W. L. Minckley and James E. Deacon, eds.
Battle Against Extinction: Native Fish Management in the American West
Tucson: University of Arizona Press, 1991
Pages 93-108. Reprinted by permission.

Chapter 6

Fishes in the Desert: Paradox and Responsibility

Holmes Rolston III

Puzzles about Fishes

Fishes in the desert—that can seem almost a contradiction in terms since by definition fishes inhabit water and deserts have little. Adverse even for terrestrial life, deserts are impossible environments for aquatic species. But, conflicting expectations to the contrary, there is water in the desert and fishes do live there—no contradiction but quite a marvel. Having discovered fishes in the desert, to ask next whether there can be duties to them seems incongruous again—a category mistake; neither a particular fish nor its species is a possible object of duty. Persons count morally, but fishes do not. Again, the prevailing expectations are wrong. Humans do have responsibilities to these marvelous fishes.

Admittedly, though, there is something odd about taking ethics underwater into the desert. Even if fishes do live there, that is only a biological description of anomalous life in arid lands. Can one conclude that humans ought to save such fishes—a prescription for conduct—without committing what philosophers call the naturalistic fallacy, which forbids logical passage from the *is* to the *ought?* Can we be more specific about what is really a double difficulty: the biological difficulty of being a fish in the desert and how this connects with an ethical difficulty? What are the challenging human responsibilities we encounter with such exceptional fishes in troubled waters?

Fishes in the North American Deserts

The North American deserts were not always dry, Pleistocene times were pluvial; lakes and streams were abundant. But the waters left, and the lands have been arid for more than ten thousand years, resulting in a dry climate presently more severe than at any earlier time (Axelrod 1979; M. L. Smith 1981). Though the fishes largely vanished, relicts managed to survive in oases—springs, pools, and seeps, often fed by underground aquifers with waters that rained in the ancient past; that is, "fossil" water. They also survived in rivers, especially those that crossed the deserts but had their headwaters in wetter, mountainous terrain.

The isolation and duress produced some remarkable fishes. They were subject to extremes: shifting water supplies—cold torrents during spring floods, followed by dry-up during summer heat—shifting streambeds, salinity across a spectrum from the fresh waters of melting snow to briny seeps, to playa lakes on alkali flats, more than three times as salty as the sea. Desert life demands unique fish. Although such fishes are often endemic to local areas, the desert has regularly produced such endemics—about two hundred such species

in the American West (J. E. Williams et al, 1985; Minckley and Douglas, *this volume*, chap. I).

Ash Meadows, a sprawling oasis in the Nevada desert about 100 km^2 in extent, contains more than twenty springs, numerous lime-encrusted pools, small streams that flow year-round, and seepage and swampy areas. One of the most unusual places in the United States, it supports a unique flora and fauna—twenty-six plants and animals found nowhere else in the world—more endemics for its size than any other place in the continental United States (Beatley 1971, 1977; Schwartz 1984), Ash Meadows is named for the endemic velvet ash, *Praxinus velutina* var. *coriacea.* At least eleven species of invertebrates, including insects and snails, are found only there. Lying in one of the most arid areas of the world, all its native fish are endemics: three desert pupfishes *(Cyprinodon* spp.) in twenty distinct populations, the Ash Meadows speckled dace *(Rhinichthys osculus nevadensis),* and the Ash Meadows poolfish *(Empetrichthys merriami* [extinct]; Soltz and Naiman 1978; J. E. Williams et al. 1985).

The Colorado River basin similarly contains a higher percentage of endemic species than does any other river in North America, Sixty-four percent of its native freshwater fish species (35% of native genera) are found nowhere else (R. R. Miller 1963; Carlson and Muth 1989). As a contrasting extreme in size to the tiny pupfish, the big mainstream rivers flowing from the Rocky Mountains through the desert have here shaped the Colorado squawfish *(Ptycbocheilus lucius),* the largest member of the minnow family in this hemisphere and one of the largest in the world, once attaining lengths approaching 1.8 m and weights of 40 kg (Deacon 1979). The humpback chub *(Gila cypha)* is one of the most bizarre fishes of this continent, extraordinarily specialized for life in torrential waters. Of all fishes, it has the most extreme stabilizing nuchal hump. The related bony tail (G. *elegans)* has the most fusiform body. All these fishes have expansive fins for maximum power in swift currents.

We could go on cataloging the queer, the rare, the curious twists and turns that life has taken underwater in the desert. But a lengthening list of the aberrant and weird does not imply increasing duty. The blue whale is the largest animal that has ever lived on Earth, with 3600 1 of 'blood and a heart big enough for a person to crawl around inside. Should one therefore save whales? Does bigness generate duty? Ptiliid beetles are smaller than the periods on this page, yet each has six legs, a pair of wings, a digestive tract, reproductive organs, a nervous system, and genetic information that, translated into a code of English words printed in letters of standard size, would stretch 1600 km, Should one save ptiliid beetles because they are so small? The facts are striking, but they do not as such yield obligations. Extremes have no evident logical connection with value.

Some will argue that such odd facts as premises really yield another conclusion: that desert fishes are a fluke, there by luck already—living Tertiary fossils, detritus from the past. What survives or perishes does so by chance; it has nothing to do with value or human duties. Nature has no standards of value, and there is no reason to think that she has been protecting treasures in the desert, conserving them either because they had value in themselves or because humans were coming. So there is no cause for humans to care particularly about this scanty, chance selection of desert fishes. Precariously situated by a whim of nature, they are going to become extinct by natural causes sooner or later anyway. Most of the other fauna that were there in the Pliocene and Pleistocene are long since extinct—mastodons, ground sloths, saber-toothed tigers, dire wolves, camels, horses, to say nothing of other species of fishes. If these

desert fishes come to an end, they have already gone on long enough, and they are all an accident in the first place. So why should we care? What is happening to these fishes now is nothing different from what happened in geological times; desert streams dry up all the time, not just when humans draw them down; floods inundate channels and backwaters annually; landslides and lava flows dammed rivers before the U.S. Bureau of Reclamation arrived. Always, the fittest survive, and the rules do not change when humans arrive, modify habitats, and introduce exotic parasites, predators, or game species that deplete the natives. It does not seem far out of line with evolutionary natural history that humans should drive a few more species to extinction.

Human Duties to Desert Fishes

Faced with these difficulties, those who argue for preservation along the commonest, easiest path take an anthropocentric turn. Regarding humans, we do have duties. Regarding the fish, we need only deal with the present and be pragmatic about that. The first biological premise is the descriptive fact that fishes exist in desert waters; a second biological fact is the anomaly of their existence. But no conclusion needs to be drawn about duties to fishes. The conclusions have rather to do with human benefits, such as sport fishing and food. The resulting ethic is one of resource management. With this redirecting of the argument, there is no problem with the premise about anomalous luck, because humans often value resources that they have obtained by whim of nature. Whatever humans desire is, ipso facto, valuable; the natural history of the origin of the object of desire—chance or necessity, common or rare, typical or anomalous—is irrelevant. In the Endangered Species Act, Congress lamented the lack of "adequate concern [for] and conservation [of]" species, and insisted that endangered species are of "esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people (US, Congress 1973, sec, 2[a])." On the masthead of the journal *Fisheries,* after notice that the American Fisheries Society is, since 1870, the oldest and largest professional society representing fisheries scientists, we read that "AFS promotes scientific research and enlightened management of aquatic resources for optimum use and enjoyment by the public." There is similar language in the enabling legislation of every federal and state agency charged with managing fishery resources.

Confronting directly the question of why we should bother to save desert fishes, James Everett Deacon (1979:56), a pioneer in desert fish preservation, gave two answers: "Because it is in our self-interest to do so, and because our society's values, expressed through federal law, require us to bother. . ." The first, he says, is "really the core of the endangered species debate."

The question is one of human class self-interest, and any duties are embedded in that class self-interest. "The preservation of species," by the usual utilitarian account reported by Hampshire (1972:3–4), is "to be aimed at and commended only in so far as human beings are, or will be emotionally and sentimentally interested." Feinberg (1974:56) says, "We do have duties to protect threatened species, not duties to the species themselves as such, but rather duties to future human beings, duties derived from our housekeeping role as temporary inhabitants of this planet." All this simplifies the logic and the ethics. It enables philosophers to concur with the arguments of legislators and resource managers. Within the collective human self-interest there are no duties *to* endangered species, only duties *to* persons. The relation is threefold. Person A has a duty *to* person B that *concerns* species C, but is not *to* C. A's duty is to promote benefits deriving from C that satisfy B's preferences.

Human Benefits from Desert Fishes

A third tacit premise must be made explicit before this anthropocentric argument can succeed: that desert fishes do yield human benefits—aesthetic, ecological, scientific, and so on—in excess of any benefits to be gained by their extinction. Can we be more specific about how the preservation of desert fishes is in our self-interest? How do these odd fishes satisfy our preferences?

Persons have a strong duty of nonmaleficence not to harm other humans, and a weaker, though important, duty of beneficence to help other humans. Humans will be harmed if their ecosystems are degraded, and diverse species are critical to our life-support systems. Arguing the threat of harm, Paul and Anne Ehrlich (1981) maintained that the myriad species are rivets in the airplane in which humans are flying. Extinctions are maleficent rivet popping. On the earthship on which we ride there is redundancy, but humans cannot safely lose 1.5 million species/rivets, and any loss of redundancy is to be deplored. Ecosystems have no useless parts, and we are foolish to think they do. Species, including endangered ones, are stabilizers. What the hump is to the humpback chub, endangered species are to humans.

Once this premise is made explicit, it is not always convincing. *Astragalus detritalis,* an uncommon milk vetch and one of the few legumes that grow on shale in the Uinta Basin of eastern Utah, fixes nitrogen and might be important in that ecosystem. But if this or that desert fish goes extinct, everything else going on in the West—ecologically and culturally—will continue about as usual. Just because they are relict species, these fishes form no significant part of our human life-support system. They are not rivets in spaceship earth. They are not even rivets in California or Nevada or Arizona. If they have any ecological value, it must be of some other kind.

Some argue that this value lies in their role as ecological indicators. The rare species are the first to show environmental stresses; they are a red flag indicating that even common species, including humans, will soon be in trouble if trends go unreversed. It is not just the fishes in the desert that need water; every living thing there needs water—from plants and invertebrates through bobcats and bighorn sheep. Fishes are but early indicators of the water quality, and the quality of life in the desert. Still, perhaps we can read that signal of trouble and take remedial action; after we get the warning it does not matter whether the indicator fish is protected or goes extinct—unless we need it as an ongoing indicator. Also, given increased expertise in building instruments, we can eventually make better monitors and will no longer need indicator fish. Once miners used canaries to detect foul air; now they use electronic meters,

Congress also expects "recreational" benefits from conserving endangered species. One whooping crane in a flock of sandhills perks up a bird-watcher's day. People go on field trips to see the endangered Arizona hedgehog cactus *(Echinocereus triglochidiatus* var. *arizonicus),* known only from small populations in central Arizona. Others take cruises to watch whiles and dolphins. There is fish-watching at Virgin Islands National Park and the Great Barrier Reef. Does this work with desert fish? Recreators come to visit Devil's Hole, and these odd fish can fascinate enthusiastic ichthyologists.

But let us be frank. These fish are underwater, not part of the scenery. They are out of sight and largely out of mind. Recreators overlooking a marsh or a spring may experience a bit of excitement at viewing the sole habitat for an endemic fish, but there is not and cannot be widespread, recreational desert fish-watching analogous to bird-watching, According to surveys, one American in four takes at least occasional time each year to

watch birds—in backyard, field, or woods. But not one American in four million watches desert fish.

Anglers are as numerous as bird-watchers. But most of these desert fishes are disliked by anglers; either there are not enough to catch, or they are not desirable, or they are protected by law and cannot be caught. From an angler's point of view the western fish fauna is depauperate; that is why fishes have been introduced into every major stream in the West: to provide recreation that the native fishes did not. These introduced fishes outcompete the natives, yield more fish per kilometer of stream, and—to recall the goal of the American Fisheries Society—we thus have "enlightened management of aquatic resources for optimum use and enjoyment by the public." With this management objective in mind, in September 1962 more than 81,000 1 of rotenone were applied to 700 km of the Green River in Wyoming, Utah, and Colorado to rid the river of nine species of native "trash" fish such as squawfish and bony tail (as well as some introduced trash fish), so that, after the poison had passed or been neutralized, Flaming Gorge Reservoir, which was soon to fill, could be stocked with rainbow trout *(Oncorhynchus mykiss)* for quality fishing (R. R. Miller 1963; Holden, *this volume,* chap. 3). Proponents of this project alleged that the waters had to be made safe for sport fishing by killing the native species.

Anglers like to catch golden trout (O. *aguabonita)* endemic to three California creeks—the South Fork of the Kern River, Golden Trout Creek, and the Little Kern River. When the golden trout became threatened by introduced brown trout *(Salmo trutta),* the California Department of Fish and Game spent $300,000 over eighteen years (1966—1984) in a campaign to eliminate the browns and restore the goldens in their native habitat (E. P. Pister, pers. cormm.). This time the poisoning was applied to remove the introduced fish and restore the endemic. A major justification was so that anglers could have their prized, flashy catch. The Colorado River cutthroat trout (O. *clarki pleuriticus),* the only native trout in the upper Colorado River drainage, is another desirable catch. The Gila trout (O. *gilae)* and Apache trout (O. *apache)* are also game species. Sometimes desert fish have recreational value; but a major problem for conservation is that usually they do not.

"Economic" is not on the list of endangered species benefits specified by Congress. Congress seems to have omitted it deliberately in order to suggest that the noneconomic benefits of conservation will override thoughtless human-caused extinctions in the name of development. At least in later amendments of the law, the burden of proof lies with those who think economic benefits justify extinction. Nevertheless, the most pragmatic argument for conserving endangered species is that some of them—which ones we do not know—will have agricultural, industrial, or medical uses in the future. The International Union for the Conservation of Nature and Natural Resources says, "The ultimate protection of nature, ... and all its endangered forms of life, demands ... an enlightened exploitation of its wild resources" (J. Fisher et al. 1969:19). Myers (1979a:56) says, "If species can prove their worth through their contributions to agriculture, technology, and other down-to-earth activities, they can stake a strong claim to survival space in a crowded world." He urges "conserving our global stock" (Myers 1979b).

Those species that are neither rivets nor indicators nor recreationally desirable may be raw materials. They may provide medicines or chemicals or genetic breeding materials. This argument works on occasion. Most species of *Aloe,* succulent plants, grow in deserts, The juice of *Aloe vera* promotes rapid healing of burns; rare species of *Aloe* may be destroyed before they can be examined for this effect.

But it seems unlikely that desert fishes are going to be good for anything agriculturally, medically, or industrially. Exploit desert fishes! That advice is not even pragmatically persuasive, and it seems somewhat demeaning for humans to regard all nonhuman species as "stock."

Congress anticipated that endangered species will have "scientific value." Indeed, they sometimes are key study species for both applied and theoretical science. A National Science Foundation report (NSF 1977:28) advocated saving the Devils Hole pupfish *(Cyprinodon diabolis)* because it and its relatives thrive in hot or salty water.

> Such extreme conditions tell us something about the creatures' extraordinary thermoregulatory system and kidney function — but not enough as yet, . . . They can serve as useful biological models for future research on the human kidney — and on survival in a seemingly hostile environment. . . . Man, in the opinion of many ecologists, will need all the help he can get in understanding and adapting to the expansion of arid areas over the Earth.

The pupfish has a sort of medical use after all; it is a survival study tool.

Where applied scientific value fails, there still remains theoretical scientific value. Species are clues to natural history; desert fishes, like fossils, help us to decode the past. Paleogeographers can figure out where the rivers formerly ran, where the lakes once were. Paleobiologists can figure out how fast speciation takes place and learn how dispersal occurs across wide ranges.

Some of these fishes are genetic anomalies because of their small population sizes. "The Devil's Hole pupfish . . . has apparently existed for thousands of generations with populations hovering near several hundred individuals. Classical genetic models predict that continual inbreeding should probably have already led to the extinction of this species, yet it still thrives in its single locality" (Meffe *1986:21).*

The even smaller population of *C. nevadensis pectoralis* (twenty to forty fish) in Mexican Spring (the size of a bathtub) should not have been there—in theory (Soltz and Naiman 1978). But there it was, and had been for thousands of years (J. H, Brown 1971). Until very recently, before humans interfered, there it still was; geneticists cannot yet say how. From the viewpoint of pure theory, it would be interesting to know—even if this knowledge had no trickle-down benefit in applied genetics. It might help us to understand founder effects in evolutionary natural history, where accidental events in small, early populations may have large consequences later on.

Destroying species is like tearing pages out of an unread book, written in a language humans hardly know how to read, about the place where they live. No sensible person would destroy the Rosetta Stone, and no self-respecting person will destroy desert fishes. Humans need insight into the full text of natural history. They need to understand the evolving world in which they are placed, and scientific study of these fishes is likely to reveal something presently unknown about the prehuman history of the lands we now possess as the American West. Following this logic, humans do not have duties to the book, the stone, or the species, but to themselves—duties both of prudence and education. Fishes have, as Congress expected, "educational," "scientific," and "historical" values.

These arguments, sometimes sound, can quickly become overstated. No one can be sure that the pupfish will not teach us something vital about human kidneys or how to survive in arid lands, but it seems unlikely that these lessons can be learned only or best with *Cyprinodon diabolis,* and not—if that species should be lost—with C. *nevadensis,* or even some plentiful anadromous fish like salmon, which migrate from salt to fresh water. If certain information that scientists need to revise genetic theory can be obtained only from C.

diabolis what happens after we have obtained it? We can discard the fish as we please, like laboratory rats after an experiment is over—unless a new argument is brought forth that C *diabolis* might hold further theoretical or practical secrets.

All these utilitarian reasons will not work all the time; no single one will work in every case. Still, as a collective set some will work nearly all the time, It is a versatile tool kit; there is something handy for almost every job, even though, rarely, one may not be able to find a suitable tool. Most of the desert fishes can be conserved by one or another of these pragmatic justifications, although for a few rare fishes we can anticipate no likely benefits. That will get us 95% conservation.

Duties and Human Excellence

We can preserve the remaining, nonresource, fishes (the 5%) with a final, double-sided humanistic argument—so continues this anthropocentric environmental ethics. On the positive side, an admirable trait in persons is their capacity to appreciate things outside themselves, things that have no economic, medical, or industrial uses, perhaps even no ordinary recreational, aesthetic, or scientific value. An interest in natural history ennobles persons. It stretches them out into bigger persons. Humans must inevitably be consumers of nature; but they can and ought to be more—admirers of nature—and that redounds to their excellence, A condition necessary for humans to flourish is that humans enjoy natural things in as much diversity as possible—and enjoy them at times because such creatures flourish in themselves.

On the negative side, there is something philistine and small-spirited about the inveterate exploiter of nature. There is always something wrong with callous destruction. Vandals destroying art objects cheapen their own character. Humans of decent character will refrain from needless destruction of all kinds, including destruction of even unimportant species. Americans are ashamed of having destroyed the passenger pigeon. They will be ashamed if they destroy these desert fishes; they will be more excellent persons if they conserve them. Destruction of these desert fishes is "uncalled for." Short of overriding justifications, humans really ought to save them all—including those few species from which we can gain no conceivable pragmatic, economic, ecological, aesthetic, recreational, scientific, educational, historical, or other benefits. We can always gain excellence of character from acts of conservation. We have a duty to our higher selves to save these fishes.

In another version of this argument, humans ought to preserve an environment adequate to match their capacity to wonder. Human life is often routine and boring, especially in town and on the job, and the great outdoors stimulates wonder that enriches human life. The desert evokes the sense of the sublime, and these curious desert fishes can certainly serve as objects of wonder. We have a duty to our higher selves to keep life wonderful.

At this point, however, we have pushed the anthropic arguments to the breaking point. Straining to develop a conservation ethic that is in our enlightened, highest human self-interest, the argument has become increasingly refined, only—alas—to become increasingly hollow. The logic of the utilitarian arguments was sometimes hard, but often soft. The promised benefits were real enough on some occasions, but on other occasions probabilistic and iffy. The loftiest preservationist argument is to preserve human excellence, to stretch humans out of themselves in wonder. But let us be frank again. It seems unexcellent—cheap and philistine, in fact—to say that excellence of human character is what we are after when we preserve these fishes. We want virtue in the beholder; is value in the fishes only tributary to that? If a person made a large donation to

the Desert Fishes Council, and, being asked what motivated his charity, replied that he was cultivating his excellence of character, we should rightly react that, small of spirit, he had a long way to go!

Why is callous destruction of desert fishes uncalled for if not because there is something in the fish that calls for a more appropriate attitude? Excellence of human character does indeed result from a concern for these fishes, but if this excellence of character really comes from appreciating otherness, then why not value that otherness in wild nature first? Let the human virtue come tributary to that. It is hard to gain much excellence of character from appreciating an otherwise worthless thing. One does not gain nobility just from respecting curios. Prohibiting needless destruction of fish species seems to depend on some value in the species as such, for there need be no prohibition against destroying a valueless thing. The excellence of human character depends on a sensitivity to excellence in these marvelous fishes flourishing in the desert.

The human mind grows toward the realization of its possibilities (excellences) by appropriate respect for nature (fishes), but that respect is the end, and the growth the by-product. It is even true that realizing this excellent humanity in *Homo sapiens* is a greater value than the flourishing of fish life in *Cyprinodon diabolis,* but the realization of excellent humanity here is exactly the *expansion* of human life into a concern for fish life for what it is in itself, past concern for utility, resource conservation, or self-development. Here humans are higher than fishes only as and because humans, moving outside their own immediate sector of interest, can and ought to be morally concerned for fishes, while fishes have no moral capacities at all and can neither cognitively entertain a concept of humans nor evaluate the worth of humans. "Higher" means here having the capacity to be concerned for the "lower." Humans are subjectively enriched in their experience as and because they love the other, nonhuman species for what they objectively are.

Excellence is intrinsically a good state for the self, but there are various intrinsic goods that the self desires and pursues in its relation to others (for example, welfare of another human, or of desert pupfish) that are not self-states of the person who is desiring and pursuing. The preservation of the pupfish is not covertly the cultivation of human excellences; the life of the pupfish is the overt value defended. An enriched humanity results, with values in the fishes and values in persons compounded—but only if the loci of value are not confounded.

One does indeed want to keep life wonderful, but the logic is topsy-turvy if we only value the *experience* of wonder, and not the *objects* of that wonder. Merely valuing the experience commits a fallacy of misplaced wonder; it puts the virtue in the beholder, not in the species beheld. Earth's five to ten million species are among the marvels of the universe, and fishes tenaciously speciating in the desert are exceptional even on earth. Valuing species and speciation directly, however, seems to attach value to the long-standing evolutionary products and processes (the wonders, the wonderland), not merely to subjective experiences that arise when latecoming humans reflect over events (the felt wonder).

Evolutionary development in these fishes runs to quantitative extremes, and human awareness of this can enrich our quality of life. But what is objectively there, before human subjective experience, is already quality in life, something remarkable because it is exceptional. If you like, humans *need* to admire and respect these fishes more than they need bluegrass lawns, or an overpopulated Arizona, or a few more beef cattle, or introduced game fish. That is a moral need. Humans need moral development more than they

need water development; they need a moral development that constrains any water development that endangers species.

Authorities are to be commended because, on the Virgin River drainage in Utah in 1980, they abandoned the Warner Valley Project lest it jeopardize the woundfin *(Plagopterus argentissimus)* and built the Quail Creek Project instead (Deacon 1988). Humans needed to do that. But the focus of this *need* cannot be simply a matter of human excellences. The alternate dam was not built to generate noble human character, or to preserve experiences of wonder. The alternative was chosen to preserve notable fishes and their natural excellences.

It is safe to say that, in the decades ahead, the quality of life in the American West will decline in proportion to the loss of biotic diversity, though it is usually thought that we are sacrificing biotic diversity to improve human life. So there is a sense in which humans will not be losers if we save endangered fishes, cactuses, snakes, toads, and butterflies. There is a sense in which those who do the right thing never lose, even when they respect values other than their own. Slave owners do not really lose when they free their slaves, since the slave owners become better persons by freeing people to whom they ran thereafter relate person to person. Subsequent human relationships will be richer. After we get the deepest values clear in morality, only the immoral lose. Similarly, humans who protect endangered fishes will, if and when they change their value priorities, be better persons for their admiring respect for other forms of life.

But this should not obscure the fact that humans can and sometimes should be short-term losers. Sometimes we ought to make sacrifices, at least in terms of what we presently value, to preserve species. On such occasions humans might be duty-bound to be losers in the sense that they sacrificed values and adopted an altered set of values, although they would still be winners for doing the right thing. Ethics is not merely about what humans love, enjoy, and find rewarding, nor about what they find wonderful, ennobling, or want as souvenirs. It is sometimes a matter of what humans *ought* to do, like it or not, and these *oughts* may not always rest on the likes of other humans or on what ennobles character.

Sometimes we ought to consider worth beyond that within ourselves. It would be better, in addition to our strategies, our loves, our self-development, our class self-interest, to know the full truth of the human obligation—to have the best reasons as well as the good ones. If one insists on putting it this way—emphasizing a paradox in responsibility—concern for nonhumans can ennoble humans (although this concern short-circuits if the concern is explicitly or tacitly just for noble humans). Genuine concern for nonhumans could humanize our race all the more. That is what the argument about human excellence is trying to say, only it confuses a desirable result with the primary locus of value.

Where the preceding arguments work, we have an ethic concerning the environment, but we have not yet reached an environmental ethic in a primary sense. The deeper problem with the anthropocentric rationale, beyond overstatement, is that its justifications are submoral and fundamentally exploitive and self-serving, even if subtly so. This need not be true intraspecifically, when out of a sense of duty one human altruistically defers to the values of fellow humans. But it is true interspecifically, since *Homo sapiens* treats all other species as rivets, resources, study materials, entertainments, curios, or occasions for wonder and character building. Ethics has always been about partners with entwined destinies. But it has never been very convincing when argued as enlightened self-interest (that one ought always to do only what is in one's intelligent self-interest), including class self-interest, even though in practice altruistic ethics often needs to be reinforced psychologi-

cally by self-interest. Some humans—scientists who have learned to be disinterested, ethicists who have learned to consider the interests of others, naturalists exceptionally concerned for these odd fishes—ought to be able to see further. Humans have learned some intraspecific altruism. The challenge now is to learn interspecific altruism.

Species as Historical Lineages

There are many barriers to thinking of duties between and to species, however, and scientific ones precede ethical ones. It is difficult enough to argue from an *is* (that a species exists) to an *ought* (that a species ought to exist). If the concept of species is flawed to begin with, it will be impossible to get the right ethical conclusion from a flawed biological premise. Perhaps the species concept is arbitrary, conventional, a mapping device that is only theoretical, Perhaps species do not exist. Individual fish exist, but *Cyprinodon milleri*, the Cottonball Marsh pupfish, once described as a full species from Death Valley (LaBounty and Deacon 1972), became just a subspecies (R. R. Miller 1981) when ichthyologists changed their minds. If species do not exist except embedded in a theory in the minds of classifiers, it is hard to see how there can be duties to save them. Duties to them would be as imaginary as duties to contour lines, or to lines of latitude and longitude. Is there enough factual reality in species to base duty there?

If a species is only a category or class, boundary lines may be arbitrarily drawn because the class is nothing more than a convenient grouping of its members. Darwin (1968 [1859]:108 wrote, "I look at the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other." Which natural properties are used for classification—reproductive structures, fins, or scales—and where the lines are drawn are decisions that vary with taxonomists. Indeed, biologists routinely put after a species the name of the "author" who, they say, "erected" the taxon.

But a biological "species" is not just a class. A species is a living historical form (Latin *species),* propagated in individual organisms, that flows dynamically over generations. Simpson (1961:153) concluded that "an evolutionary species is a lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies."

Eldredge and Cracraft (1980:92) found that "a species is a diagnosable cluster of individuals within which there is a parental pattern of ancestry and descent, beyond which there is not, and which exhibits a pattern of phylogenetic ancestry and descent among units of like kind." Species, they insisted, are "discrete entities in time as well as space," Grene (1987:508) claimed, "species ... can be thought of as definite historical entities playing a role in the evolutionary process. Lineages, chunks of a genealogical nexus, can count as real, just as genes or organisms do."

It is difficult to pinpoint precisely what a species is, and there may be no single, quintessential way to define species; a polythetic or polytypic gestalt of features may be required. All we need to raise the issue of duty, however, is that species be objectively there as living processes in the evolutionary ecosystem; the varied criteria for defining them (descent, reproductive isolation, morphology, gene pool) come together at least in providing evidence that species are really there. In this sense, species are dynamic natural kinds. A species is a coherent, ongoing form of life expressed in organisms, encoded in gene flow, and shaped by the environment.

The claim that there are specific forms of life historically maintained in their environments over time does not seem arbitrary or fictitious at all, but rather is as certain as anything else we believe about the empirical

world. After all, the fishes are objectively there in Ash Meadows, and the reason we are concerned about them is that they are unlike fishes anywhere else. Species are not so much like lines of latitude and longitude as they are like mountains and rivers—phenomena objectively there to be mapped. What we want to protect is kinds of desert fishes, not taxa that taxonomists have made up to classify them. Humans do not want to protect the labels they use but the living process in the environment.

Taxonomists from time to time revise the theories and taxa with which they map these forms. They make mistakes and improve their phylogenetic knowledge. They successfully map numerous species that are distinctively different. Beyond that, we can expect that one species will slide into another over evolutionary time. But the fact that speciation is sometimes in progress does not mean that species are merely made up, instead of being found as evolutionary lines articulated into diverse forms, each with its more or less distinct integrity, breeding population, gene pool, and role in its ecosystem. That one river flows into another, and that we make some choices about what names to apply where, does not disprove the existence of rivers.

We can begin to see how there can be duties to species. What humans ought to respect are dynamic life-forms preserved in historical lines, vital informational processes that persist genetically over millions of years, overleaping short-lived individuals. It is not *form* (species) as mere morphology, but the *formative* (speciating) process that humans ought to preserve, although the process cannot be preserved without its products. Endangered "species" is a convenient and realistic way of tagging this process, but protection can be interpreted (as the Endangered Species Act permits) in terms of subspecies, varieties, or other taxa or categories that point out the diversity of life.

Our concern is with the products of the process, but it is just as much with the process itself—as much with speciation as with species. Here fishes in the desert are of concern whether or not the edges between species are sharp. Where the edges are clear, we have a well-defined product of the evolutionary process. Where the edges are transitional, we have the process under way. As we. have already noted, *Cyprinodon milleri,* the Cottonball Marsh pupfish, was first described as a species separate from C. *salinus,* the Salt Creek pupfish in nearby Salt Creek. It is smaller and more slender, with a more posterior dorsal fin and a marked reduction or complete absence of pelvic fins (Soltz and Naiman 1978). But LaBounty and Deacon (1972) found evidence that at high water they may mix and interbreed; R. R, Miller (1981) found similarities in tooth structures; and C. *milleri* is now considered a subspecies of C. *salinus.* Still, the discovery that this fish is only a subspecies is no reason for less concern, it is reason for concern that speciation under way be allowed to continue.

The Death Valley area, including Ash Meadows, is a good place to see what is wrong with a proposal sometimes made that—while we do want to preserve all the species of mammals—with fishes, especially nongame fishes, it is enough to save at the genus level. Perhaps one *Cyprinodon* will do; they are all pretty much alike. Extending the same logic to insects, unless they have special economic or ecosystemic importance, saving beetles at the family level is enough. One member of the Ptiliidae will do. But that kind of representative saving does nothing to save the speciating process. Species are most similar where the speciating process is fecund; there the dynamic lineages are profuse and procreative. This speciating fertility would be reduced to nothing if but one such species were preserved.

Even saving a species in a hatchery stops speciation. A species removed from the full set of interactions with its competitors and neigh-

bors no longer works as it formerly did in the biotic community. A species is what it is where it is. Wild fish brought into hatcheries are soon selected for hatchery conditions, and the genome deteriorates, sometimes within a few generations (Meffe 1986). This is especially true with groups of fishes that speciate rapidly, groups that often include the endemics. Ex situ preservation, at times vital to the survival of a species whose habitat humans have radically disturbed, can never be more than an interim means to gain in situ preservation. We want to protect endangered speciation as well as endangered species.

Vanishing Desert Fishes and Human Development

These speciating processes and their product species will come to a stop—if present development trends go unreversed. The Endangered Species Committee of the Desert Fishes Council identified 164 fishes in North American deserts as endangered, vulnerable, rare, or of indeterminate status and suspected to be of concern. In addition, 18 fishes have already become extinct (J. E. Williams et al. 1985). In the West, Deacon (1979) listed 55 taxa (species and subspecies in 26 genera) of fishes that are extinct, endangered, threatened, or of concern. Four species and 6 subspecies in 6 genera have become extinct in recent decades, A fifth species feared extinct has been rediscovered (Pister 1981a). In Arizona, 81% of the native fish fauna is presently classified or proposed as threatened or endangered by state or federal agencies. In New Mexico, 42% are in trouble; and California, Nevada, and Texas fishes are in no better shape (J. E. Johnson and Rinne 1982; Rinne et al. 1986). Most of the big-river fishes endemic to the Colorado River basin are in grave danger; three (Colorado squawfish, humpback chub, and bonytail) are listed as endangered, the fourth, the razorback sucker *(Xyrauchen texanus),* is reduced to scattered individuals in all but Lake Mohave, where adult fish are of great age (thirty years or more) and are not being replaced. Unless there are sustained recovery efforts, the sucker is predicted to be extinct in the lake by the year 2000 (Minckley 1983; McCarthy and Minckley 1987). The bonytail is functionally extinct; only a few rare individuals exist. Behnke and Benson (1980:20) said of the bonytail's demise, "If it were not for the stark example provided by the passenger pigeon, such rapid disappearance of a species once so abundant would be almost beyond belief."

The cui-ui *(Chasmistes cujus)* is endemic to Pyramid Lake, Nevada, a deep, large Pleistocene remnant. Withdrawal of upstream water has reduced the lake level more than 20 m and endangered the lacustrine sucker, which is now maintained in the lake by hatchery reintroductions and by providing assistance to the spawning run (Scoppettone and Vinyard, *this volume,* chap. 18). The U.S. Fish and Wildlife Service estimates that more than thirty-five species of southwestern fishes will need some type of artificial propagation if they are to survive (J. E. Johnson and Rinne 1982; Rinne et al. 1986).

The native fish fauna of North America has been tampered with possibly as extensively as, and certainly more rapidly than, the fish fauna of any other continent—by introductions of "game" and elimination of "trash" fish, by dams, pollution, and erosional sedimentation, and by thoughtless development, together with the accidental results of development such as introduced parasites and diseases. Of the endangered and threatened fishes of the world, about 70% are in North America (Ono et al, 1983). Of fish species in the United States and Canada, 56% are receiving some degree of protection (J. E. Johnson 1987a). The fishes in the United States have been as

disturbed as any other faunal component, more so in the West than the East, and most of all in the Southwest (Moyle et al 1986). Sixty-seven non-native fishes have been introduced into the Colorado River basin (Carlson and Muth 1989, in press).

The fishes of the West are like the birds of Hawaii. Both have a unique past natural history; both have been disastrously upset by the arrival of modern culture; both have a doubtful future. Desert fishes evolved in oases in an ocean of sand; Hawaiian birds evolved on islands in the sea. Both are bellwethers, casualties of explosive development. Of sixty-eight species of birds unique to Hawaii, forty-one are extinct or virtually so (Ehrlich and Ehrlich 1981). If there is any place in the United States that today approaches and even exceeds the catastrophic extinction rates of the geological past, it is in Hawaii and the West. Extinction rates rise with development rates.

Development seems like a good thing, but we cannot really know what we are doing in the West until we know what we are undoing. What is evident in the West is its development—condominiums, dams, highways, shopping centers, mushrooming cities. Less evident is how this cultural development is bringing about a tragedy—the catastrophic collapse of evolutionary developments there since the Pleistocene and earlier, a collapse unprecedented in scale since Tertiary times. Irreversible destruction of the generative and regenerative powers on earth cannot be the positive, "development" that humans want.

This is why arguing the matter in terms of sport fishing versus trash fish (as was done in the Green River poisoning) is blind to what is really going on. Sport fishing does not justify the extinction of fish species that offer humans no fun. That pits trivial, short-range, nonbasic human pleasures against long-range evolutionary vitality. The deeper issue is respect for life, not "optimum enjoyment by the public." No non-native fish should be stocked in desert waters unless it has been determined that this practice does not adversely affect (officially or unofficially) threatened or endangered species. (This is the U.S. Fish and Wildlife Service policy for listed species in the Colorado River basin.) Non-native fish presently adversely affecting such species ought to be eliminated. The reintroduction of vanished fishes into their historic ranges ought to have priority over sport fishing.

Even to argue the matter in terms of water development requires caution. Not all water use is vital. Often one is trading bluegrass lawns, new golf courses, and two showers a day for shutting down evolutionary history. The Devils Hole pupfish was threatened by irrigation drawdown so that a few thousand cattle could be raised on land clearly marginal for that purpose (Deacon and Deacon 1979; Deacon and Williams, *this volume,* chap. 5). After that, until Preferred Equities sold its holdings in Ash Meadows to The Nature Conservancy, the threat to Ash Meadows was water development for a pleasure city (Adler 1984). Not even a pleasure city justifies tragedy in natural history!

Some who claim to be forward-looking will reply that the American West is in a post-evolutionary stage; the current story there is culture, and the latest chapter is the twentieth-century boom. The old rules do not apply. For millennia development took place through natural selection; development today takes place through real estate agencies and state legislatures. Nature must give way to culture. You cannot allow a few relict fish to hold up progress. Or, if you like, the old rules do apply even after the advent of culture: the fittest survive, and these archaic fishes cannot compete. Culture triumphs. That is the way it is, and that is the way it ought to be!

But before humans undo the natural history of the desert, we ought to ask whether cul-

tural development compatible with a respect for developments going on independently of our presence is possible. In the first decade of the Endangered Species Act there were 1632, consultations on possible adverse effects to endangered species by federally sponsored projects in Arizona, New Mexico, Texas, and Oklahoma. Only 13 resulted in jeopardy opinions, and in all 13 cases alternatives were found to alleviate the impact (J. E. Johnson and Rinne 1982). That does not mean that development will never be seriously constrained by efforts to preserve species, but it does indicate that forms of development compatible with preservation are possible.

Is it not the time to reconsider whether the "enlightened management of aquatic resources for optimum use and enjoyment by the public" is all there is to be said? Is it only a matter of exploiting resources, or is it also one of admiring the sources, the creative powers that wrought the land we would now manage entirely in our self-interest? From that perspective, the deepest reason to deplore the loss of these fishes is not senseless destabilizing, not the loss of resources and rivets, but the maelstrom of killing and insensitivity to forms of life and the sources producing them. This final imperative does not urge optimal human use and pleasure, or prudent reclamation, but principled responsibility to the biospheric Earth.

Duties to Desert Fishes

These fishes are objectively there! That primary, long-standing biological fact is one premise of the argument. After that, we go astray if we emphasize anomalous luck as a second premise, or inevitable natural extinction as a third premise, or if we treat human-caused extinction as equivalent—biologically or morally—to natural extinction. The argument begins to move toward another conclusion if, for instance, after the primary biological fact that the fishes are still there, we posit a remarkable biological competence (instead of luck) as a second premise. Then we put as a third premise that speciation is still going on in the desert (along with inevitable extinction) and, fourth, we distinguish between natural and human-caused extinction rather like we do between death from old age and murder.

We initially suppose that desert fishes are dead ends in the evolutionary process; active speciation is being shut down, and the few remaining fishes are anomalous relicts. But that is to misjudge the story. Fishes speciate extensively; there are more species of fishes in the world than of all other vertebrates (mammals, birds, reptiles, and amphibians) combined. Fishes can speciate explosively. In fishes, speciation has taken place spontaneously during recorded human history (Greenwood 1981); fishes are the highest phylogenetic category—the only vertebrate taxon—in which this is known to have happened. In less than five thousand years, since ancestral Lake Manly in Death Valley dried up with the retreat of the glaciers, different *Cyprinodon* species learned to survive in remarkably different environments—in shallow streams and marshes, in groundwater springs, in water as salty as the sea, in thermal springs, in springs where water levels fluctuate widely, in hot artesian wells dug by humans. Some survive in environments as constant as any known in the temperate zone; others live in environments that fluctuate widely from cold winter rains to summer heat. About all *Cyprinodon* seems to need is water—-any kind, place, or amount—and a little time to adapt to circumstances.

Though a place like Ash Meadows is a freakish anomaly, the life that prospers there has extraordinary vigor forced to ingenious modes of adaptation. Accidental life is matched with tenacity of life. The hardy, sprightly *Cyprinodon diabolis* has been clinging to life on a

small shelf of rock for ten thousand years or more. No other vertebrate species is known to exist in so small a habitat (Pister 1981b; Deacon 1979). This species "has evolved in probably the most restricted and isolated habitat of any fish in the world" (Soltz and Naiman 1978:35). We begin to wonder if there is not something admirable taking place as well as something accidental, something excellent because it is extreme.

Although the West is as dry as it has ever been in geologic history, and its fishes are as stressed as they have been in millennia, there are no signs of incompetence in the remaining fishes or of the slowing down of speciation. Death Valley *Cyprinodon* evolved into four species in at least twenty-eight populations (twenty remaining, eight exterminated by humans), with almost every population of C. *nevadensis* exhibiting evident differences. That shows an unusual capacity for rapid evolution (McNulty 1973). Desert fishes "present one of the clearest illustrations of the evolutionary process in North America, rivaling in diversity the finches of the Galapagos Islands which first caused Charles Darwin to crystallize his ideas on the evolutionary process" (Soltz and Naiman 1978:1). Relicts of the past, these fishes also live on the cutting edge of adaptability. They are endemics, and—far from being evidence of any biological incompetence—that attests to their specialized achievements in harsh habitats.

The same is true with hundreds of endemic fishes, reptiles, amphibians, invertebrates, and plants throughout the desert West. Even though fishes have been less common in the increasingly arid environment in recent times than in earlier eras (fishes in the United States as a whole were not), these desert fishes persisted more than ten thousand years in hundreds of endemic species. Before Europeans arrived in Arizona, California, and New Mexico, there was no end in sight for the fish. Pushing on at the edge of perishing, in their struggle for life they offer a moment of perennial truth.

In terms of conservation biology, the humanist scientist thinks that conservation biology begins with human concern. But conservation biology has been going on in the desert since before Pleistocene times. The pupfish, the squawfish, the woundfin—these are projects in biological conservation; these species have been conserving their kind for ten thousand years; they have been passing into transformed species tracking fitness in their environments. What human conservation biologists should do, arriving in this dramatic natural history, is admire and respect biological conservation taking place objectively to their conservation goals.

The wrong that humans are doing, or allowing to happen through carelessness or apathy, is stopping the historical flow of the vitality of life. One generation of one species is stopping all generation. Every extinction is an incremental decay in this stopping of life—no small thing. Every extinction is a kind of superkilling. It kills forms *(species),* beyond individuals. It kills "essences" beyond "existences," the "soul" as well as the "body." It kills birth as well as death. It kills collectively, not just distributively. It is not merely the loss of potential human information that we lament, but the loss of biological information, present independent of instrumental human uses for it. At stake is something vital, beyond something biological,

This superkilling is unprecedented in either natural history or human experience, and it is happening now in Arizona, New Mexico, Colorado, and Nevada. European Americans arrived in the West a few hundred years ago and gained the technological power to become a serious threat to fishes only a few decades ago. True, the issue faced here—desert fish—is not the whole global story. But it is an increment

in it. "Ought desert fish to exist?" is a distributive element in a collective question, "Ought life on Earth to exist?" The answer to the local question is not identical with that of the global question, but the two are sufficiently related that the burden of proof lies with those who wish to superkill the fishes and simultaneously to care for life on Earth. If these fishes become extinct, that event alone will not stop evolutionary development elsewhere on the globe. But it will stop the story underwater in the desert. Life is a many-splendored thing; fishes sparkle in desert waters. Extinction dims that lustre.

Can humans reside in the desert West with a respect for place, fauna, and flora? Is there not something morally naive about one species taking itself as absolute and regarding everything else relative to its utility? Though we have to make tradeoffs, do not these exceptional fishes claim our responsible care? They are right (fit) for life, right where they are, and that biological fact generates an ethical duty: it is right for humans to let them be, to let them evolve.

A Developing Ethic

Nature has equipped *Homo sapiens*, the wise species, with a conscience to direct the fearful power of the brain and hand. Only the human species contains moral agents, but perhaps conscience is less wisely used than it ought to be when it exempts every other form of life from consideration, with the resulting paradox that the sole moral species acts only in its collective self-interest toward all the rest. Among the remarkable developments on Earth with which we have to reckon, there is the long-standing ingenuity of these fishes, underwater in the desert; there is the recent, explosive human development in the American West; and there ought to be, and is, a developing environmental ethic. This is the biology of ultimate concern.

The author appreciates critical comments from R. J. Behnke, C. A. Carlson, D. A. Crosby, and E. P. Pister.

REFERENCES CITED

ADLER, J. 1984. Edge of extinction. *Newsweek*, 30 January 1984: 7.

AXELROD, D. I. 1979. Age and origin of Sonoran Desert vegetation. *Occ. Pap. California Acad. Sci.* 132:1-74.

BEATLEY, J. C. 1971. *Vascular plants of Ash Meadows, Nevada.* Univ. California Lab. of Nuclear Med. Rad. Biol. Rept. 12-845.

BEATLEY, J. C. 1977. Ash Meadows, *Mentzelia* 3: 20-35.

BEHNKE, R. J. and D. E. BENSON, 1980. *Endangered and threatened fishes of the upper Colorado River basin.* Coop. Ext. Serv., Colorado St. Univ., Bull. 503A: 1-34.

BROWN, J. H. 1971. The desert pupfish. *Sci. Am.* 225(5): 104-110.

CARLSON, C,. A. and R. T. MUTH, 1989. The Colorado River: lifeline of the American Southwest. Pp. 220-239 in *Proceedings of the International Large River Symposium,* D. P. Dodge (ed.) Canadian Journal of Fisheries and Aquatic Sciences, Special Publication 106.

CARLSON, C. A. and R. T. MUTH. Endangered species management. Chapter 14 in *Management of North American Fisheries,* C. C. Kohler and W. A. Hubert (editors). American Fisheries Society, Bethesda, Maryland. In press.

DARWIN, C. 1968(1859). *The Origin of Species.* Penguin Books, Harmondsworth, United Kingdom.

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

DEACON, J. E. 1988. The endangered woundfin and water management in the Virgin River, Utah, Arizona, Nevada. *Fisheries* (Bethesda, Maryland) 13(1): 18-24.

DEACON, J. E. and M. S. DEACON. 1979. Research on endangered fishes in National Parks with special emphasis on the Devils Hole pupfish. Pp 9-19 in *Proceedings of the First Conference on Scientific Research in the National Parks.* R, M. Linn (ed.). U, S. Nat. Pk. Serv., Trans. Proc. Ser. 5.

EHRLICH, P. R. and A. H. EHRLICH. 1981. *Extinction: The Causes and Consequences of the Disappearance of Species.* Random House Publ., New York.

ELDREDGE, N. and J. CRACRAFT. 1980. *Phylogenetic Patterns and the Evolutionary Process.* Columbia Univ. Press, New York.

FEINBERG, J. 1974. The rights of animals and unborn generations. Pp. 43-68 in *Philosophy and Environmental Crisis.* W. T. Blackstone (ed.). Univ. Georgia Press, Athens.

FSHER, J., N. SIMON, J. VINCENT and IUCN staff. 1969. *Wildlife in Danger.* Viking Press, New York

GREENWOOD, P. H. 1981. Species-flocks and explosive evolution. Pp. 819-834 in *The Haplochromine Fishes of the East African Lakes.* P. H. Greenwood (ed.). Cornell Univ. Press, Ithaca, New York.

GRENE, M. 1987. Hierarchies in biology. *Am. Sci.* 75: 504-510.

HAMPSHIRE, S. 1972. *Morality and Pessimism.* Cambridge Univ. Press, Cambridge, United Kingdom.

JOHNSON, J. E. 1987a. *Protected fishes of the United States and Canada.* American Fisheries Society, Bethesda, Maryland.

JOHNSON, J. E. and J. N. RINNE. 1982. The Endangered Species Act and southwest fishes. *Fisheries* (Bethesda, Maryland) 7(4): 2-8.

LaBOUNTY, J. F. and J. E. DEACON. 1972. Cyprinodon milleri, a new species of pupfish (family Cyprinodontidae) from Death Valley, California. *Copeia* 1972: 769-780.

McCARTHY, M. S. and W. L MINCKLEY. 1987. Age estimation for razorback sucker (Pisces: Catostomidae) from Lake Mohave, Arizona and Nevada. *J. of Arizona-Nevada Acad. Sci.* 21: 87-97.

McNULTY, F. 1973. Kill the pupfish? Save the pupfish! *Audubon* 75(4): 40-47.

MEFFE, G. K. 1986. Conservation genetics and the management of endangered fishes. *Fisheries* (Bethesda, Maryland) 11(1):l4-22.

MILLER, R. R. 1963. Is our native underwater life worth saving? *Nat Parks Mag.* 37(188): 4-9.

MILLER, R. R. 1981. Coevolution of deserts and pupfishes (genus Cyprinodon) in the American Southwest. Pp. 39-94 in *Fishes in North American Deserts.* R. J. Naiman and D. L. Soltz (editors). John Wiley and Sons, New York.

MINCKLEY, W. L 1983. Status of the razorback sucker, Xvrauchen texanus (Abbott), in the lower Colorado River basin. *SW Nat.* 28:167-187.

MOYLE, P. B., H. W. LI, and B. A. BARTON. 1986. The Frankenstein effect: Impact of introduced fishes on native fishes in America. Pp. 415-426 in *Fish Culture in Fisheries Management.* R. H. Stroud (ed.). American Fisheries Society, Bethesda, Maryland.

MYERS, N. 1979a. *The Sinking Ark.* Pergamon Press, Oxford, United Kingdom.

MYERS, N. 1979b. Conserving our global stock. *Environment* 21(9): 25-33.

NATIONAL SCIENCE FOUNDATION (NSF). 1977, The biology of aridity. *Mosaic* 8(1): 28-35.

ONO, R. D., J. D. WILLIAMS, and A. WAGNER. 1983. *Vanishing fishes of North America.* Stone Wall Press, Washington, D. C.

PISTER, E. P. 1981b. The conservation of desert fishes. Pp. 411-445 in *Fishes in North American Deserts.* R. J. Naiman and D. L Soltz (editors). John Wiley, New York.

RINNE, J. N., J. E. JOHNSON, B. L. JENSEN, A. W. RUGER, and R. SORESON. 1986. The role of hatcheries in the management and recovery of threatened and endangered fishes. Pp. 271-285 in *Fish Culture in Fisheries Management.* R. H. Stroud (ed.). American Fisheries Society, Bethesda, Maryland.

SCHWARTZ, A. 1984.. Bright future for a desert refugium. *Garden* 8(3): 26-29.

SIMPSON, G. G. 1961. *Principles of Animal Taxonomy.* Columbia Univ. Press, New York.

SMITH, M. L. 1981. Late Cenozoic fishes in the warm deserts of North America: A reinterpretation of desert adaptations. Pp. 11-38 in *Fishes in North American Deserts.* R. J. Naiman and D. L. Soltz (editors). John Wiley, New York.

SOLTZ, D. L. and R. J. NAIMAN. 1978. *The natural history of native fishes in the Death Valley System.* Nat. Hist. Mus. Los Angeles Co. (California) Sci. Ser. 30:1-76.

U.S. CONGRESS. 1973. *Endangered Species Act.* 87 Statutes 884. Public Law 93-205. U.S. Govt. Print. Off., Washington, D. C.

WILLIAMS, J. E. and D. W. SADA. 1985. Status of two endangered fishes, Cyprinodon nevadensis *mionectes and Rhinichthvs osculus nevadensis, from two springs in Ash Meadows, Nevada. SW Nat.* 30:475-484.

WILLIAMS, J. E., D. B. BOWMAN, J. E. BROOKS, A. A. ECHELLE, R. J. EDWARDS, D. A. HENDRICKSON, and J. J. LANDYE. 1985. Endangered aquatic ecosystems in North American deserts with a list of vanishing fishes of the region. *J. Arizona-Nevada Acad. Sci.* 20:1-62.