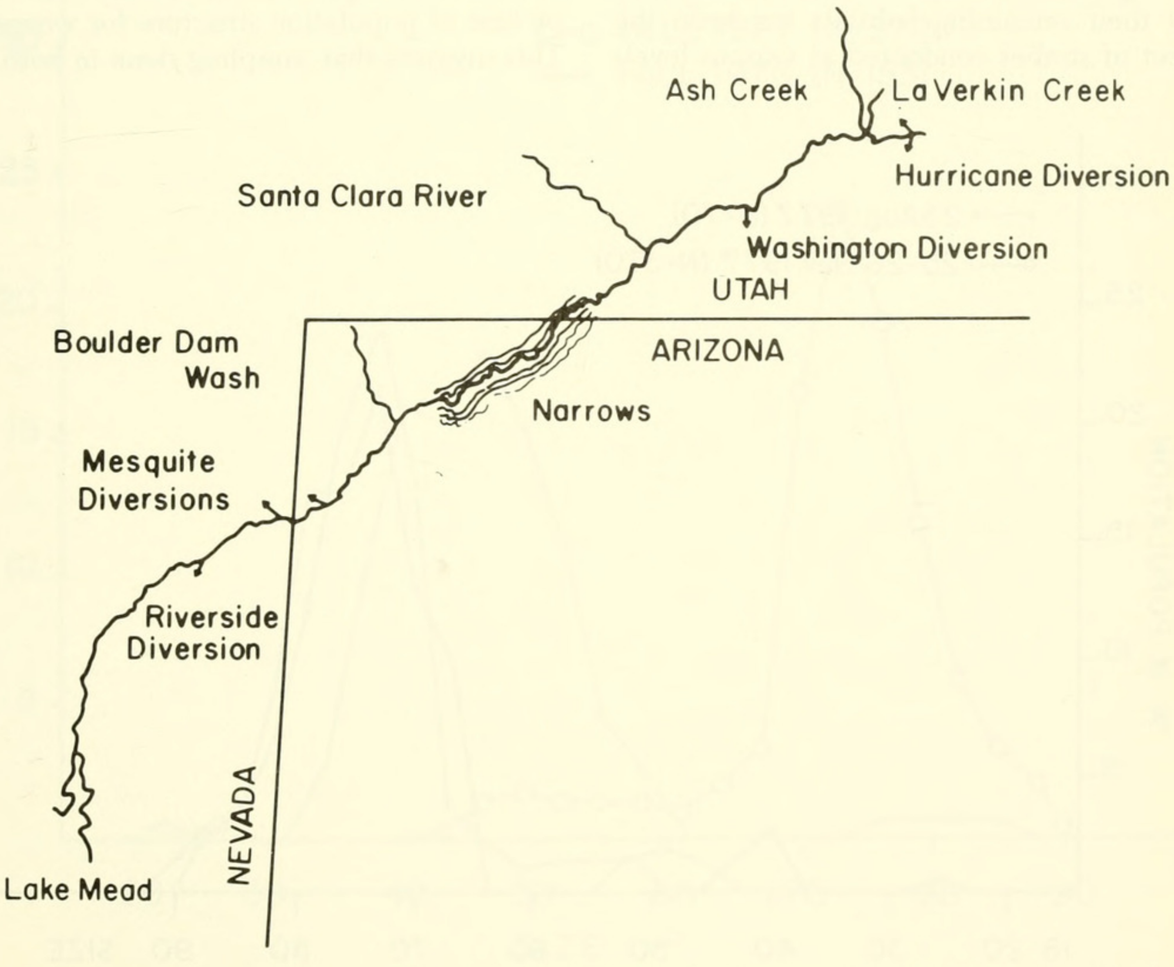

Fig. 1. Mainstream Virgin River below Hurricane diversion showing total remaining potential habitat for the endangered woundfin and roundtail chub, and significant modifications currently restricting their range.

Verkin Springs, entering just below the Hurricane Diversion, plus inflow from LaVerkin and Ash Creeks, maintain permanent stream flow downstream to Washington Diversion (Fig. 1). Littlefield Springs, entering at the lower end of the narrows, maintain permanent streamflow downstream to the Mesquite Diversion (Fig. 1). When the total streamflow is actually used at the above diversion points, only about 52.5 km (or 29 percent) of the remaining 180 km of potential habitat for the two endangered species restricted to the mainstream is actually constantly available to them.

The narrows (Fig. 1) divides the mainstream into an upper and a lower component that appears to effectively isolate the contained fish populations. Elevation and climate in the two regions differ significantly. The difference was reflected by the nearly one-month earlier spawning of the woundfin population in the lower river in the spring of 1977 (Fig. 7).

The question of requirements of these fishes in their remaining habitats has been the subject of studies conducted at various levels of intensity since 1961 (Cross 1975, 78, Williams 1977, Schumann 1978, Peters 1970, Lockhart 1979, Vaughn Hansen Associates 1977). The drought of 1977 resulted in some of the lowest flows on record in the Virgin River, a circumstance which allowed significant insights into the probable effects of water development projects which would tend to reduce or alter flows in the river. The more normal flows of 1978 provided a useful comparison to the low-flow conditions of 1977.

Length-frequency analysis was used as a convenient means of examining the population structure of the fishes in the Virgin River. Samples were taken by repetitively seining an area until the number of fish collected amounted to less than 10 percent of the highest number collected. In this way we insured a good representative sample of all fish occurring in the sampled area. Figure 2 demonstrates that samples taken in August 1977 and more extensive sampling from November 1977 provide essentially the same picture of population structure for woundfin. This suggests that sampling done in both Au-

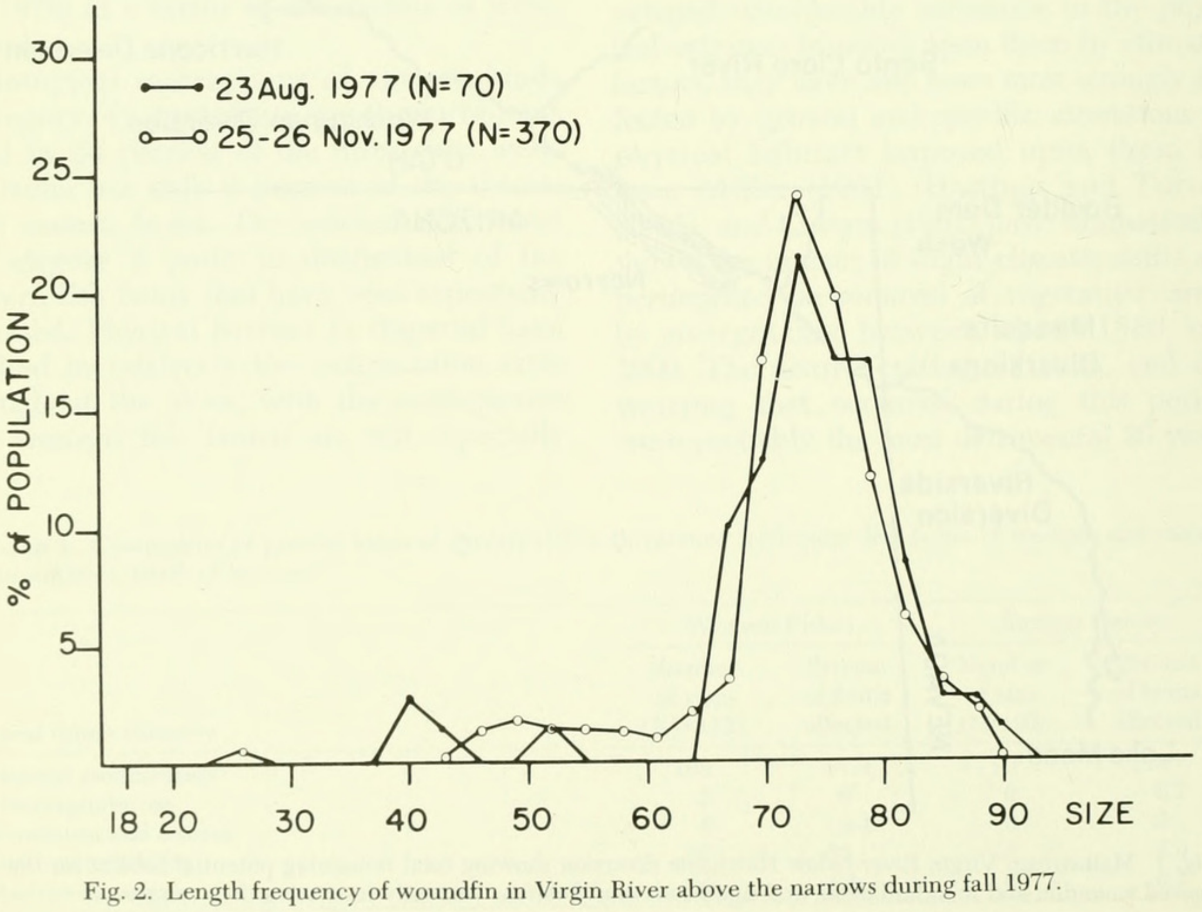

Fig. 2. Length frequency of woundfin in Virgin River above the narrows during fall 1977.

gust and November was extensive enough to provide a good representation of population structure in woundfin. The major fact revealed is that in 1977 young-of-the-year comprised a very small (nearly inconsequential) proportion of the woundfin population above the narrows. By contrast, a comparison of population structure in woundfin above the narrows in 1977 and 1978 (Fig. 3) indicates that young-of-the-year dominated the population in 1978.

When sampling is extensive enough, and stunting can be discounted as a significant factor, much of the information gleaned from an examination of length frequency can be summarized by calculation of a mean length for the population. In this case, for both woundfin and roundtail chub, small mean length indicates relatively high reproductive success and vice versa. Figure 4 and Table 2 present data available on mean length of woundfin above the narrows in 1973, 1977, and 1978, together with a hydrograph of mean monthly flows. They show that in 1973 and 1978, with high winter and spring flows, reproductive success was high, but in 1977, with low flows, reproductive success was low.

A similar situation appears to have existed for the roundtail chub, *Gila robusta seminuda* (Fig. 5, Table 2), except that the species was so rare in 1977 that very few were captured in spite of extensive sampling efforts. This, of course, indicates that not only were environmental conditions in Virgin River during 1977 inimical to successful spawning in this species, they also apparently reduced the survival of adults. Figure 5 does show that the species spawned successfully in at least one location on the upper mainstream of the Virgin River in 1978. Relatively high population density or evidence of a successful hatch was not found at any other location sampled in the upper or lower Virgin River

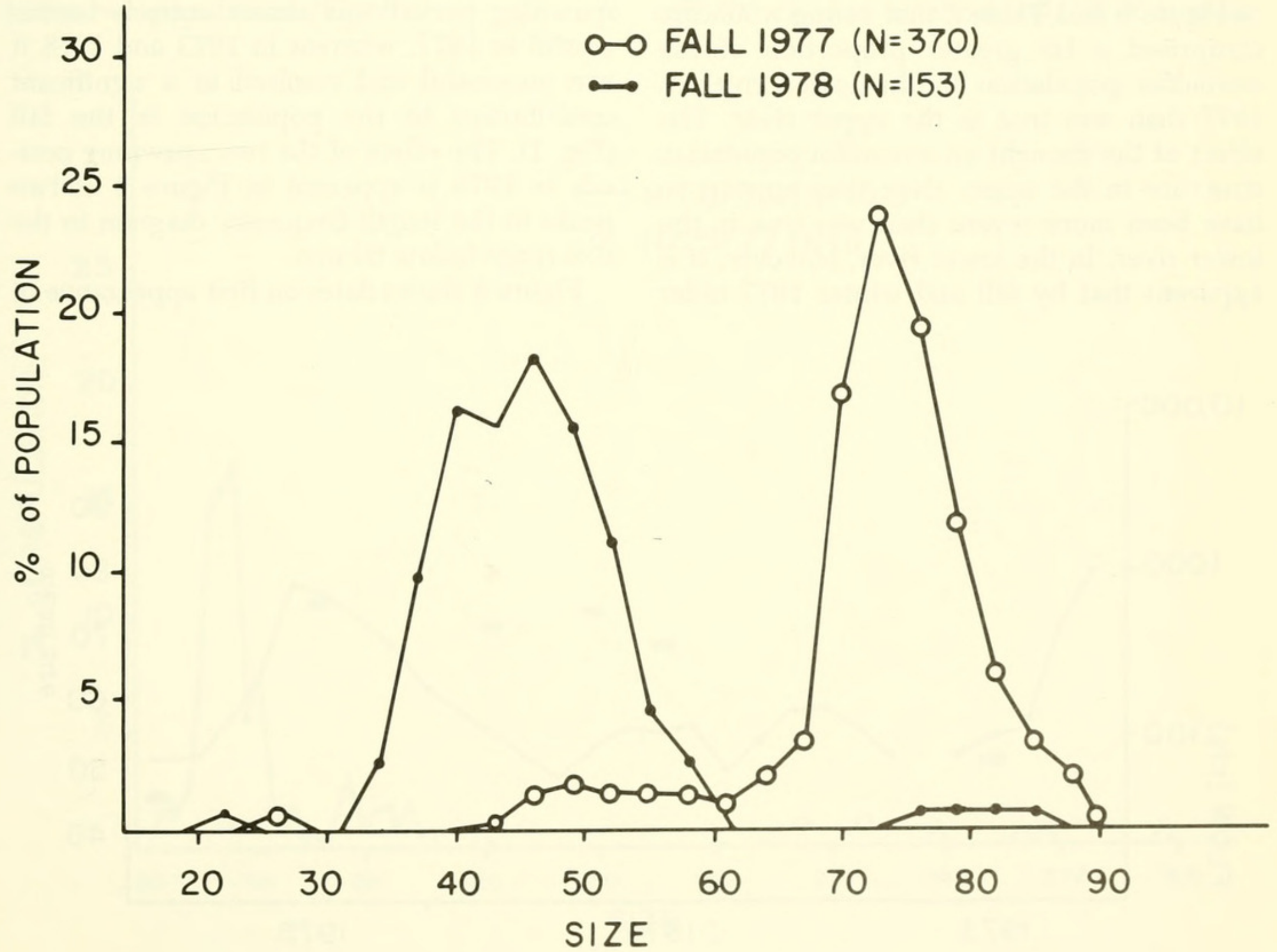

Fig. 3. Comparison of length frequency of woundfin in Virgin River above the narrows in fall 1977 and fall 1978.

TABLE 2. Mean size of woundfin and roundtail chub in Virgin River. The 0 indicates collections were made in the area but no individuals of the species were taken. The – indicates the area was not collected. Data on woundfin from 1973 were provided by Mr. Jerry Lockhart. He probably also took chubs; however, data are not available.

		1973		1977								1978					
		Aug & Sept		1–8 June		23–30 Aug		14–15 Nov		25–26 Nov		12 April		28 Sept		1 Nov	
		X̄	N	X̄	N	X̄	N	X̄	N	X̄	N	X̄	N	X̄	N	X̄	N
Upper river	Woundfin	52.1	60	69.3	172	74.3	70	71.2	416	72.3	371	76.2	190	46.0	153		–
	Chub			158.2	5	173	1		0		1		0	67.6	102		–
Lower river	Woundfin	50.2	105	44.0	177	53.6	202		–	56.6	383	58.2	112	44.4	427	48.6	46
	Chub			45.0	1	173	1		–	158	3		0	84.3	4	70.0	1

in September 1978. Perhaps even in times of "normal" flows there are relatively few optimal habitats for the roundtail chub remaining in the Virgin River.

In addition to the marked differences in reproductive success of woundfin and roundtail chubs in 1977 and 1978, interesting differences in population structures of woundfin above and below the narrows in 1977 were evident. It is apparent from an examination of Figure 6 and Table 2 that young woundfin comprised a far greater proportion of the woundfin population in the lower river in 1977 than was true in the upper river. The effect of the drought on woundfin population structure in the upper river thus appears to have been more severe than was true in the lower river. In the lower river, however, it is apparent that by fall and winter 1977 older or larger fish tended to predominate to a greater extent than was true in either fall 1973 or fall and winter 1978. This suggests (1) that growth of young in 1977 may have been faster than was the case in 1973 and 1978, (2) survivorship may have differentially favored older woundfin during summer 1977, (3) spawning may have occurred earlier in summer 1977 than in 1973 or 1978, or (4) perhaps more probable, the later secondary spawning period was almost entirely unsuccessful in 1977, whereas in 1973 and 1978 it was successful and resulted in a significant contribution to the population in the fall (Fig. 1). The effect of the two spawning periods in 1978 is apparent in Figure 2 as two peaks in the length-frequency diagram in the size range below 60 mm.

Figure 8 shows dates on first appearance of

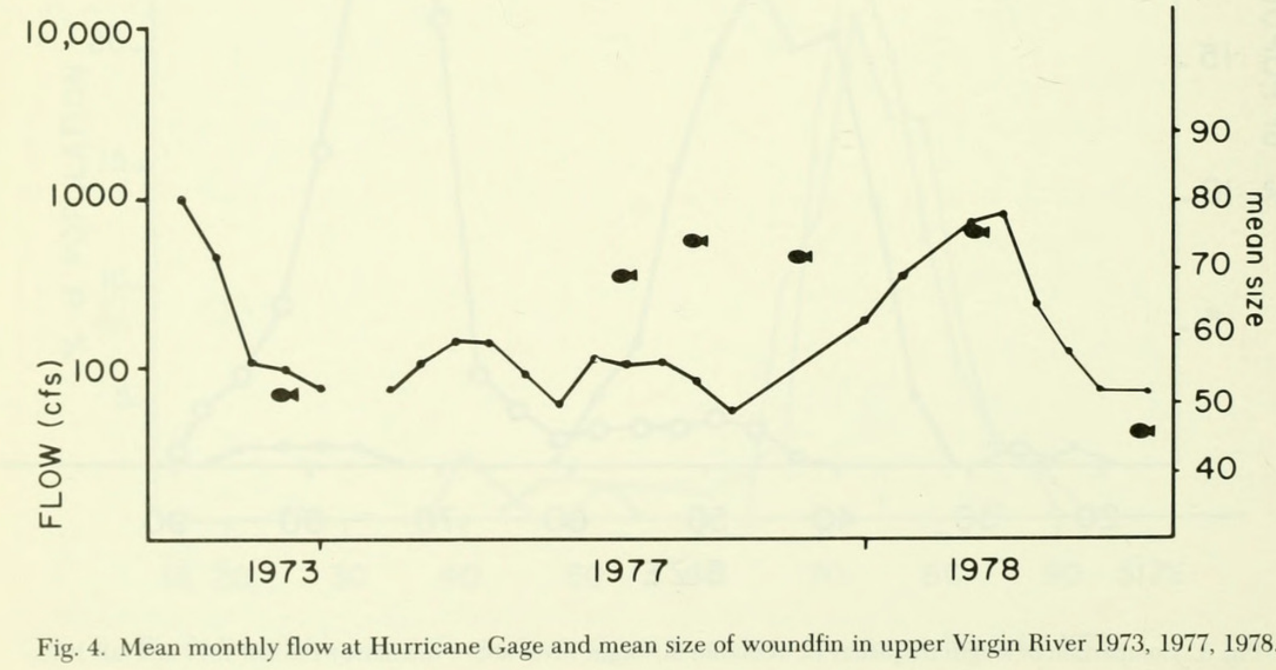

Fig. 4. Mean monthly flow at Hurricane Gage and mean size of woundfin in upper Virgin River 1973, 1977, 1978.

woundfin fry at various locations along the Virgin River during summer 1977. Collections were made at one- to two-week intervals until fry were taken at each location indicated. The uppermost location, indicated by 23 July in Figure 8 was actually below the Hurricane Diversion but above LaVerkin Creek. It is apparent that hatching occurred earlier in the lower river than in the upper river. Furthermore, in the lower river hatching appears to have been delayed by about two weeks at the lowermost station where habitat modification is most obvious.

The earlier appearance of young woundfin in the Arizona segment of the lower river was followed by relatively good survival in 1977 (Fig. 7). By contrast, the later appearance of young woundfin in the upper river was followed by very poor survival in 1977 (Fig. 3). With higher flows in 1978, both upstream and downstream populations of woundfin showed good reproduction, and by fall 1978 the mean size was nearly identical in the two populations (Fig. 6).

Comparisons of hydrographs of Virgin River flows for 1973, 1977, and 1978 show that the major differences in flow occurred during winter and spring. Summer flows suggest a relatively greater degree of similarity for all three years (Vaughn Hansen Associates 1977). If winter and spring flows significantly influence reproductive success of the endangered fishes of the Virgin River, the effect should be discernable in the population structure during the following fall. Figure 9 presents data comparing mean size of woundfin in the fall in both the upstream and downstream populations against mean flows of the river during the spring. Of particular significance is the fact that when stream flow is low, mean size is high and vice versa. Interestingly, Figure 9 also suggests that when mean spring flows are above 700 cfs, reproductive success may be slightly poorer than when mean spring flows are between 400 and 600 cfs. Data are not available for times when mean spring flows fall between 100 and 400 cfs, but at about 100 cfs it is clear

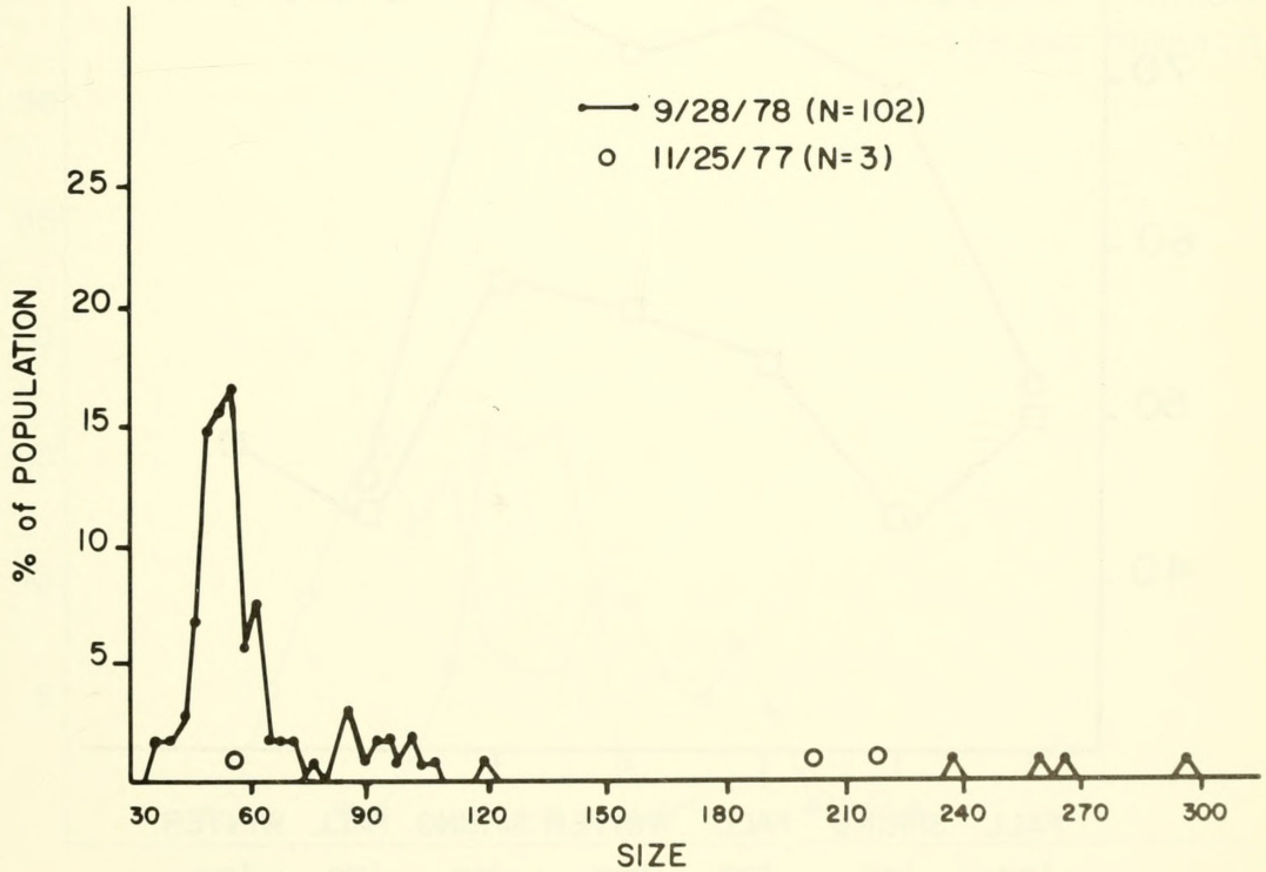

Fig. 5. Length frequency of roundtail chub in Virgin River above the narrows. The o's indicate size of the only three individuals taken in extensive sampling on 25 November 1977.

that reproductive success falls off dramatically. Essentially, the same relationships exist if mean flows from January to June, inclusive, are compared. This examination suggests that reproductive success of woundfin (and roundtail chub) in their only remaining habitat is extremely poor when mean winter and spring flows fall to about 100 cfs.

The drought of 1977, resulting in some of the lowest flows on record in the Virgin River, has permitted a significant insight into the habitat requirements of the endangered native fishes of the river. It is apparent that current utilization practices of the water resources permit survival of the native fishes in about 29 percent of their remaining potential habitat. Intermittent flows coupled with higher summer temperatures throughout the remainder of the potential range (Schumann 1978, Lockhart 1979) make it unreliable as a fish habitat. Within the remaining 29 percent of the potential habitat, reproduction occurs during years of normal flow, but is extremely poor to absent during years of low flow. This circumstance suggests that at present the fishes are living in a habitat which has extremely little potential for further development or alteration without adverse impacts on the endangered species present. Continued monitoring of reproductive success and population structure under varying conditions of stream flow will permit refinement of flow requirements. It is apparent that the roundtail chub is in an even more precarious position than is the woundfin and that both species require higher flows in spring and winter than they do in summer.

Obviously, problems associated with the

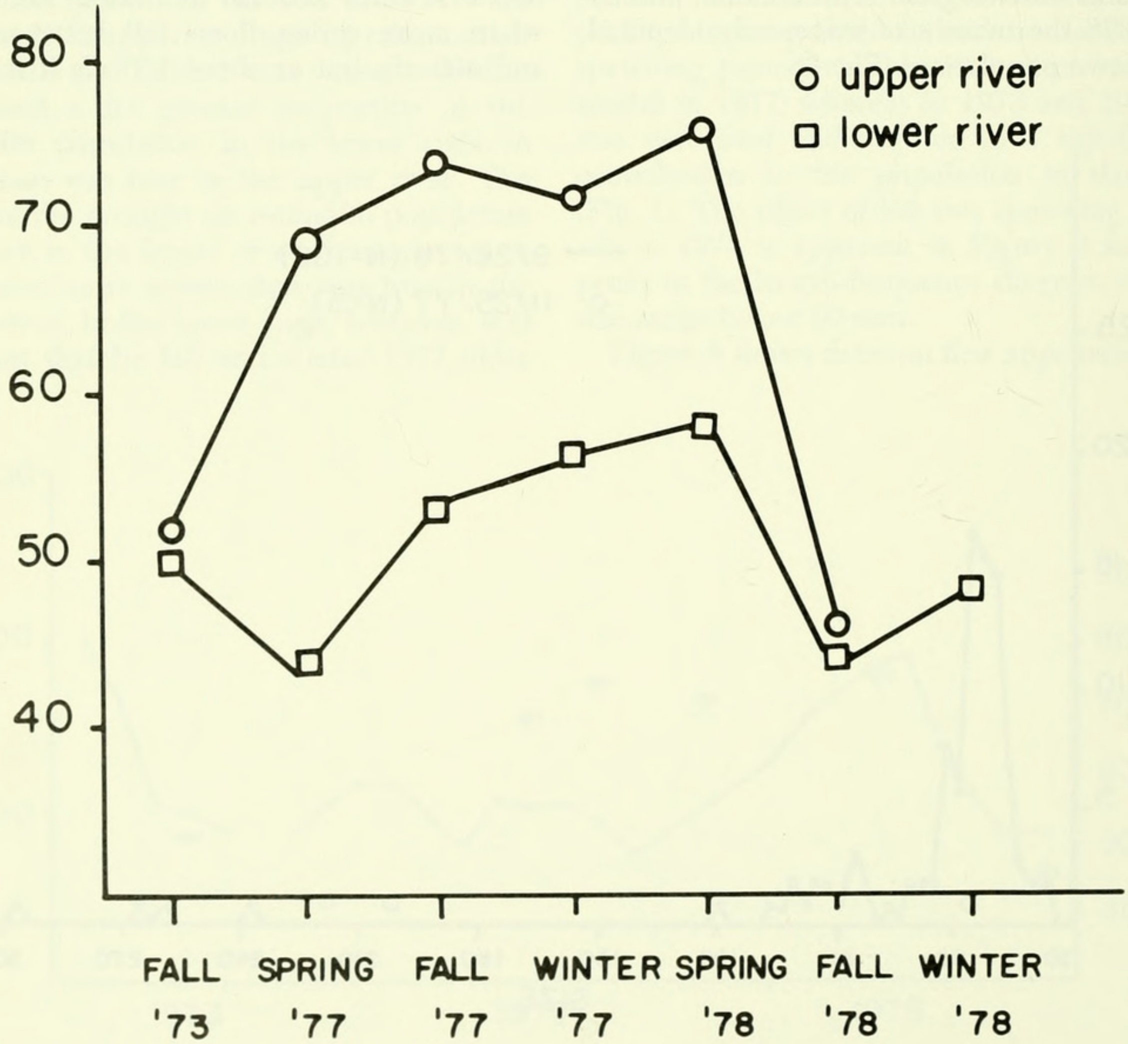

Fig. 6. Comparison of mean size of woundfin in the upper and lower mainstream Virgin River 1973, 1977, 1978.

effects of habitat modifications are complex, often having been developing for more than a century, and always difficult to quantify or even specifically identify. The problems identified and briefly examined here for the Virgin River have numerous counterparts throughout the West, as is obvious from the fact that 97 percent of the western fishes listed herein are on this list in part because of the present or threatened destruction, modification, or curtailment of their habitat or range.

Disease and Parasitism

Wilson et al. (1966) and Seethaler (1978) have suggested that parasitism may place significant stress on western fishes being subjected to other alterations in their environments. Examination of museum specimens of *Crenichthys baileyi* collected since 1938, supplemented by examination of both museum specimens and individuals taken in the field in 1965 and 1966, yields interesting insights into responses to stress. *Crenichthys baileyi* occurs in warm springs along the course of the Pluvial White River of eastern Nevada. During the early 1960s various exotic or nonnative species were established in some *Crenichthys* habitats (Deacon et al. 1964, Hubbs and Deacon 1964).

Figure 10 and Table 3 show the incidence of parasitism by *Lernea* on *Crenichthys baileyi* populations living in Crystal Spring and in the warm headwaters springs of the Moapa River from 1938 to 1966. All available data are presented in Table 3. Only data resulting from an examination of 20 or more individuals are plotted in Figures 10 and 11. During this period no nonnative fish were established in Crystal Spring. The poulation remained abundant and virtually free of parasitism by *Lernea*.

In the headwaters of Moapa River, the

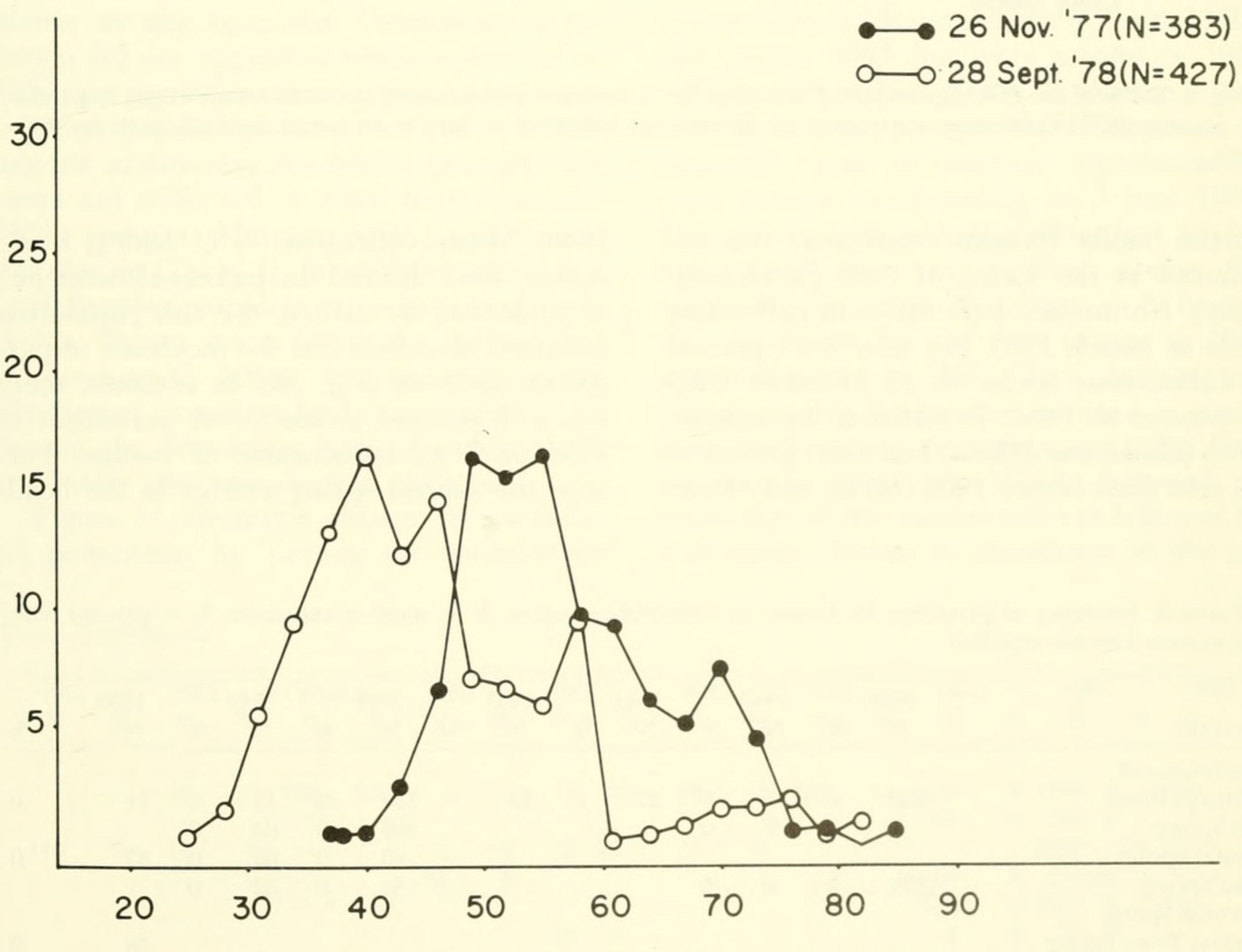

Fig. 7. Length frequency of woundfin in the lower Virgin River, fall 1977 and fall 1978.

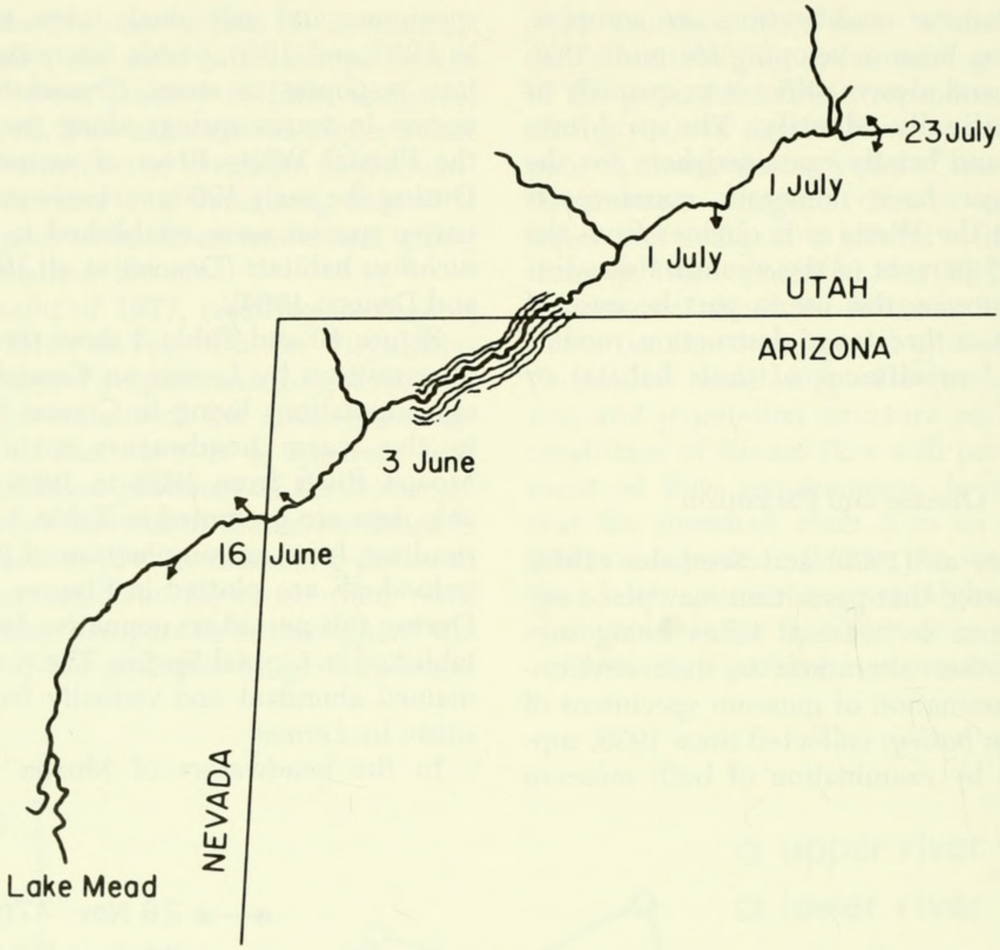

Fig. 8. Dates of the first appearance of woundfin fry at various locations along the mainstream Virgin River during summer 1977. Collections were made at all locations indicated at one- to two-week intervals until fry were taken.

shortfin molly (*Poecilia mexicana*) was introduced in the spring of 1963 (local testimony). No mollies were taken in collections made in March 1963, but they were present in collections made on 12 October 1963 (Deacon et al. 1964). In addition, the mosquitofish (*Gambusia affinis*) had been present in the area since before 1938 (Miller and Alcorn 1946). While collections of *C. baileyi* made during 1963 showed an increased incidence of parasitism by *Lernea*, the fish population remained abundant and the incidence of parasitism declined (Fig. 10). In addition, there was a 5 percent incidence of parasitism in 1959 prior to introduction of mollies. Perhaps the several spring sources in the head-

TABLE 3. Incidence of parasitism by *Lernea* on *Crenichthys baileyi*. N = number examined. % = percent with one or more *Learnea* attached.

	1938		1940		1941		1947		1948		1949		1950	
Location	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Headwaters of Moapa River	250	0	7	0	27	0	28	0	158	0	11	0	11	0
Ash Spring	5	0	8	0					106	0	64	0		
Crystal Spring									20	0	64	0	83	0
Hiko Spring	1576	0	6	0					54	0	52	0		
Mormon Spring														
Preston Town Spring													58	0
Preston Big Spring													17	0

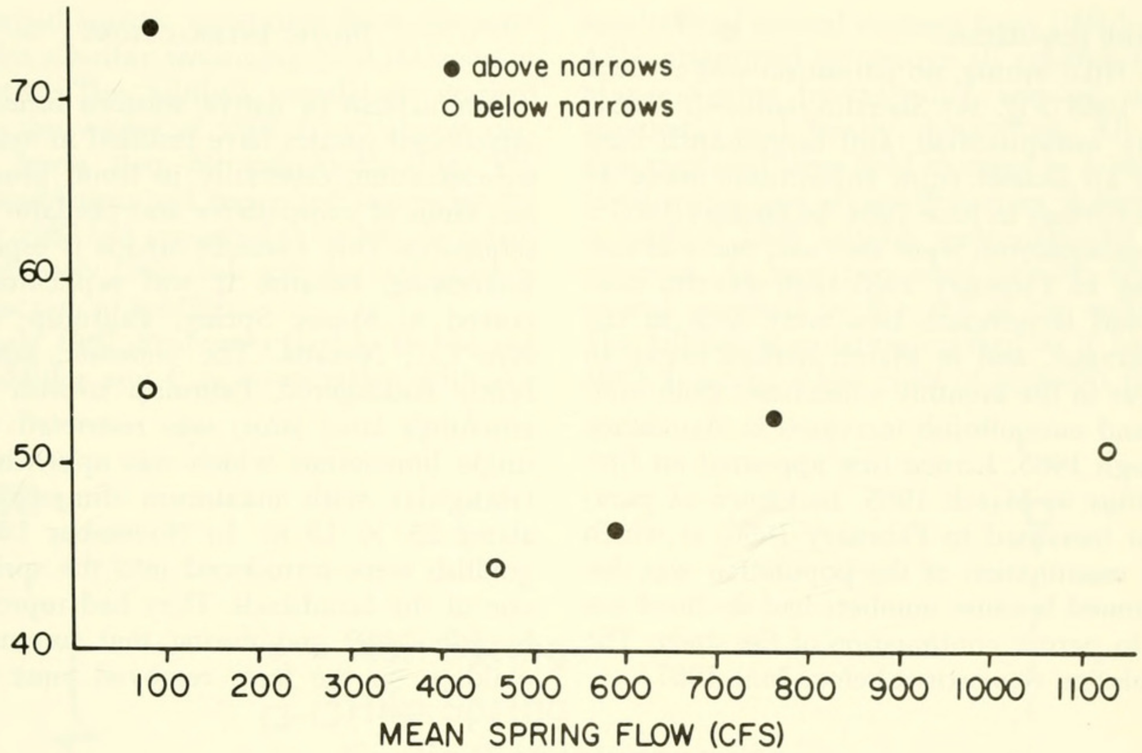

Fig. 9. Mean spring flows in Virgin River related to mean size of woundfin in the following fall. Data are from 1973, 1977, 1978. Mean spring flow is the average of the monthly means for April, May, and June.

waters were invaded by mollies at different times; in any case, the *Crenichthys* population did not appear to either sustain or reflect any permanent damage from parasitism.

Other populations for which historical data are not so extensive but which, through 1966, were not subjected to stress from nonnative fishes occur at Mormon Spring and Preston Big Spring (Table 3). In addition, while guppies *Poecilia reticulata* have been in Preston Town Spring since sometime before 1961 (Deacon et al. 1964), we have seen no indication of parasitism by *Lernea* (Table 3). Of course, the population was not examined immediately after introduction of *Poecilia*.

Figure 11 illustrates changes in incidence of parasitism by *Lernea* for populations which became rare or extinct. In Ash Spring, mosquitofish were not present in 1946 (Miller and Alcorn 1946) but were present in 1959 (Miller and Hubbs 1960). In March 1963, *Poecilia* was not present, but *P. latipinna*, *P. mexicana*, and *Cichlasoma nigrofasciatum* were present and breeding on 3 June 1964. They have since remained abundant in Ash Spring and its warm outflow stream. Incidence of parasitism by *Lernea* on *C. baileyi* was significant for the first timme in 1964 and remained so in 1965. The *C. baileyi* population in this limnocrene declined in abundance and remains extremely rare today. The increase in parasitism closely followed introduction of the exotics and was followed by a dramatic decline in abundance of the na-

TABLE 3 continued.

1951		1954		1959		1960		1961		1962		1963		1964		1965		1966	
N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
		19	0	920	5.1			11	9.1	68	0	238	14	15	0	1259	0	253	0
														90	10	224	9	5	0
110	0	11	0			4	0	16	25	16	0					2828	.04	356	0
		101	0			82	0							69	0	313	20	27	59
														159	0	1051	0	188	0
								25	0					5	0	25	0		
117	0							17	0					20	0	704	0	440	0

tive fish population.

At Hiko Spring, no parasitism was evident until 1965 (Fig. 11). Shortfin mollies (*P. mexicana*), mosquitofish, and largemouth bass were all absent from collections made at Hiko Springs in June 1964. In January 1965 a few mosquitofish were seen and one was collected. In February 1965 both shortfin mollies and largemouth bass were seen in the limnocrene, and in March mollies began to appear in the monthly collections. Both mollies and mosquitofish increased in abundance through 1965. *Lernea* first appeared on *Crenichthys* in March 1965. Incidence of parasitism increased to February 1966, at which time examination of the population was discontinued because numbers had declined too low to permit continuation of the study. The population was extinct before June 1967.

BIOTIC INTERACTIONS

Interactions of native western fishes with introduced species have resulted in extensive hybridization, especially in trout, plus various kinds of competitive and predatory consequences. One example which is especially interesting, because it was replicated, occurred in Manse Spring, Pahrump Valley, Nye Co., Nevada. The endemic, and currently endangered, Pahrump killifish (*Empetrichthys latos latos*) was restricted to the single limnocrene which was approximately triangular with maximum dimensions of about 25 × 15 m. In November 1961 six goldfish were introduced into the spring by one of the farmhands. They had reproduced by July 1962 and during that summer the children on the farm removed most of the

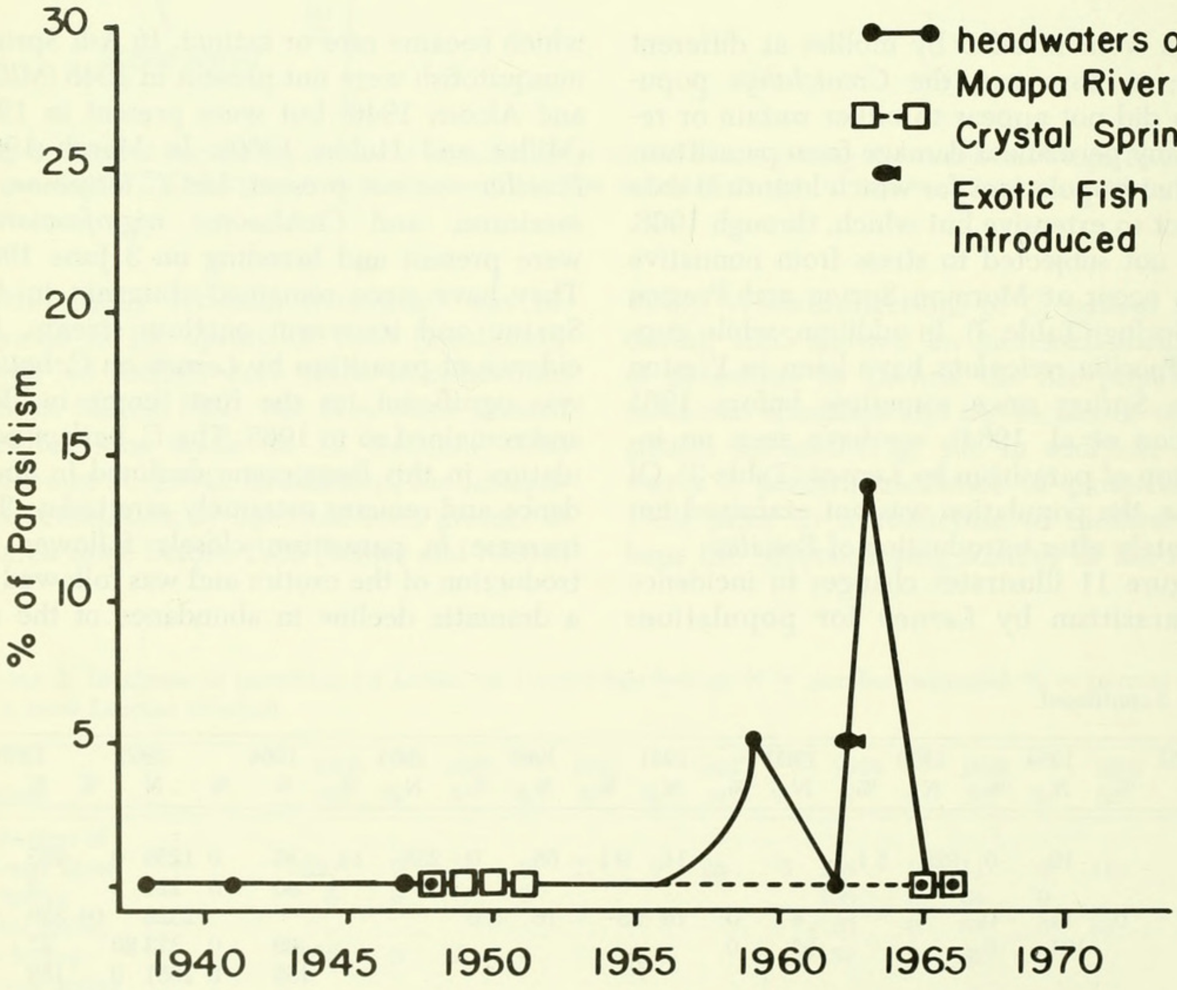

Fig. 10. Incidence of parasitism by *Lernea* on *Crenichthys baileyi* populations which remained abundant.

submerged aquatic vegetation from the pond to make a better swimming pool (Deacon et al. 1964). The killifish population crashed during the winter of 1962–63 to almost certainly fewer than 50 individuals (Fig. 12). The population had recovered somewhat by winter 1963 but appeared to be less abundant through early 1965 than was the case prior to introduction of goldfish.

In July 1967, Professors Carl L. Hubbs and R. R. Miller and I, in cooperation with our families and several students from UNLV and ASU, attempted to remove all goldfish from Manse Spring by trapping, seining, using anesthetic, and, finally, dynamiting. All killifish captured were held in cages in a nearby small spring and all goldfish were destroyed. A total of 1239 killifish were captured and returned. At least two adult goldfish eluded us and spawned by the end of the summer. The killifish population crashed as it had in 1963, reaching a low point of probably fewer

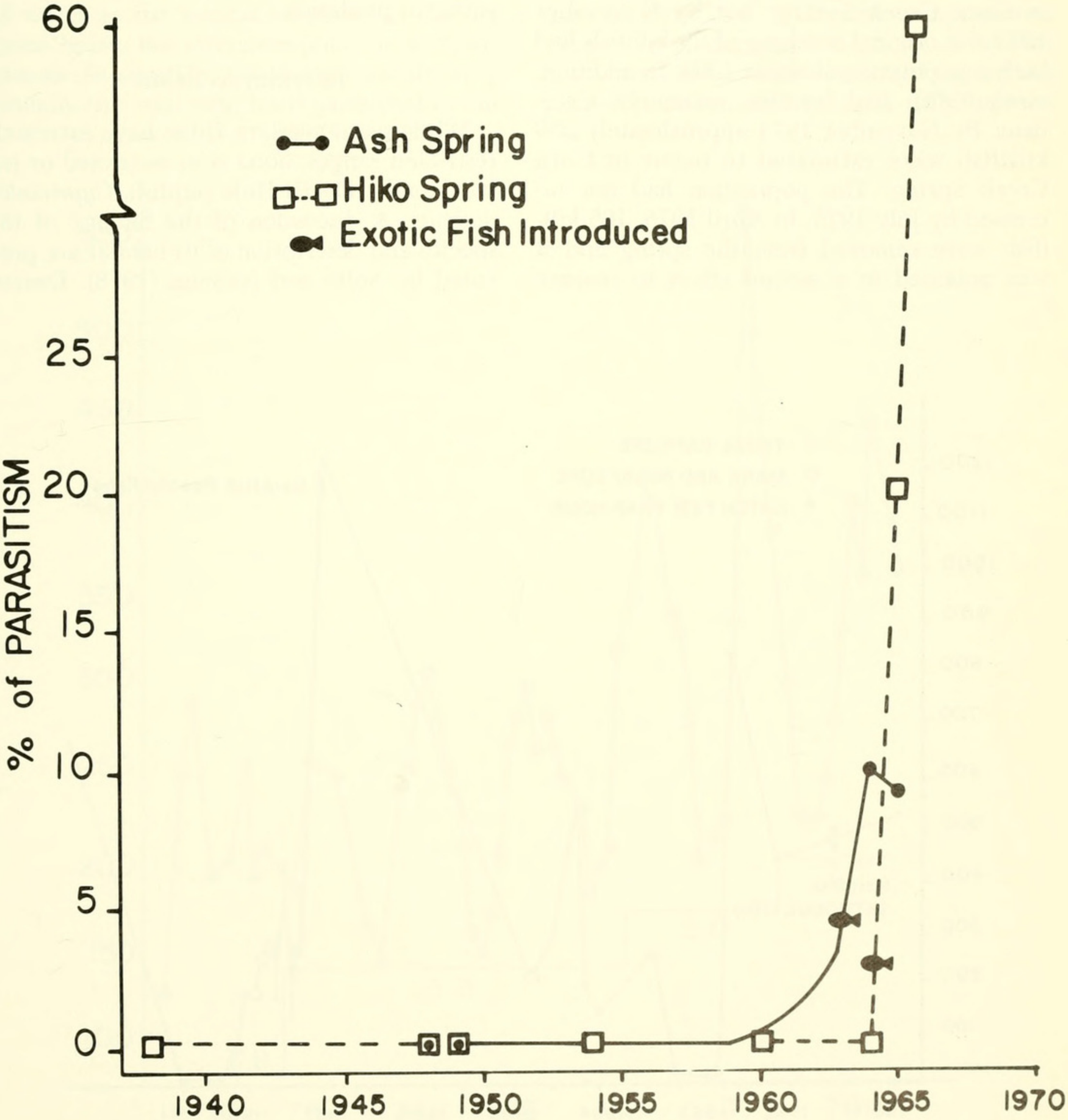

Fig. 11. Incidence of parasitism by *Lernea* on *Crenichthys baileyi* populations which became rare or extinct.

than 50 individuals in July 1968. This low population size persisted through January 1969 (Fig. 12), but by August 1971, when a transplant was made into Corn Creek Spring, the population had recovered significantly. In August 1975, Manse Spring failed as a result of excessive pumping of groundwater in the area (Soltz and Naiman 1978).

Prior to making the killifish transplant into Corn Creek Spring the population of introduced largemouth bass and mosquitofish (*Gambusia affinis*) was removed. A few mosquitofish escaped the final poisoning efforts in Corn Creek Spring, but by November 1973 the original stocking of 29 killifish had built a population of about 1300. In addition, mosquitofish had become extremely abundant. By November 1974 approximately 250 killifish were estimated to occur in Corn Creek Spring. The population had not increased by July 1975. In April 1976, 165 killifish were removed from the spring and it was poisoned in a second effort to remove mosquitofish. The effort was successful and killifish had built an estimated population of 2000 fish by November 1976 and 2500 by October 1977.

These data show that on two occasions in Manse Spring a population increase of goldfish was accompanied by a marked population decline of Pahrump killfish, and on one occasion in Corn Creek Spring a population increase of mosquitofish was accompanied by a killifish population decline. A cause-effect relationship is strongly suggested, perhaps relating to competitive interactions of the young or predation.

Restricted Range

While many western fishes have extremely restricted ranges, none is so restricted or isolated as the Devils Hole pupfish, *Cyprinodon diabolis*. A discussion of the biology of this species and description of its habitat are presented by Soltz and Naiman (1978). Deacon

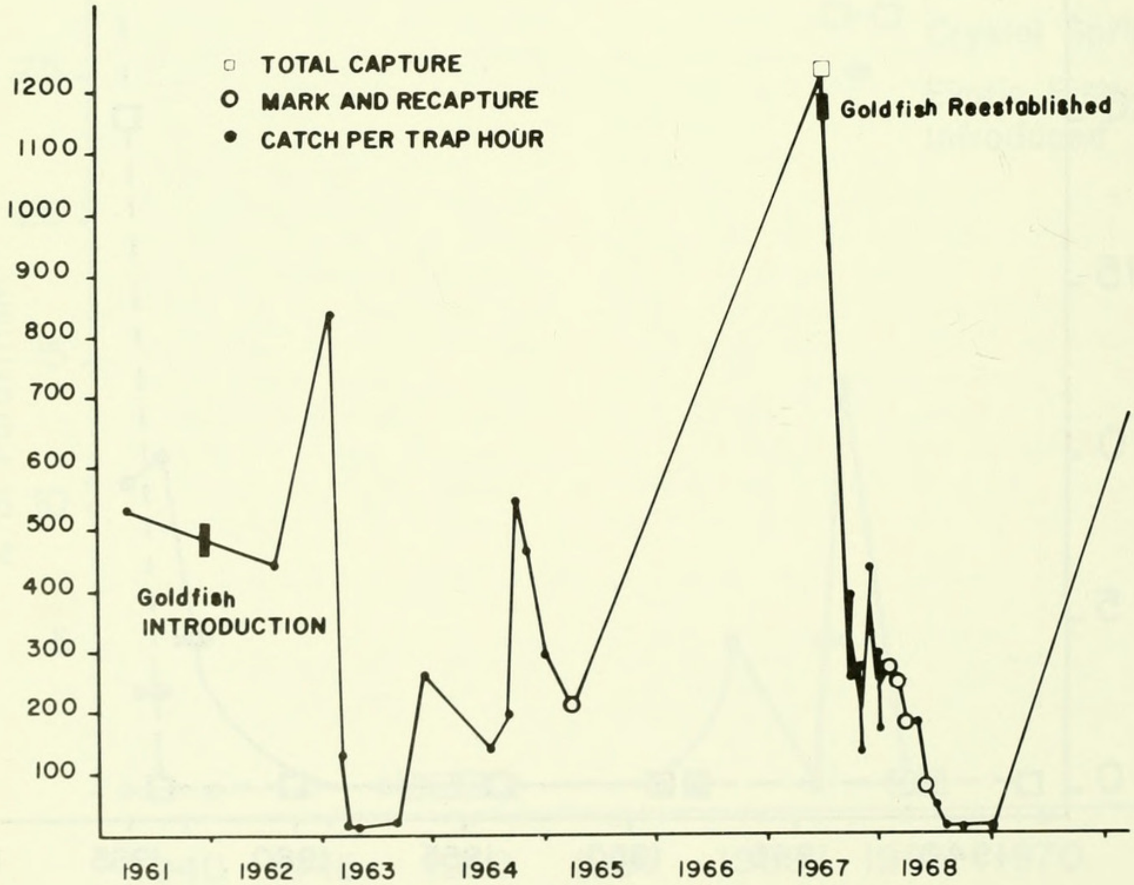

Fig. 12. Changes in population size of Pahrump killifish 1961–1968.

and Deacon (1979) provide a detailed description of fluctuations in population size and probable causes for these fluctuations through December 1976. Data on fluctuations in population size presented here extend through December 1978 (Fig. 13, Table 4). Figure 13 illustrates the direct and marked influence of relatively small changes in water level in Devils Hole on minimum population size of *Cyprinodon diabolis*. The water levels indicated in Figure 13 refer to a reference point established by USGS above the maximum water level. Therefore, depth of water in the habitat increases as the distance below the reference point (in feet) decreases. In addition, the water level shown is actually the minimum level permitted by the courts during the time indicated. The first level indicated (3.9) represents the lowest water level reached prior to intervention of the courts. Water levels normally fluctuated somewhat above the level indicated, but almost never below that level. Generally, water levels were highest in winter and very near the permissible minimum during the summer irrigation season. This, of course, reflects the fact that the water level in Devils Hole is directly and rapidly influenced by pumping of groundwater nearby.

The somewhat erratic population fluctuations in 1972 and 1973 reflect responses to temporary management attempts as well as to scouring floods which occurred during this period (Deacon and Deacon 1979). Once

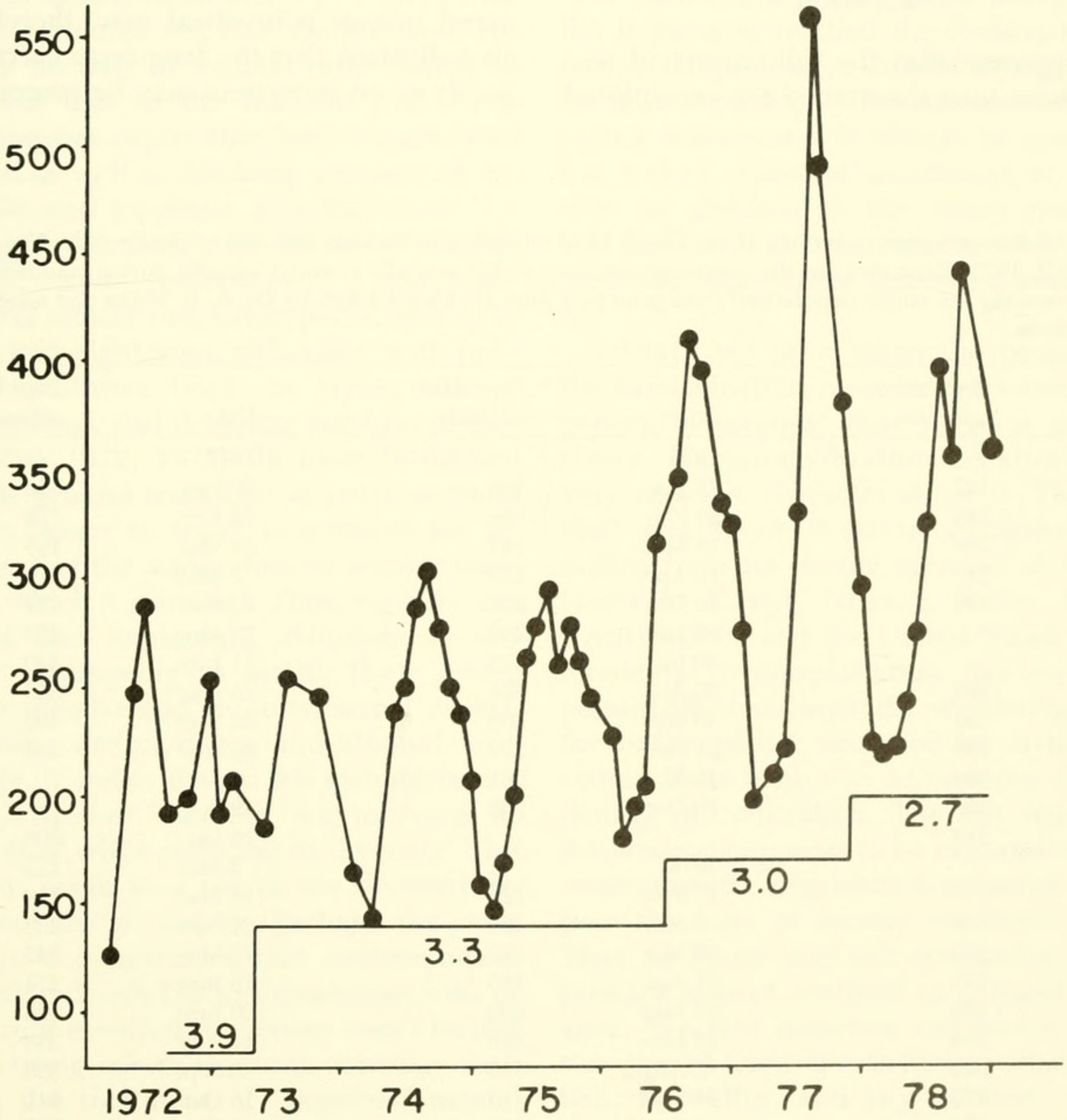

Fig. 13. Devils Hole pupfish population size compared to minimum water levels 1972–1978.

some stability was achieved in water levels, it became possible to attempt management of water level to achieve a desired minimum annual population size. The desired minimum population size was established at 200 in an effort to insure that the population would not fall so low as to tend to accelerate toward extinction. The present court-mandated level of 2.7 appears to be just maintaining minimum population size (Fig. 13, Table 4).

This example illustrates the direct and rapid impact on restricted native fishes which can result from even modest developments nearby. Often, as was true in this case, the developer may be almost entirely unaware of the consequences of his activities. For fishes living in restricted environments, this lack of awareness can mean extinction.

Discussion

It is apparent that the full variety of reasons for becoming threatened are exemplified among the endangered or threatened fishes of the West. The legitimate question arising from this and every consideration of endangered species is "Why bother? What good are they?" The answers to those questions, I believe, must include at least two parts: (1) because it is to our own self-interest to do so, and (2) because our society's values, as expressed through federal law, require us to "bother." The second answer has been and will continue to be debated and perhaps modified. The first is really the core of the endangered species debate. The argument, simplified, I believe, involves at least the following considerations. Because populations are dependent upon and interact within ecosystems, extinction is an indication of a significant change in the ecosystem—in general, a reduced capability to support life or at least to support diversity. The fact that an endangered species is involved may, therefore, be an indication that the long-term carrying capacity of an ecosystem may be exceeded (the

TABLE 4. Estimated population size of the Devils Hole pupfish (*Cyprinodon diabolis*) in Devils Hole, Nye County, Nevada, 1972–1978. Estimates are the maximum number of fish actually counted visually during standardized attempts at counting the entire population. Data prior to 4 June 1974 were taken by Dr. R. R. Miller and subsequently by J. E. Deacon.

Date	Population estimate	Date	Population estimate	Date	Population estimate
1972		1975		1977	
6 April	127	22 Jan	208	20 Jan	324
2 June	248	20 Feb	159	24 Feb	276
28 July	286	18 Mar	148	24 Mar	198
27 Sept	191	10 Apr	158	5 May	210
14 Nov	199	19 May	201	6 June	221
		16 June	262	27 June	359
1973		30 July	278	11 July	330
10 Jan	252	20 Aug	294	15 Aug	553
20 Feb	191	30 Sept	260	26 Sept	490
28 Mar	208	21 Oct	279	28 Nov	381
12 June	184	25 Nov	261		
30 Aug	253	16 Dec	246	1978	
6 Nov	244			16 Jan	296
		1976		2 Mar	225
1974		17 Feb	228	16 Mar	219
5 Feb	163	3 Mar	180	24 Apr	223
29 Apr	143	30 Mar	181	19 May	242
5 June	239	27 Apr	195	19 June	274
11 July	250	18 May	203	20 July	326
22 Aug	286	22 June	316	11 Aug	388
15 Sept	302	2 Aug	345	13 Sept	358
9 Oct	277	24 Sept	410	18 Oct	441
19 Nov	250	18 Oct	385	11 Dec	361
18 Dec	238	3 Dec	334		

argument of the canary in the coal mine). Thus, it follows that if we are concerned about the ability of our children to function in the ecosystem in a manner at all comparable with our present functioning, it may be important to maximize the survival of species other than *Homo sapiens* who are also dependent on that ecosystem.

Another major line of argument is the diversity-stability one (i.e., there appears to be a tendency for more diverse ecosystems to be more stable). Because more stable ecosystems tend to permit coping with times of poor productivity, it seems that enlightened self-interest would dictate that we make efforts to promote stability. Another cogent part of this argument is the inverse relationship between diversity and energy flow (in molecular systems, ecological systems, and in organization of cities) described by Watt (1972, 1973). He pointed out that the principle appears to be true in societal organization to the extent that in the U.S. we find fewer book titles per capita than less industrialized societies, as well as declining numbers of automobile and airplane manufacturers, increasingly standardized foods in supermarkets and restaurants, symphony orchestras almost restricting performances to the work of eight men, difficulties with publishing innovative books or trying out innovative ideas, and declining numbers of species (Watt 1972, 1973). In some ill-defined way this general reduction in environmental diversity seems to result in a search for replacement of the satisfaction or sensory stimulation which it provided. Thus, we have significant and expanding elements in our society attempting to satisfy their senses through membership in cults, sexual experimentation, use of drugs and alcohol, etc. Basically, it seems that as we manufacture a more "efficient" society we increase its energy flow while reducing its diversity. This seems to result in a search for diversity by the members of society. Perhaps the most dramatic demonstration that environmental stimulation derived from experiences with or in nature is *essential* to modern man's feeling of well-being comes from the successes realized in the treatment of "hopeless" mental cases (Iltis 1967). Dramatic improvements resulted from taking these people on camping trips. Many people obviously have experienced the tremendous release of tension that can be felt when you "get away from it all," or, to put it another way, when you have an opportunity to become acquainted with the diversity and sensory stimulation available in nature. Finally, the availability of genetic diversity in plants and animals as a basis for producing new or better crops, medicines, and pharmaceuticals (Reisner 1978) has been emphasized as one of the most compelling arguments for saving species.

Thus, there are a number of biological reasons to justify saving endangered species. These usually have implications that extend to other areas of human endeavor. If man's uniqueness in fact is his knowledge of his world, if *Homo sapiens* is the knowing one, then each extinction diminishes man's capacity of know—and to that extent man's humanity. It seems to me that the Endangered Species Act represents a society saying "This is as far as we will go." The necessity of making such a statement will always be questioned, but it does represent an attempt at insuring that our children on into many generations will have available to them some of the humanizing experiences that were available to us.

Perhaps we have taken the position that the extermination must stop because of our general awareness that there is no other choice. Human civilization has always had a very nomadic character about it. The dominant center of Western civilization has shifted from the fertile crescent of Mesopotamia to Egypt, Greece, Rome, Europe, Great Britain, and the United States as environmental overexploitation has forced (or permitted) these nomadic wanderings. With the entire planet occupied by civilized societies, there is no way to continue the wanderings of civilization. The last remnant of the tendency appears to be exportation of the environmental degradation required to support the kind of society we have created. Thus, no longer does our civilization have its primary impact confined to national boundaries. We find ourselves responsible for destruction of tropical rain forests, whales, pupfish, woundfin, and any number of other worldwide resources, both renewable and nonrenewable. A balance of payments deficit is clearly one serious and unacceptable consequence, but it is completely overshadowed by the rapid diminution of the world's ability to support the biotic diversity so essential to man's physical and mental well-being.

During this symposium Lovejoy (1979) has provided a frightening description of the awful magnitude of the problem. Clements (1979) has clearly shown that it is our own society, not societies in the under-developed countries of the tropics, that must be held primarily responsible for such all-pervasive, worldwide environmental degradation. Perhaps an understanding of these important facts will hasten the hard decisions which must be made to apply the principles of the Endangered Species Act on a worldwide scale. Spencer (1979) provided extensive documentation to show that the very difficult and costly decisions essential to slowing the rate of environmental degradation in the United States are being made in some specific cases. His presentation is perhaps the most encouraging evidence presented at the symposium to indicate that there are forces at work in our society which have a slim possibility of forcing the significant shifts in societal values which Clements (1979) described as essential if we are to prevent the collapse of our system.

The answers to "Why save species?" are many-faceted, almost always translate into "Why save ecosystems?" and clearly demand searching examination of human values. It seems particularly powerful, therefore, to find philosophers, theologians, and ecologists converging on essentially the same answers to these questions. Though ecologists tend to understandably emphasize species and ecosystems and theologians tend to emphasize individuals and anthropocentricity, pretty much the same conclusions emerge. The most succinct and, to the Christian world, probably the most widely understandable conclusion we can arrive at was expressed by Professor Hugh Nibley. In a 1978 essay examining man's relationship with his environment he said, "Man's dominion is a call to service, not a license to exterminate."

ACKNOWLEDGMENTS

Numerous people have assisted in the development of data and ideas presented herein. To all I express sincere gratitude. James D. Williams, Gail Kobetich, Thom Hardy, and the American Fisheries Society Endangered Species Committee were instrumental in development of Tables 5 and 6. Jerry

TABLE 5. Described taxa of threatened freshwater fishes of western North America: 1979.

Common name	Scientific name	Status	Present° threat	Historical distribution
Trouts, family Salmonidae				
Little Kern golden trout	*Salmo aquabonita whitei* Jordan	T	1,4	CA
Arizona trout	*Salmo apache* Miller 1972	T	1,4	AZ
Lahontan cutthroat trout	*Salmo clarki henshawi* Gill and Jordan	T	1,4	CA,NV,UT,WA
Colorado River cutthroat trout	*Salmo clarki pleuriticus* Cope	SC	1,4	CO,UT,WY
Paiute cutthroat trout	*Salmo clarki seleniris* Snyder	T	1	CA
Greenback cutthroat trout	*Salmo clarki stomias* Cope	T	1,4	CO
Utah cutthroat trout	*Salmo clarki utah* Suckley	T	1,4	UT,WY,NV
Rio Grande cutthroat trout	*Salmo clarki virginalis* (Girard)	SC	1,4	CO,NM
Gila trout	*Salmo gilae* Miller	T	1	NM,AZ
Sunapee trout	*Salvelinus alpinus aureolus* Bean	T	4	ME,NH,ID
Montana Arctic grayling (stream form)	*Thymallus arcticus montanus* (Pallas)	T	1	MT
Mudminnows, family Umbridae				
Olympic mudminnow	*Novumbra hubbsi* Schultz	SC	1	WA

Minnows, family Cyprinidae				
Mexican stoneroller	*Campostoma ornatum* Girard	SC	1,3	AZ,TX,(Mexico)
Devils River minnow	*Dionda diaboli* Hubbs and Brown	T	1	TX
Desert dace	*Eremichthys acros* Hubbs and Miller	T	1,5	NV
Alvord chub	*Gila alvordensis* Hubbs and Miller 1972	SC	1	NV,OR
Fish Creek Springs Tui chub	*Gila bicolor euchila* Hubbs and Miller 1972	E	1,4,5	NV
Independence Valley Tui chub	*Gila bicolor isolata* Hubbs and Miller 1972	T	1,4,5	NV
Mohave Tui chub	*Gila bicolor mohavensis* (Snyder)	E	1,4	CA
Newark Valley Tui chub	*Gila bicolor newarkensis* Hubbs and Miller 1972	SC	1,5	NV
Oregon Lakes Tui chub	*Gila bicolor oregonensis* (Snyder)	SC	1	OR
Lahontan Tui chub	*Gila bicolor obesa* (Girard)	SC	1	NV
Owens Tui chub	*Gila bicolor snyderi* Miller 1973	E	1,4,5	CA
Thicktail chub	*Gila crassicauda* (Baird and Girard)	E	1	CA
Humpback chub	*Gila cypha* Miller	E	1	AZ,CO,UT,WY
Bonytail	*Gila elegans* Baird and Girard	E	1,4	AZ,CA,CO,NV,UT,WY
Gila chub	*Gila intermedia* (Girard)	SC	1,4	AZ,NM
Chihuahua chub	*Gila nigrescens* (Girard)	E	1,4	NM,Mexico (Ch)
Yaqui chub	*Gila purpurea* (Girard)	E	1,4	AZ,Mexico (So)
Gila roundtail chub	*Gila robusta grahami* Baird and Girard	T	1,4	AZ,NM
Pahranagat roundtail chub	*Gila robusta jordani* Tanner	E	1,4	NV
Virgin River roundtail chub	*Gila robusta seminuda* Cope	E	1	AZ,NV,UT
Oregon chub	*Hybopsis crameri* Snyder	SC	1,4	OR
Least chub	*Iotichthys phlegethontis* (Cope)	T	1,4	UT
White River spinedace	*Lepidomeda albivallis* Miller and Hubbs	T	1,4	NV
Virgin spinedace	*Lepidomeda mollispinis mollispinis* Miller and Hubbs	*T*	*1,4*	*AZ,UT*
Big Spring spinedace	*Lepidomeda mollispinis pratensis* Miller and Hubbs	*E*	*1,4,5*	*NV*
Little Colorado spinedace	*Lepidomeda vittata* Cope	SC	1	AZ
Spikedace	*Meda fulgida* Girard	T	1,4	AZ,NM
Moapa dace	*Moapa coriacea* Hubbs and Miller	E	1,3,4,5	NV
Yaqui Beautiful shiner	*Notropis formosus mearnsi* Snyder	SC	1	AZ (Mexico)
Rio Grande shiner	*Notropis jemezanus* (Cope)	SC	1,4	NM
Proserpine shiner	*Notropis porserpinus* (Girard)	T	1	TX
Bluntnose shiner	*Notropis simus* (Cope)	E	1,4	NM,TX
Woundfin	*Plagopterus argentissimus* Cope	E	1	AZ,NV,UT
Splittail	*Pogonichthys macrolepidotus* (Ayres)	SC	*1*	CA
Colorado squawfish	*Ptychocheilus lucius* Girard	E	1,3,4	AZ,CO,UT,CA,NM,NV,WY
Relict dace	*Relictus solitarius* Hubbs and Miller 1972	SC	1	NV

Independence Valley speckled dace	*Rhinichthys osculus lethoporus* Hubbs and Miller 1972	E	1,4,5	NV
Ash Meadows speckled dace	*Rhinichthys osculus nevadensis* Gilbert	E	1,4	NV
Clover Valley speckled dace	*Rhinichthys osculus oligoporus* Hubbs and Miller 1972	E	1,4,5	NV
Kendall Warm Springs dace	*Rhinichythys osculus thermalis* Hubbs and Kuehne	SC	5	WY
Moapa speckled dace	*Rhinichthys osculus moapae* Williams 1978	T	1,3,4	NV
Loach minnow	*Tiaroga cobitis* Girard	SC	1,4	AZ,NM
Suckers, family Catostomidae				
Yaqui sucker	*Catostomus bernardini* Girard	SC	1	AZ (Mexico)
White River desert sucker	*Catostomus clarki intermedius* (Tanner)	T	1	NV
Webug sucker	*Catostomus fecundus* Cope and Yarrow	SC	1,4	UT
Zuni bluehead sucker	*Castostomus dicobolus yarrowi* Cope	T	1	NM
Lost River sucker	*Catostomus luxatus* (Cope)	SC	1,4	CA,OR
Modoc sucker	*Castostomus microps* Rutter	E	1,4	CA
Warner sucker	*Catostomus warnerensis* Snyder	E	1,4	OR
Shortnose sucker	*Chasmistes brevirostris* Cope	T	1,4	CA,OR
Cui-ui	*Chasmistes cujus* Cope	E	1	NV
June sucker	*Chasmistes liorus* Jordan	SC	1,4	UT
Razorback sucker	*Xyrauchen texanus* (Abbott)	T	1,4	AZ,CA,CO,NV,UT,WY
Freshwater catfishes, family Ictaluridae				
Yaqui catfish	*Ictalurus pricei* (Rutter)	SC	1	AZ (Mexico)
Widemouth blindcat	*Satan eurystomus* Hubbs and Bailey	T	1	TX
Toothless blindcat	*Trogloglanis pattersoni* Eigenmann	T	1	TX
Killifishes, family Cyprinodontidae				
Railroad Valley springfish	*Crenichthys nevadae* Hubbs	SC	1	NV
Leon Springs pupfish	*Cyprinodon bovinus* Baird and Girard	T	1,4,5	TX
Devils Hole pupfish	*Cyprinidon diabolis* Wales	E	1,5	NV
Comanche Springs pupfish	*Cyprinodon elegans* Baird and Girard	E	1	TX
Gila desert pupfish	*Cyprinodon macularius macularius* Baird and Girard	T	1,4	AZ, Mexico
Valley Amargosa pupfish	*Cyprinodon nevadensis amargosae* Miller	SC	1,4	CA
Ash Meadows Amargosa pupfish	*Cyprinodon nevadensis mionectes* Miller	T	1,4	NV
Warm Springs Amargosa pupfish	*Cyprinodon nevadensis pectoralis* Miller	E	1,4,5	NV
Owens pupfish	*Cyprinodon radiosus* Miller	E	1,4	CA
White Sands pupfish	*Cyprinodon tularosa* Miller and Echelle 1975	SC	1,4,5	NM

Pahrump killifish	*Empetrichthys latos latos* Miller	E	1,4,5	NV
Livebearers, family Poecilidae				
Amistad gambusia	*Gambusia amistadensis* Peden 1973	E	1,5	TX
Big Bend gambusia	*Gambusia gaigei* Hubbs	E	1,5	TX
San Marcos gambusia	*Gambusia georgei* Hubbs and Peden	E	1,4,5	TX
Clear Creek gambusia	*Gambusia heterochir* Hubbs	T	4	TX
Pecos gambusia	*Gambusia nobilis* (Baird and Girard)	SC	1,4	TX,NM
Gila topminnow	*Poeciliopsis occidentalis* (Baird and Girard)	E	1	AZ,NM
Sticklebacks, family Gasterosteidae				
Unarmored threespine stickleback	*Gasterosteus aculeatus williamsoni* Girard	E	1,4	CA
Sunfishes, family Centrarchidae				
Guadalupe bass	*Micropterus treculi* (Vaillant and Bocourt)	SC	1	TX
Perches, family Percidae				
Fountain darter	*Etheostoma fonticola* (Jordan and Gilbert)	E	1,5	TX
Gobies, family Gobiidae				
O'opu nakea	*Awaous stamineus* (Eydoux and Souleyet)	SC	1,4	HI
Tidewater goby	*Eucyclogobius newberryi* (Girard)	SC	1	CA
O'opu alamo'o	*Lentipes concolor* (Gill)	T	1	HI
O'opu nopili	*Sicydium stimpsoni* Gill	SC	1,4	HI
Sculpins, family Cottidae				
Rough sculpin	*Cottus asperrimus* Rutter	SC	1	CA
Utah Lake sculpin	*Cottus echinatus* Bailey and Bond	E	1,4	UT
Shoshone sculpin	*Cottus greenei* (Gilbert and Culver)	SC	1	ID

*1—Present or threatened destruction of habitat
2—Overutilization
3—Disease
4—Hybridization, competition, exotic or translocated
5—Restricted natural range

Lockhart provided data on woundfin from 1973. Brian Wilson assisted greatly with development of data on parasitism, which could not have been accumulated without accessibility to fish collections at the University of Michigan Museum of Zoology (R. R. Miller), the University of Nevada—Reno (Ira LaRivers), and BYU (Dave White). Encouragement and approval of permits necessary to the work has been provided by the Nevada, Utah, and Arizona Game and Fish departments. Stimulating discussions and searching examination of values have been provided by my family (Maxine, Dave, and Jack and Cindy Williams) and by classes at UNLV. Financial assistance for various aspects of work reported herein has been provided by the U.S. Fish and Wildlife Service, National Park Service, National Science Foundation, Sport Fishing Institute, U.S. Bureau of Reclamation, University of Nevada—Las Vegas, and the City of St. George, Utah, through Vaughn Hansen Associates.

Questions for Dr. Deacon

Q. Once a species is on its way to recovery, how does one determine what the population level or population density would be for the species to be considered no longer in danger?

A. That is an extremely knotty problem. In the case of the Devils Hole pupfish we were primarily concerned with maintaining a large enough population to prevent population instabilities that might tend to accelerate the process of extinction. It is generally understood that populations have a minimum size below which they are unlikely to maintain viability. Bob Miller at the University of Michigan did some experimental rearing of other species of pupfish in the 1940s and also performed a number of transplants into springs devoid of fish. His work indicated that experimental populations started with small numbers of individuals tended to decline in abundance after a few generations, sometimes to extinction. His numerous transplants of pupfish into other natural waters were never successful if fewer than 200 individuals were transplanted, and in only two instances were they successful when more than 200 individuals were transplanted. During the middle 1960s a graduate student of mine, Carol James (now Ivy), did some work on the Devils Hole pupfish which, in retrospect, indicated that its population had probably never fallen below 200 individuals. Finally a transplant of 24 Devils Hole pupfish into an artificial pond below Hoover Dam resulted in a population maximum of about 200 individuals, followed by a decline to about 50 individuals. This pattern suggested loss of viability may be occurring in the transplanted population of Devils Hole pupfish. This line of argument was successful in establishing the fact that it would be unacceptably dangerous to permit the population of Devils Hole pupfish to fall below 200 individuals. Once that point was established it was not difficult to show, with four or five years of monthly data on estimated population size, that a water level of 2.7 was necessary to sustain a population of no fewer than 200 individuals. These ecological relationships are being reported in the symposium volume on research in the national parks to be published in 1979.

Q. At what level do you consider the population to not be threatened?

TABLE 6. Undescribed taxa of threatened freshwater fishes of western North America: 1979.

Common name	Scientific name	Status	Present* threat	Historical distribution
Trouts, family Salmonidae				
Alvord cutthroat trout	*Salmo clarki* ssp.	SC	1	OR
Humboldt cutthroat trout	*Salmo clarki* ssp.	SC	1	NV
Redband trout	*Salmo* sp.	SC	1,4	CA,OR,ID,NV
Minnows, family Cyprinidae				
Catlow Tui chub	*Gila bicolor* ssp.	SC	1	OR
Sheldon Tui chub	*Gila bicolor* ssp.	SC	5	NV
Cowhead Lake Tui chub	*Gila bicolor* ssp.	SC	1	CA
Hutton Spring Tui chub	*Gila bicolor* ssp.	T	1	OR
Borax Lake chub	*Gila* sp.	T	1,5	OR
Foskett Spring speckled dace	*Rhinichthys osculus* ssp.	T	1,5	OR
Killifishes, family Cyprinodontidae				
Preston White River springfish	*Crenichthys baileyi* ssp.	T	4,5	NV
Southern White River springfish	*Crenichthys baileyi* ssp.	T	1,3,4	NV
Warm Springs White River springfish	*Crenichthys baileyi* ssp.	SC	1,4,5	NV
Devils River Conchos pupfish	*Cyprinodon eximius* ssp.	T	1	TX
LeConte desert pupfish	*Cyprinodon macularius* ssp.	E	1,4	CA
Quitobaquito desert pupfish	*Cyprinodon macularius* ssp.	SC	1,5	AZ
Sculpins, family Cottidae				
Malheur mottled sculpin	*Cottus bairdi ssp.*	SC	1	OR

*1—Present or threatened destruction of habitat
2—Overutilization
3—Disease
4—Hybridization, competition, exotic or translocated
5—Restricted natural range

A. I consider 200 pupfish to be one which puts the species in approximately the position it was prior to the appearance of man—not completely in that position, but approximately. Now it's as threatened as it always was because of its restricted habitat, but it is no more threatened because of man's activities.

Q. Would cleaning up the waters here in the West affect the species population?

A. In those areas where pollution is a problem it certainly would. Almost anything that's proposed which will modify habitats must be examined with respect to the possibilities of adversely affecting species, whether or not they are endangered. It doesn't necessarily mean that, for instance, salinity control projects will affect the woundfin minnow. In fact, some of my work has demonstrated that there is probably a good opportunity to design salinity control projects that will be unlikely to affect the mainstream fishes of the Virgin River. That conclusion is expandable to many other instances in the Southwest. The important thing is to design projects that are compatible with the habitat requirements of the species impacted. In other words, cleaning up the waters of the West could affect species in a number of ways, both adversely and favorably.

Q. I'm not convinced that what you have said about the proposal to not go ahead with the power plant in Dixie is reasonable. The suggestion was that they divert some of the water from the Virgin River into a reservoir in Warner Valley and with that carry on with their electrical work. Now, of course, it would be a coal plant and this would be cooling water for the hydro plant. What is the problem? How is it going to endanger that fish?

A. The question is how is the Warner Valley Project likely to add to the threats to the woundfin minnow and roundtail chub in the mainstream Virgin River. Thanks very much for asking it, Vasco (Tanner). This obviously is not a simple problem. The basic answer I see is that the Warner Valley Project as projected will alter the flows of the mainstream Virgin River. The hydrologists point out that most of the water will be taken during the winter and spring. Data I presented here today indicate that during the low-flow winter, spring, and summer of 1977, woundfin and roundtail chub reproduction was extremely low. To the extent that the Warner Valley Project increases the frequency with which flows similar to 1977 occur, that project will adversely impact the endangered fishes living there. Essentially, the problem is that the data so far demonstrate that 1977, which was a low-flow year, resulted in conditions incompatible with very much reproduction of those two species. If you cut off that reproduction, you're likely to cause an extinction. Certainly every time you modify the flow regime of the Virgin River such that the native fish populations living there miss a year of reproduction, you're very demonstratively affecting the capability of those species to maintain themselves in the river. My conclusions here are really based on the fact that we have demonstrated very poor reproduction during a time which represents the kind of postproject flows we could expect.

Q. Of course I've seen that river fluctuate from great to almost nothing, so naturally I don't see that there is any justification for not going ahead with it. They're going to get water from Warner Valley as well as just divert a little from the Virgin River into the reservoir.

A. The crux of the matter, I think, is what flows are necessary to permit reproduction of the woundfin minnow. The data I presented suggest that flows in the neighborhood of 100 cubic feet per second are necessary to permit reproduction of woundfin and roundtail chub. In fact, there is some suggestion that winter flows must be somewhat higher. If the Warner Valley project doesn't reduce winter and spring flows below about 110 cubic feet per second, then I would say that there is likely to be no adverse impact. On the other hand, if it does, and it was demonstrated by the hydrological study that it would, then it does represent an impact. I'm not saying you shouldn't have the project. All I am saying is, if you reduce flows, you're going to impact the minnow and the chub.

Q. Just a comment more than a question. I understand the Warner Project during 1977 would not have been allowed to divert because the water was so low that project requirements would not have permited diversion. The 1977 situation would not be repeated unless there was another low-water year.

A. If that's the case, then I fail to see the basis for the rather marked objections that have been raised to the conclusions I have reached.

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