Endangered Invertebrates: the case for greater attention to invertebrate conservation

Scott Hoffman Black
The Xerces Society, 4828 Southeast Hawthorne Boulevard, Portland, OR 97215-3252; sblack@xerces.org
Matthew Shepard
The Xerces Society, 4828 Southeast Hawthorne Boulevard, Portland, OR 97215-3252; mdshepherd@xerces.org
Melody Mackey Allen
The Xerces Society, 4828 Southeast Hawthorne Boulevard, Portland, OR 97215-3252; mma@xerces.org

Abstract

Invertebrates eclipse all other forms of life on Earth, not only in sheer numbers, diversity, and biomass, but also in their importance to functioning ecosystems. Invertebrates perform vital services such as pollination, seed dispersal, and nutrient recycling. Although invertebrates are vitally important, they are often overlooked in management decisions, especially in management for endangered species. One indicator of the low emphasis on invertebrates is the lack of invertebrates included in both worldwide and U.S. endangered species programs. A review of current U.S. Endangered Species Act listings and policies show that this endangered species program is biased toward vertebrates. We believe there is compelling evidence that agencies, scientists, conservationists, and land managers should do more to promote the conservation of imperiled invertebrates. We briefly outline the steps that need to be taken to protect invertebrates and detail butterfly farming and a pollinator protection campaign as two possible ways to protect and restore invertebrate diversity and habitat.

Introduction

Although invertebrates are often overlooked and ignored, they eclipse all other forms of life on earth, not only in sheer numbers, diversity (number of species), and biomass (dry weight), but also in their importance to functioning ecosystems. The group includes an amazing array of organisms, including dragonflies, snails, bees, worms, sea urchins, mayflies, spiders, centipedes, scorpions, worms, starfish, clams, and lobsters. A review of the Endangered Species Act (ESA) and international endangered species lists shows government agencies need to do more to promote invertebrate conservation.

Invertebrate diversity and biomass

The animal kingdom has just over a million scientifically described species categorized into 32 phyla. The phylum Arthropoda (insects, spiders, crustaceans, millipedes, and centipedes, among others) has an estimated 1,085,000 identified species, or 82 percent (Table 1, Figure 1) of the total identified animal species, and with all other invertebrates (excluding viruses and bacteria) the number reaches 1,238,000 or 94 percent (UNEP 1995). The phylum Chordata, which includes all fish, birds, and mammals, contains around 45,000 (3%) species of which only 4,000 (0.03%) are mammals (UNEP 1995). It is estimated that 5 to 8 million insect species have not been identified or discovered (Figure 2), while only 5,000 to 10,000 species of Chordates may await discovery and description (UNEP 1995). Certain marine taxa, particularly small benthic organisms, are nearly as poorly known as terrestrial arthropods, suggesting that we have also greatly underestimated oceanic species diversity of invertebrates (Murphy and Duffus 1996).

Invertebrates are also the undisputed heavyweights of the planet (Figure 3). In the oceans, zooplankton and shrimp-like krill develop vast surface blooms of incredible mass. In the U.S. the biomass of earthworms and arthropods is estimated at 1,000 kg/ha, while the comparative biomass of human beings and all other terrestrial vertebrates is just 36 kg/ha (Pimentel 1980). If the weight of all land animals is summed, arthropods comprise over 85 percent of the total (Wilson 1992).

Invertebrates' importance to functioning ecosystems

The sheer number and mass of invertebrates reflect their enormous ecological impact. Admittedly, some have a negative impact on humans, either by harming us directly (as disease agents) or attacking food crops, tree plantations, and livestock. Even so, all adverse effects combined are insignificant compared to invertebrates' beneficial actions. Invertebrates are a part of nearly every food chain, either directly as food for other insects, fishes, amphibians, reptiles, birds, mammals, and other arthropods (Gilbert 1980), or indirectly as agents in the endless recycling of soil nutrients. Insects, worms, and mites are extremely important in helping microbes break down dung and dead plant and animal matter. Invertebrates are thought to decompose 99 percent of human and animal waste (Pimentel 1980). The perpetuation of food webs is often dependent on critical species performing essential services such as pollination or seed dispersal (Dodson 1975). Invertebrates, particularly native bees, pollinate most human food crops, and most other plant species. In the U.S., approximately 90 agricultural crops are cross-pollinated by insects (Pimentel 1980).

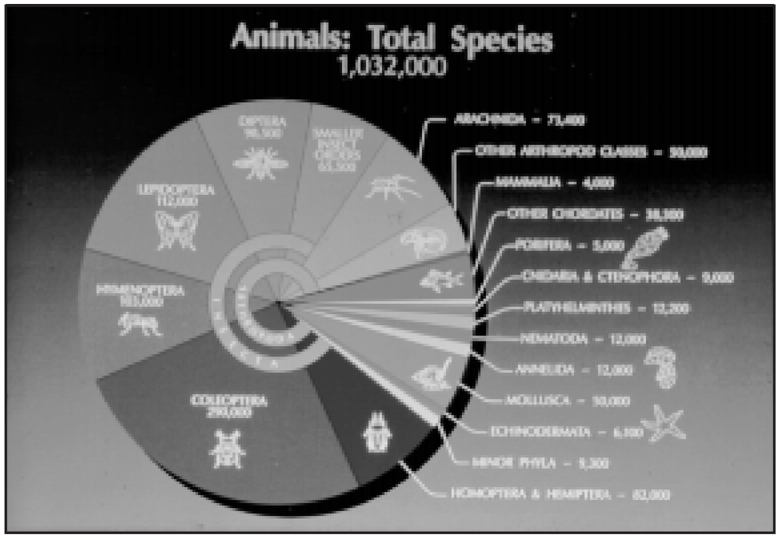

Figure 1. Total number of animal species (© E. O. Wilson 1988, reproduced with permission).

Some invertebrates are keystone species, playing particularly important roles in maintaining biotic communities (Kellert 1993). Coral reefs, providing a wide range of niches for a diversity of plants and possibly one-third of all fish species (Goreau 1979), serve as perhaps the most dramatic example of a keystone species. There are dozens more examples of how invertebrates benefit ecosystems and humans as natural biological control, food (such as lobster and shrimp and the many insects consumed by different cultures), and as potential cures for human disease. Without insects most of the terrestrial life forms on this planet would quickly disappear (Wilson 1992).

Invertebrate endangerment

Wilson (1992) believes that we are in the sixth great extinction spasm in the history of the world, with a 20 percent extinction of total global diversity a strong possibility by 2022 if the present rate of environmental destruction continues. One unappreciated aspect of this mass extinction is its concentration among invertebrates.

In 1987, West Germany classified 34 percent of its 10,290 insect and other invertebrate species as threatened or endangered; in Austria this figure was 22 percent of 9,694 invertebrate species (Wilson 1992). More recent figures for Great Britain (DETR 2001) show that 10.8 percent (1,578 species) of its 14,634 insects species are rare, vulnerable, or endangered. Many unpublicized scientific observations indicate that marine biodiversity is also severely threatened (Murphy and Duffins 1996). Many, if not most, of the threatened marine species are undoubtedly invertebrates.

Freshwater bivalves, for instance, are among the most endangered groups of organisms in North America (Mulvey 1997). The US freshwater mollusk fauna, especially rich in mussels and gill-breathing snails, is the largest in the world. Also, it is better studied and recorded than most invertebrate taxa. The species of this fauna have been steeply declining in numbers from the damming of rivers, pollution, and introduction of alien

Table 1. Partial classification of select animal Phylum (Modified from UNEP 1995).

ANIMALIA	1,320,000
MESOZOA	
METAZOA	1,320,000
Porifera (sponges)	10,000
Cnidaria (hydras, jellyfish, corals, etc)	10,000
Platyhelminthes (flatworms)	20,000
Nematoda (roundworms)	25,000
Echinodermata (sea uchins, etc.)	6,000
Choradata (fish, birds, mammals, etc.)	45,000
Arthrododa (crabs, spiders, insects, etc)	1,085,000
Mollusca (snails, squids, etc)	12,000
Annelida (segmented worms)	12,000

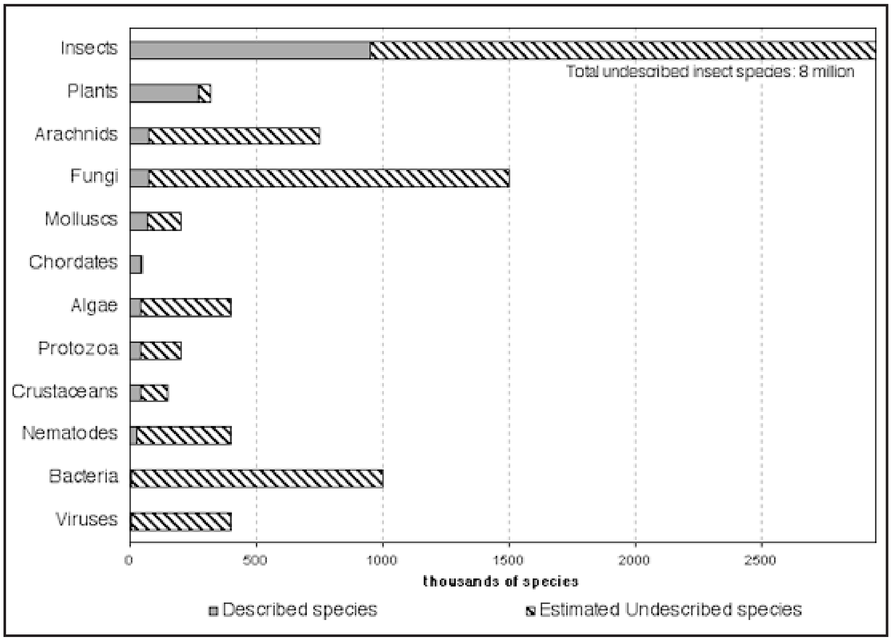

Figure 2. Numbers of described species and conservatively estimated existing species for major groups of organisms expected to contain in excess of 100,000 species. Vertebrates are included for the comparison. Note that the shaded proportion for Chordates does not show up on this graph because the estimated non-discovered species are only 5,000. Note also that the shaded portion of the bar for insects is truncated so as not to imbalance the diagram, and the length of the undescribed species portion is particularly speculative for the various groups of micro-organisms.

mollusks and other aquatic animals. At least 21 mussel taxa (7% of the fauna) are presumed extinct throughout their ranges (Williams and Neves 1995). Imperiled species account for 48.5 percent of freshwater mussels, 22.8 percent of freshwater gastropods, and 32.7 percent of crayfishes in North America (Ricciardi and Rasmussen 1999). The combined effects of impoundment and pollution alone extinguished two genera and 30 species of gill-breathing snails in the Tennessee and Cossa Rivers (Wilson 1992).

We may never know how many invertebrate species are at risk. The true impact of extinction on invertebrates is hard to quantify, partly because endangered species documentation is biased in favor of vertebrates. According to the 2000 IUCN (International Union for the Conservation of Nature and Natural Resources) *Red List of Threatened Species*, 375 invertebrates are listed as extinct, and 757 are listed as critically endangered or endangered. In comparison, 318 vertebrate species are listed as extinct and another 1,521 are listed as critically endangered or endangered (IUCN 2000). The IUCN list of critically endangered or endangered species contains only one Arachnid, even though there are 75,000 known species. Only 33 percent of the endangered species on the red list are invertebrates, yet they make up more than 94 percent of global animal diversity.

The disparity is also apparent in a statistics summary of the US Fish and Wildlife Services (USFWS) Threatened and Endangered Species System (TESS). Currently, only 37 percent of U.S. animal species listed as endangered are invertebrates and only one percent of listed foreign endangered species are invertebrates (USFWS 2001).

Invertebrates and the ESA

The ESA has always treated vertebrates more generously than it does invertebrates. Insects are singled out as the only group that cannot be protected if a particular species is determined by the Secretary of Agriculture to be an agricultural pest. This provision has never been used, as any serious pest would not likely be an endangered species. Whereas the ESA authorizes the protection of species, subspecies, and "distinct population segments" of vertebrates, only species and subspecies of invertebrates may be protected. This provision was a compromise between the House of Representatives and the Senate in 1978 after the House voted to eliminate protection for invertebrates altogether (Bean 1993).

Out of 31 species removed from endangered status only two are invertebrates. The first insect officially listed, the Bahama swallowtail butterfly (*Heraclides andraemon bonhotei*), was taken off the list because of an ESA amendment (it was determined to be only an occasional stray in the US and the authority to protect discrete invertebrate populations was ended by the 1978 amendments to the ESA). Sampson's pearlymussel (*Epioblasma sampsoni*) was also taken off the list because it went extinct. Unlike the American alligator and the brown pelican success stories, no insect has been taken off the list because its populations have recovered. Only one species, the Louisiana pearlshell (*Margaritifera hembeli*), has been downlisted from endangered to threatened in the last ten years.

Currently, TESS contains 103 animal species that are considered candidates for endangered or threatened species status, 92 (89%) of which are invertebrates. According to the USFWS, candidate taxa are those for which the Service has on file sufficient information to support issuance of a proposed rule to list under the Act. Designating a species as a candidate taxon does not give it any legal protection under the ESA; protection begins only when a species is formally designated as threatened or endangered. Often these species remain in limbo for years (Suckling pers. comm. 2000) and sometimes go extinct while waiting for formal designation. In 1995 three pomace flies (*Drosophila* sp.) from Hawaii went extinct while on the candidate list (USFWS 1997). The Marianas euploea butterfly (*Euploea eleutho*), an endemic to the Mariana Islands, met the same fate (USFWS 1997). No comprehensive survey has been completed to determine how many species have gone extinct while on the candidate list, and it is likely that many more have disappeared unnoticed.

In the 1990s, many invertebrates (as well as plants and other animals) that might have warranted listing were dropped from consideration. In the 1980s and early 1990s, TESS contained over 1,200 invertebrates and 570 vertebrates on the candidate list. The candidate list consisted of three categories: C1 = sufficient information on hand to list, C2 = appears to need listing, additional information required, and C3 = taxonomic uncertainty. In 1994, the Clinton Administration dropped all C2 and C3 species from the list, including over 1,100 invertebrates.

Although there is no significant difference of the median population size at the time of listing between vertebrates and invertebrates (Wilcove et al. 1993), invertebrate species may be more vulnerable to extinction than listed vertebrates because their smaller body size and shorter individual lifetimes may make them more vulnerable to environmental fluctuations (Murphy et al. 1990). Thomas (1990) suggests that to ensure comparable viability, populations of rare insects should be at least one order of magnitude greater than populations of vertebrates.

Some scientists believe that recovery plans are biased toward vertebrates (Murphy 1991), and other analyses of recovery plans have showed that, with few exceptions, a taxonomic bias has favored vertebrates. It was detected in the recovery process that a higher percentage of vertebrates than invertebrates had approved recovery plans (Tear et al. 1995). There is also a striking contrast between expenditures for invertebrates when compared to vertebrates. In fiscal year 1991, state and federal agencies combined spent an average of $1.1 million for each bird species listed, $684,000 for each listed mammal species, and only $44,000 for each listed invertebrate species (Bean 1993).

Some of the apparent neglect of invertebrates may be because we know a lot less about individual invertebrate species than we do about most vertebrate species. Apart from the relatively few invertebrates that do significant economic damage or that have significant economic value, there has been relatively little research completed on insect ecology.

Regardless of the reason, environmental policy often overlooks invertebrates despite their staggering importance, and despite the catastrophic loss of so much invertebrate life. The general public also seems largely unaware of invertebrates' potential impact on human well-being. Many in the general public view invertebrates with aversion, fear, avoidance, and ignorance (Kellert 1993). Scientists, and to a lesser extent conservationists, have more favorable attitudes toward invertebrates (Kellert 1993), but still favor vertebrate over invertebrate species in research, education, and conservation action.

Causes of endangerment

The causes of invertebrate endangerment is similar to many other animals. According to the IUCN, the leading causes of both vertebrate and invertebrate endangerment include habitat destruction, displacement by introduced species, alternation of habitat by chemical pollutants (such as pesticides), hybridization with other species, and over-harvesting (Wilson 1992).

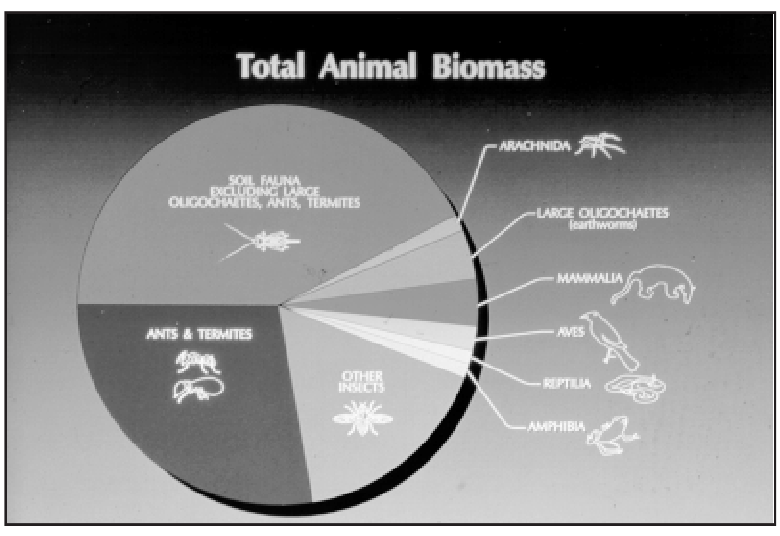

Figure 3. Total animal biomass, as measured in a plot near Manaus, Brazil (© E. O. Wilson 1988, reproduced with permission).

Many insect species are vulnerable because their populations have a severely restricted distribution, often just a single locality. The giant flightless darkling beetle (*Polposipus herculeanus*), for instance, lives only on dead trees on the tiny Frigate Island in the Seychelles. The Socorro sowbug (*Thermosphaeroma thermophilum*), an aquatic crustacean that has lost its natural habitat, survives in an abandoned bathhouse in New Mexico (Wilson 1992). Although freshwater and land mollusks are sometimes widespread species, they are generally vulnerable to extinction because so many are specialized for life in specific habitat conditions and are unable to move quickly from one place to another (Wilson 1992). As a result, isolated populations are highly susceptible to change. For instance, invasive introduced species are a significant problem for many Hawaiian species, including tree snails. In contrast, other species, such as the monarch butterfly, migrate great distances but still face an uncertain future.

Rare insect species often have subtle habitat requirements and have even been lost from reserves as a result of apparently minor habitat changes (Thomas 1995). The large blue butterfly (*Maculina arion*) larvae is an obligate parasite of red ant (*Myrimica sabuleti*) colonies. Accordingly, in 1979 this butterfly went extinct in England because plant communities were not managed for the ants. (The large blue has subsequently been successfully reintroduced to appropriately managed sites in England using a subspecies from Sweden.) Studies of some European grasslands showed that areas not grazed or reforested harbored significantly higher butterfly species richness and heterogeneity, and hosted more Red List species, than grasslands in the early successional stages (Balmer and Erhardt 2000). Old-growth forests in temperate zones also have higher invertebrate diversity than younger stands (Schowalter 1989). Tropical rain forests, however, may hold the majority of terrestrial invertebrate diversity (Wilson 1992). With rainforests and temperate old growth forests around the world being lost at a rapid rate, invertebrates are bound to go with them.

What should be done to protect invertebrates?

Detailing a precise conservation plan for invertebrates would take volumes. The widespread destruction of the earth's biodiversity occurring today must be matched by a conservation response on an order of magnitude greater than that which currently exists. Ultimately, the key to protection of any species is protecting its habitat. Many scientists advocate community–level conservation for non-charismatic taxa. Moreover, community-wide studies appear to offer a practical way to gather information about the diversity and distribution of little known taxa (Hughes 2000). We should move forward with the gathering of information wherever possible. Although protecting whole communities is a valid scientific approach, one of the best methods for protecting species—the ESA—is based on species rather than ecosystem conservation.

Habitat protection

Large swaths of land designated as wilderness, protected for wide ranging species, or set-aside in conservation easements will ultimately benefit invertebrates. Some invertebrates only need small areas to thrive, and indeed backyard gardens can help some pollinators. Working in other countries to protect nature reserves or to protect butterfly and other insect habitat is also a valid approach. In addition, habitat needs to be protected for marine species. We need marine reserves managed for these species, not marine reserves where commercial fishing and other destructive activities are allowed, as is often the case now.

Status reviews and listing petitions

The formal listing of species as threatened or endangered under federal or state endangered species legislation, as sensitive or indicator species under U.S. Forest Service National Forest Management Act regulations, or even under lists from nongovernmental organizations such as IUCN, has been an extremely effective habitat protection tool. Groups and individuals should work to protect invertebrates as well as more charismatic megafauna and ensure that agencies and land managers realize the importance of conserving invertebrates. In some cases, legal action may be needed to ensure that federal agencies follow laws, such as the ESA.

Research

Before we can work to protect some invertebrates we need to at least know if populations are stable or declining, and we need to understand their habitat needs. Many invertebrates have not even been identified. In the long run, more emphasis needs to be placed on invertebrate systematics and taxonomy so that these species can be identified and cataloged. Research needs to go hand in hand with conservation, for there is little use for a catalog of extinct species.

Education

Successful conservation of invertebrates requires a greater understanding by the general public, scientists, land managers, and conservationists of the extraordinary value that these organisms provide. It is unlikely that very many people will develop affection or an affinity for these animals, but it plausible that a more compelling depiction of invertebrates' extraordinary contributions to human welfare and survival will do much to improve the public attitude toward these organisms (Kellert 1993). An ambitious public education program is needed to enhance the recognition of invertebrates' positive values, and indeed, of all biological diversity.

Case studies in invertebrate conservation

There are many innovative and successful conservation programs implemented by conservation organizations around the world that focus on invertebrates. Below we outline two major programs with which the Xerces Society has been involved.

Butterfly farming

People who live in the cradle of a country's natural resources, given sufficient incentives to conserve, can be (and often already are) allies—not adversaries—in sustainable natural resource management (UNEP 1995). Conservation-based butterfly farming—more accurately, ranching—can be a successful means to protect and conserve critical habitat for threatened species wherever tropical forest butterfly habitats remain intact, and where live butterfly export is legal. The tropical forests of Central and Latin America, the Philippines, Madagascar, Kenya, Malaysian Borneo, Jamaica, and Indonesian Iryan Jaya meet these criteria. Butterfly ranches can offer a sustainable means of economic development that is based on the wise use of forest resources and on the long-term prosperity for the ranchers.

We differentiate between butterfly farming and ranching in this article. According to CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) farming operations are essentially closed systems that are no longer dependent upon regular infusions of wild stock to produce successive generations in captivity. Ranching operations, however, are open-ended operations, depending upon a regular and recurrent infusion of wild stock (such as by harvesting early instar larvae in the wild, and then growing them in controlled environments). Using CITES terminology, butterfly ranching is preferable to farming because the viability of ranching efforts depends upon the continued availability of wild habitat from which to take the needed stock. This assumes, of course, that any harvest from the wild is sufficiently controlled so as not to be excessive.

Butterfly ranching utilizes any buffer zone adjacent to secondary or primary forests, and the forests themselves. It combines village economic development with education about basic biology, ecosystem dynamics, and sustainable management practices. The ranchers quickly understand the importance of their local biological diversity, especially plants and insects, and become protective stewards. Thanks to an intact forest, their butterfly breeding stock is close at hand, derived from wild, genetically vigorous populations. The larval food plants that attract the egg-laying females and feed the caterpillars are also easily accessible, as are the blooming nectar plants that lure the mating adults to the ranches. As ranchers obtain root cuttings from plants locally, they propagate live "fuel" for pupae production. The nearby forest provides the raw materials for their business, and its regenerative powers become highly important.

Butterfly ranching is a sustainable, ecologically responsible cottage industry. The market for live butterfly pupae is a robust one. Exhibits displaying exotic, live, tropical butterflies and plant communities within huge glass exhibit houses are tremendously popular. There are at least 140 butterfly houses located throughout the world in Asia, Australia, New Zealand, Canada, and Europe, and more than 60 in North America. These are lucrative enterprises, with admissions in the U.S. ranging from \$6.50 to \$18.95. Two million people a year tour the butterfly house at the San Diego Wild Animal Park. The large US exhibits budget as much as \$100,000 or more annually for butterfly livestock.

The well-being of people who live on the edges of tropical forests is a prime factor in determining whether those areas are maintained and conserved, according to conclusions reached during the United Nations Rio de Janeiro Conference on Sustainable Development in 1992 (UNEP 1995). Butterfly ranching can be a sustainable economic development tool if there is sufficient in-country support. With skilled scientific direction, it can also directly conserve and regenerate butterfly species on the brink of extinction.

The Xerces Society and Zoological Society of San Diego have been partners for five years in a butterfly ranching pilot project. The goal was to establish an income-producing cottage industry that would be sustainable, ecologically responsible, enhance protection of surrounding habitat, provide education in the natural sciences, and, if possible, involve school-age children. Barra del Colorado, a village in northeastern Costa Rica near the Nicaraguan border, was chosen because of its spiraling economic problems. This operation, employ-

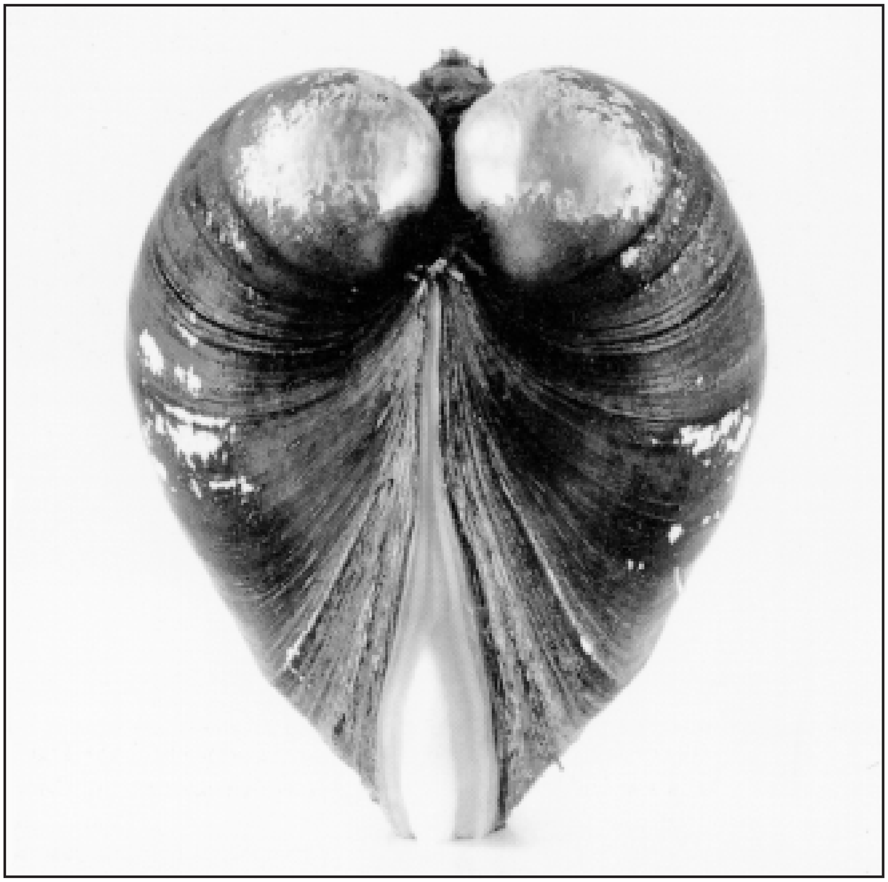

Figure 5. Listed as endangered in June 1976, there are nine known populations of fat pocketbook pearly mussels (Potamilus capax), confined to two river systems in Arkansas and Indiana. Dam building, dredging, and agricultural chemical runoff threaten these populations in their habitat of slow-moving rivers. Photo reproduced with permission of Susan Middleton and David Liittschwager (1994).

ing women farmers whose children also participated, was highly successful as long as the U.S. organizations were providing on-site management six months of the year. The women lacked the requisite training and skill to deal with the complexities of management; thus, without the presence of on site managers, they lost motivation for the project. The lesson learned is that trained, in-country advisors must be secured at the outset, and be regularly available over time to help with management, exporting, and the personal relationships between the producers.

The Xerces Society has produced a publication to provide guidance: *A Handbook for Butterfly Farmers.* (Please contact one of the authors of this article for more information on this book.)

Pollinators

Pollinators are often considered keystone species as their presence in an ecosystem ensures the continued reproduction and survival of plants, and in turn the other wildlife relying on these plants. Data on at-risk invertebrate pollinator species is lacking; however, there is mounting evidence of the decline in pollinator insects (Allen-Wardell et al. 1998). Also, concern about the potential impact of this decline on both wild lands and food production is on the rise (Buchmann and Nabhan 1996; Kremen and Ricketts 2000).

Bees, the dominant group of pollinators, face a similar series of threats as most other wildlife, especially loss of habitat to development and agriculture. In addition, bees are susceptible to fragmentation of habitat (Westrich 1996), resource competition from non-native species (Buchmann 1996; Thorp 1996; Roubik 2000), and use of pesticides (Sipes and Tepedino 1995). Despite their critical importance, few pollinator insects—including just one bee, Franklin's bumble bee (*Bombus franklini*)—get any official protection in the U.S., and then often only as Species of Concern at the state or federal level.

In 1998, a group of pollinator scientists developed recommendations for conserving pollinators (Allen-Wardell et al 1998). These recommendations were endorsed by numerous conservation organizations and professional societies. The recommendations include the following:

- Increasing attention to invertebrate systematics, monitoring, and reintroduction as part of habitat management and restoration plans;
- Assessing effects of pesticides, herbicides, and habitat fragmentation on wild pollinator populations;
- Including seed monitoring, and fruit set and floral visitation rates in endangered plant management and recovery plans;
- Including habitat needs for vital pollinators in the critical habitat designations for endangered plants;
- Identifying and protecting floral reserves near roost sites along migration corridors of threatened migratory pollinators.

The work group also recommended increased education and training to ensure that both the general public and resource managers understand the importance of pollinators.

The Xerces Society was one of the first organizations to recognize the significance of threats to pollinator insects, and was a founding member of the Forgotten Pollinators Campaign, administered from the Arizona-Sonora Desert Museum (Tucson, AZ). We continue to be an active advocate for insect pollinator conservation in the U.S. Our work focuses on native pollinator insects and includes community-based education activities, habitat enhancement, and petitioning for listing under the ESA.

To promote conservation of native pollinator insects we are working to accomplish the following:

- Increase the awareness of pollinators' important role in ecosystems and of the threats they face among the public;
- Engage people of all backgrounds in pollinator conservation, providing them with the knowledge and confidence to take action to protect pollinator diversity and habitat;
- Protect threatened and endangered pollinator species and their habitat;
- Influence decision-makers and policy through an advocacy and education campaign.

The Society, in collaboration with the USDA Bee Biology and Systematics Laboratory (Logan, UT), has worked with land managers to develop techniques to enhance pollinator habitat. Based on these techniques, pollinator management guidelines have been produced and pollinator conservation has been featured in both print and video magazines as well as on National Public Radio, generating interest and new projects across the country (Shepherd and Tepedino 2000; Shepherd et al 2001; Golf And Environment 2000; Living on Earth 2001).

In the Pacific Northwest, the Society is working to promote pollinator conservation and encourage wider involvement in projects at a grass-roots level. We have been working with educators and students, land managers, and agencies to promote awareness of pollinators, and to engage people in activities to conserve them. We are presenting workshops, establishing demonstration sites, producing a handbook on pollinator management, working with land managers on specific projects to restore pollinator habitat, and petitioning the USFWS to list endangered and threatened pollinator species.

We are also developing a website and database as a pollinator conservation resource for the Northwest region. It will become an integral part of the Society pollinator conservation program in this region, providing a place where people can access information on pollinators and habitat, participate in educational activities, and share experiences and knowledge.

The Society is not the only organization working to protect pollinator insects. In addition to the work of bee scientists at universities and research centers, major programs launched by other organizations include:

- ♦ Migratory Pollinators Project, administered by the Arizona-Sonora Desert Museum; this project focuses on protecting "nectar corridors" between Mexico and the United States for four pollinators, including the monarch butterfly (*Danaus plexippus*).
- ♦ North American Pollinator Protection Campaign, run by the Co-evolution Institute (San Francisco, CA); this campaign is a collaborative initiative to increase public awareness, create projects to protect pollinators and habitat, and initiate policy change.

Conclusion

The first step to invertebrate protection is to put invertebrates on the same footing as other species in management decisions. Conservation, research, and education are all needed to ensure sustainable populations of invertebrates. The conservation of invertebrates should be of paramount importance to all people as the ecological services they provide are vital to life as we know it on the planet. As Harvard biologist E. O. Wilson stated, "So important are insects and other land dwelling arthropods, that if all were to disappear, humanity probably could not last more than a few months."

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