ENDANGERED INSECTS

Scott Hoffman Black and D. Mace Vaughan, The Xerces Society, Portland, OR

In: *The Encyclopedia of Insects* (Eds. Resh, V. H. and Carde, R.). (In press) Academic Press. San Diego, CA.

The Xerces blue butterfly (Fig. 1), Antioch katydid, Tobias' caddisfly, Roberts's alloperlan stonefly, Colorado burrowing mayfly, Rocky Mountain grasshopper all were driven extinct by humans. With almost one million described species, insects eclipse all other forms of animal life on Earth, not only in sheer numbers, diversity, and biomass, but also in their importance to functioning ecosystems. However, human-induced changes to the natural environment threaten vast numbers of these organisms and the vital services they provide to ecosystems.

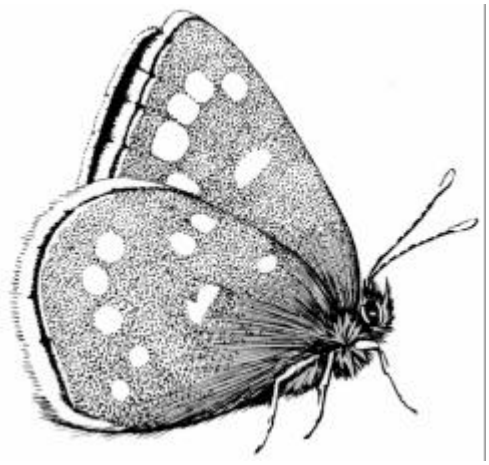

Figure 1. The Xerces blue butterfly (*Glaucopsyche xerces*), was the first butterfly in North America known to become extinct as a result of human interference. It was driven to extinction as San Francisco expanded over the butterfly's habitat. Illustrated by

I. INSECT DIVERSITY AND IMPORTANCE

As biologist J. B. S. Haldane noted more than 60 years ago, "The creator must have an inordinate fondness for beetles." The more than 300,000 species of beetle to which Haldane referred are representative of the great diversity of insects. Measured by the number of formally described species, insects are by far the most diverse group of organisms on Earth. More than 950,000 species of insects have been described, comprising 72% of the total identified animal species on Earth.

Even more remarkable are the estimates of how many insects we have not cataloged. Most insect species that have been classified and named to date are from temperate zones, but tropical habitats harbor far more. Smithsonian Institution entomologist Terry Erwin has suggested that as many as 30 million insect species may exist based on extrapolations from the number of beetles found in particular tropical tree species. The most conservative estimates suggest that five to eight million insect species have not been discovered. This number contrasts sharply with the 5,000 to 10,000 species of vertebrates that may await discovery and description around the world.

The sheer number and mass of insects reflect their enormous ecological impact. The world's ecosystems depend upon insects for pollination, decomposition, soil aeration, and nutrient and energy cycling. As Harvard biologist E. O. Wilson wrote, "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."

II. INSECT ENDANGERMENT

A report by the World Commission on Environment and Development noted, "there is a growing consensus that species are disappearing at rates never before witnessed on the planet" but that "we have no accurate figures on current rates of extinctions, as most of the species vanishing are the least documented, such as insects in tropical forests." Scientists and conservationists agree that insect species

are going extinct. But how many have been lost and how many more are at risk remains unclear.

A. Extinct Insects

The International Union for Conservation of Nature and Natural Resources (IUCN) lists 72 insects as extinct worldwide. In the United States, the Natural Heritage Program lists 160 insect species either as presumed extinct or as missing and possibly extinct. Many scientists believe that these numbers drastically underestimate actual insect extinction and that many hundreds, or perhaps thousands, of species have gone extinct unnoticed in North America and Europe in the last two centuries. The loss in tropical areas has probably been much greater.

For example, the Antioch Katydid, *Neduba extincta*, from California was described in 1977 from preserved specimens collected 40 years earlier. Searches of its sand dune habitat, now largely destroyed, have proved fruitless. The Tobias' caddisfly, *Hydropsyche tobiasi*, was described in 1977 from specimens collected on the Rhine River in the 1920s. None have been seen since.

In some cases, insects that at one time were very common have disappeared. During the mid-1800s, immense swarms of the Rocky Mountain grasshopper, *Melanoplus spretus*, periodically migrated from the northern Rocky Mountains and destroyed crops throughout the western and central portions of the United States and Canada. However, in the late 1880s this species began a precipitous decline. Some believe that a natural population crash combined with habitat destruction and introduced species led the Rocky Mountain grasshopper to extinction. If a widespread species can vanish because of human activity, the fate of many endemic tropical species must hang in the balance as their only habitat is destroyed.

B. Endangered Insects

Based on available information we can deduce that a very large number of insects are endangered. The majority of animals on the planet are insects and, if the factors that endanger other animals also affect insects, the number of endangered insects must be very large.

According to the 2000 IUCN Red List of Threatened Species, 163 insects are listed as critically endangered or endangered worldwide. In 1987, West Germany classified 34% of its 10,290 insect and other invertebrate species as threatened or endangered and, in Austria, this figure was 22% of 9,694 invertebrate species. More recent figures from 2000 for Great Britain show that 10.8% of its 14,634 described insect species are rare, vulnerable, or endangered. In the United States, both the U. S. Fish and Wildlife Service (USFWS) and the Natural Heritage Program track endangered species, including insects. The USFWS lists 42 insects as either endangered or threatened, whereas the Natural Heritage Program lists 165 insects as either critically imperiled or imperiled.

Are these figures on endangered insect species realistic? Because we lack an enormous amount of information on the taxonomy, life history, and distribution of insects and because endangered species documentation is biased in favor of vertebrates, we certainly are underestimating the number of at-risk insect species. To illustrate, only 7% and 4% of the endangered animal species listed by the IUCN and USFWS, respectively, are insects, yet insects make up more than 72% of global animal diversity. Of all the vertebrates described in the U.S., 17.9% are listed as threatened or endangered. If we assume that insects and vertebrates face similar destructive forces at similar levels of intensity, then one should expect to find on the order of 29,000 at-risk insects in the U.S. alone. Although this assumption oversimplifies the situation, it shows that the 48 insects listed as endangered and threatened by USFWS is a significant underestimate. The Natural Heritage Program may be closer to the mark for select groups of insects for which we have more information. It estimates that 43% of stoneflies, 19% of tiger beetles and butterflies, and 17% of dragonflies and damselflies are critically imperiled or imperiled in the U.S. In addition, according to the IUNC Red Book of Swallowtails, 10% of swallowtail butterflies are considered threatened. Swallowtails are the only group of insects to have been assessed worldwide.

III. IMPORTANCE OF ENDANGERED INSECTS

A rare and endangered species of insect is unlikely to determine the fate of a large ecological system, but as a group they may have a large effect. Ecosystem functions, such as the recycling of nutrients, often are done by specialists like the American burying beetle (Fig. 2) rather than generalists. There are innumerable specialized insects that feed on particular kinds of wood, dung, or carrion. For instance, the plates that cover the shells of tortoises are made of keratin, a protein few scavengers can digest. However, in Florida there is a

Figure 2. The American burying beetle (*Nicrophorus americanus*) was listed as an endangered species under the U.S. Endangered Species Act in 1989. This species was once wide-spread across the eastern U.S. and Canada, but now is only found in a few isolated populations in Rhode Island, Arkansas, Oklahoma, Nebraska, and South Dakota. At this time, the exact cause of this species' population decline remains controversial. Habitat fragmentation, changes in land use, pesticide use, increased competition with vertebrate scavengers for limited numbers of carcasses, and the installation of lights in rural areas all may play a role. (Copyright Middleton/Liittschwager 1994)

moth, *Ceratophaga vicinella*, whose caterpillar appears to have specialized on a diet of dead gopher tortoise shells.

Endangered species also can play a linchpin role in small, specialized systems, such as caves, oceanic islands, or some pollinator-plant relationships. For example, many plant species rely on one or a few pollinators. Decreased abundance or loss of any of these pollinators can have dramatic consequences, especially if a plant depends on a single, obligate pollinator.

Some endangered species might provide useful products, such as new defenses against diseases, tools for studying various ecosystem or organismal processes, as well as direct material benefits. For instance, the conservation of several species of butterflies is helped by the market value of aesthetically pleasing specimens or of live specimens for butterfly houses that charge admission.

Besides these material reasons for conserving endangered insects, we also have the responsibility of caring for the rich biological heritage we leave to future generations. At this time, we cannot begin to grasp the full value of biodiversity and, thus, it is in our best interest to be conservative.

IV. CAUSES OF ENDANGERMENT

Insects become endangered because of the same destructive forces faced by many other animals. According to the IUCN, the leading causes of animal endangerment are habitat destruction, displacement by introduced species, alteration of habitat by chemical pollutants (such as pesticides), hybridization with other species, and over-harvesting. Many at-risk insects are threatened by more than one of these causes. For example, according to the Natural Heritage Program there are six tiger beetles and 33 butterflies that are imperiled or federally listed under the U.S. Endangered Species Act. The major threat to all six tiger beetles is habitat degradation and loss. Two of these beetles also are threatened by over collecting. For the 33 butterflies, 97% are threatened by habitat loss, 36% by alien species, 24% by pollution, and 30% by over collecting.

Insects as a group are not at risk because many species are generalists or widely distributed. A significant proportion of the total diversity of insects, however, is composed of species that are highly specialized or are restricted to one or a few small patches of habitat. The giant flightless darkling beetle, *Polposipus herculeanus*, for instance, lives only on dead trees on tiny Frigate Island in the Seychelles. The stonefly *Capnia lacustra* only exists in Lake Tahoe and is also the only stonefly in the world known to be fully aquatic in the adult stage. Another unusual stonefly, *Cosumnoperla hypocrema*, is known from only one intermittent spring in the Cosumnes River Basin in California.

A. Habitat Destruction

Agriculture, commercial development, outdoor recreation (including off road vehicles), pollution, and water development rank as the most frequent causes of habitat degradation affecting federally listed endangered and threatened insect species in the U.S. (Fig. 3). Commercial and residential developments often are situated on sites that have naturally high diversity, such as along rivers or near bays and estuaries. Urban

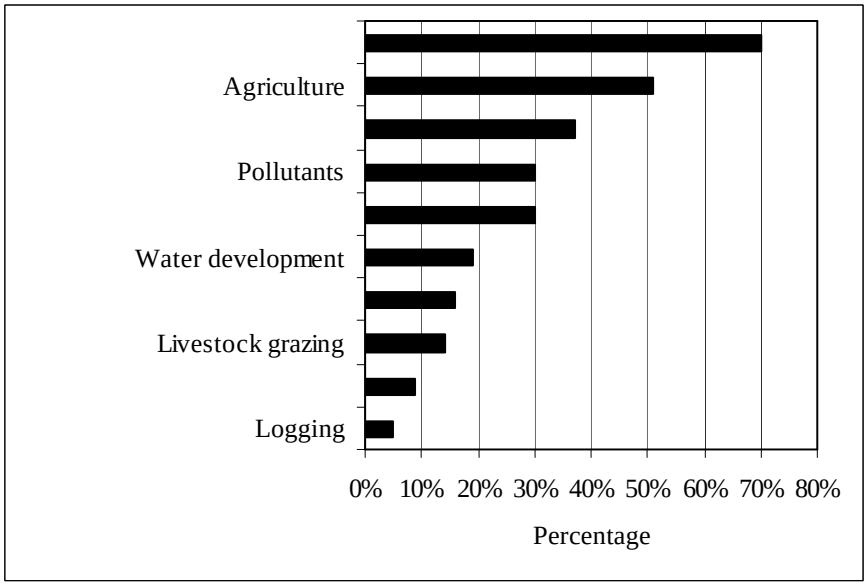

Figure 3. The percentage of the 43 U.S. federally listed threatened and endangered insect species affected by different causes of habitat destruction or degradation, as of December 2001. It is important to note that the habitats of most listed species are being degraded by more than one cause. (Bar graph format modified from B. A. Stein, L. S. Kutner, and J. A. Adams, (Eds.) *Precious Heritage: The Status of Biodiversity in the United States*, Oxford University Press, New York, NY, 2000. Data modified from D. S. Wilcove, D. Rothstein, J. Dubow, A. Phillips, and E. Losos, 1998, Quantifying threats to imperiled species in the United States, *Bioscience*, 48(8):607-615).

development in the southeastern United States and California have had particularly strong impacts on native insects because of the high rates of insect endemism where these cities were built. The best-known case is that of San Francisco, California, which now almost entirely covers what was once one of the major coastal dune ecosystems in western North America. Three dune butterflies, which were endemic to this region, are now extinct: *Cercyonis sthenele sthenele; Glaucopsyche xerces* (Fig. 1)*;* and *Plebeius icarioides pheres*. Three other butterflies, *Speyeria callippe callippe, Callophrys mossi bayensis,* and *Plebeius icarioides missionensis*, are now limited to the San Bruno Mountains just south of San Francisco, the last remnant of the San Francisco hills ecosystem.

Conversion of natural habitats for agriculture, particularly for planted food and fiber crops (e.g. cotton), is one of the most extensive land uses and, according to Robert Pyle (a noted lepidopterist and author), has resulted in the greatest loss of native insect populations. The most serious losses of endemic insects to agricultural conversion have taken place in the tropics, but because of the lack of knowledge of insects in these regions, it is impossible to know the extent of this destruction.

Dams and other water development are implicated in the decline of 21% of federally listed insect species. Impoundments destroy habitat for native aquatic organisms, such as stoneflies, as well as some terrestrial insects. For example, the damming of the Columbia River in Oregon and Washington resulted in the destruction of much of the sand bar habitat of the tiger beetle, *Cicindela columbica*.

Although we have no numbers, insects most likely are lost to large-scale timber management. Studies have shown that there is higher invertebrate diversity, as well as endemism, in late successional forests than in younger stands, and less than 10% of U.S. native forests remain intact. Widespread use of off road vehicles also threatens some species. For example, vehicles have crushed the larval burrows of the tiger beetle, *Cicindela dorsalis,* along beaches to such an extent that this once widespread, abundant species has been eliminated throughout most of its range. Wetland draining also has taken its toll. The draining of fens in England caused the extirpation of the butterfly *Lycaena dispar* in 1851 and possibly other insects as well. Capping of springs led to the loss of the fritillary butterfly, *Speyeria nokomis coerulescens*, in the U.S. portion of its range.

The biggest unknown is, of course, the loss of tropical rainforest. Tropical rain forests may hold the majority of terrestrial insect diversity and are being converted to agriculture and other uses at an alarming rate. As rainforests around the world are clearcut, insects are bound to go with them.

B. Alien Species

The introduction of various exotic organisms (whether intentional or not) has affected native insects, both directly and indirectly. For example, introduced plants may out compete native plants and, thus, lead to the loss of insect host plants or habitat. Introduced plant diseases also can wreak havoc on insect populations. A classic example involves the American chestnut. Mature examples of the tree disappeared throughout its range following the accidental introduction of chestnut blight. At least five micro-lepidopterans, including the chestnut borer, *Synanthedon castaneae*, are believed to have gone extinct because of the loss of their host plant. Some aquatic insect species are restricted to small mountain lakes in the U.S. and have been impacted by introductions of non-native fish. On the Island of Oahu, a species of *Megalagrion* damselfly is uniformly absent in stream reaches where non-native mosquitofish in the family Poeciliidae have been introduced.

Intentional introductions of insects also many harm native insects. Over the past 50 years, non-native insects often have been released to control non-native pest insects. Although the damage to non-target, native insects from these biological controls are rarely documented, some evidence is surfacing that it may be significant. For example, a parasitoid fly, *Compsilura concinnata*, that was released repeatedly in North America from 1906 to 1986 as a biological control against several pests, including the introduced gypsy moth, is implicated in the declines of four species of giant silk moths (Lepidoptera: Saturniidae) in New England. Another study in Hawaii found that 83% of parasitoids reared from native moths were former biological control agents.

C. Over Collecting

Although over collecting has not been shown to harm healthy populations of insects, it may be an important threat to insect species with very small populations and is included in the list of threats to many of the federally protected insect species in the U.S.. The Endangered Species Act expressly forbids the collection of endangered or threatened species, and most insect conservationists feel that collecting from small populations only should be done for well-designed, hypothesis-driven, scientific studies. It is not too much to ask that scientists rise to this standard when studying populations that are at risk.

D. Other Potential Threats

Pesticides and other pollutants are implicated in the decline of many native bees and some aquatic insects, although the degree of impact is not conclusive. Lights along streets and highways also have been implicated in losses of nocturnal insects, particularly large moths. Finally, even though we cannot specify the exact effects of climate change at this time, it could lead to endangerment of endemic insects with specific, narrow habitat requirements. A changing climate may be especially detrimental to species that cannot disperse, like the Uncompahgre fritillary butterfly (*Boloria improba acrocnema*), which is restricted to high mountain slopes in southern Colorado.

V. WHAT SHOULD BE DONE TO PROTECT AT-RISK INSECT SPECIES?

Conservationists have concluded that the current, widespread destruction of the earth's biodiversity must be matched by a conservation response an order of magnitude greater than currently exists.

A. Protecting Habitat

Ultimately, to protect any species one must protect its habitat. Some insects need only small areas to thrive, and even backyard gardens may help some pollinator insects. Large swaths of land set aside as reserves, wilderness, national parks, and conservation easements ultimately may benefit insects and other invertebrates. Recent evidence, however, shows that some reserves, with management plans tailored to vertebrates, do little to protect insects such as butterflies.

One important caveat for setting aside land for insects is that species often have subtle habitat requirements and can be lost even from reserves because of apparently minor habitat changes. For example, larvae of the large blue butterfly (*Maculinea arion*) are obligate parasites of red ant colonies (*Myrmica sabuleti*). In 1979, this butterfly went extinct in England because plant communities were not managed for these red ants. The large blue subsequently has been reintroduced successfully to appropriately managed sites in England using a subspecies from Sweden.

B. Federal Laws and Legislative Efforts

Federal legislation is vital to the protection of endan-

gered insects. In the U.S., the formal listing of species as threatened or endangered under federal or state endangered species legislation has been an extremely effective habitat protection tool because (1) these species are protected by law and (2) money is allocated for recovery efforts. In addition to this protection, a listing as “sensitive” or “indicator species” under U.S. Forest Service National Forest Management Act regulations, or even a formal listing from nongovernmental organizations such as IUCN and the Natural Heritage Program, raises visibility and an awareness of these species. This increased attention may lead to the stricter legal protection of a federal listing under the U.S. Endangered Species Act.

Other countries also have legislative efforts to protect insects and other invertebrates. In 1986, the Committee of Ministers of the Council of Europe adopted a charter favoring the protection of invertebrates. This charter has raised awareness to the plight of endangered invertebrates and, in some cases, led to habitat protection. For most developing countries in the world, protective legislation for insects is either lacking or only sporadically applied. One exception is Papua New Guinea where there is legislation, as well as a management program, that protects the rarest birdwing butterflies, allows only citizens to sell native insects, and protects some insect habitat.

C. Research

Before we can work to protect insects and other invertebrates we need to know, at least, what species are present, if populations are stable or declining, and the habitat needs of these populations. In the long run, more emphasis needs to be placed on invertebrate survey, systematics, taxonomy, and population ecology so that these species can be identified, cataloged, and their life histories understood. Research needs to go hand in hand with conservation, for there is little use for a catalog of extinct species.

D. Insects as Commodities

Conservation-based ranching of butterflies and other charismatic insects, like scarabs, can protect and conserve critical habitat for threatened species where the appropriate tropical forests remain intact and where live insect export is legal. The tropical forests of Central and Latin America, the Philippines, Madagascar, Kenya, Malaysian Borneo, Jamaica, and Indonesian Irian Jaya meet these criteria. These ranches not only offer protection to these charismatic insects and their habitat, but also serve as a sustainable means of economic development.

We differentiate between butterfly farming and ranching. According to Convention on International Trade in Endangered Species (CITES) "farming" operations are essentially closed systems, no longer dependent upon regular infusions of wild stock to produce successive generations in captivity. Ranching operations, on the other hand, are open-ended and depend upon a recurrent infusion of wild stock (such as by harvesting early instar larvae in the wild, and then growing them out in controlled environments). Using the 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.

F. Education

To conserve insects successfully, the general public, scientists, land managers, and conservationists need to understand the extraordinary value that these organisms provide. It is unlikely that very many people will develop an affinity for these animals, but it is plausible that a more compelling depiction of the contributions insects make to human welfare and survival will improve the public’s attitude toward these organisms. An ambitious public education program would enhance recognition of the positive values of invertebrates, and, indeed, all biological diversity.

VI. THE TIME IS NOW

The number of endangered insects is large and growing. The rate of destruction and degradation of natural habitats currently is so great that there are not nearly enough biologists to even catalog, much less study, the species that are suddenly on the edge of extinction. In Indonesia, approximately 1.3 million hectares of tropical forest were cut last year. In Argentina, 7,964 metric tons of insecticides were used in 1998. In the U.S., imported red fire ants have infested over 260 million acres in the southeast. These examples of threats to endangered insects continue to mount across the world. The time is now for agencies, scientists, conservationists, and land managers to promote the conservation of imperiled insects.

GLOSSARY

Critically endangered Synonymous with Endangered; designation used by the International Union for Conservation of Nature and Natural Resources (IUNC)

Critically imperiled Synonymous with Endangered; designation used by the U.S. Natural Heritage Program.

Endangered* Species that are facing a high risk of extinction in the near future unless action is taken to protect them; designation used by the U.S. Fish and Wildlife Service and IUNC.

Imperiled Synonymous with Threatened; designation used by the U.S. Natural Heritage Program.

Sensitive Species for which population viability is a concern; designation used by the United States Forest Service.

Threatened* Species that face a high risk of becoming endangered in the near future unless action is taken to protect them; designation used by the U.S. Fish and Wildlife Service and IUNC.

Vulnerable Facing a risk of extinction in the medium term future; designation used by the IUNC

***** A formal listing as endangered or threatened by the U. S. Fish and Wildlife Service is the only designation that provides legal protection to species that are at risk of extinction.

BIBLIOGRAPHY

Bean, J. M. 1993. Invertebrates and the Endangered Species Act. *Wings*, Summer. The Xerces Society.

Buchmann, S. L., and Nabhan, G. P. 1996. *The Forgotten Pollinators*. Island Press, Washington, D.C.

Collins, N. M. and Thomas, J. A. (Eds.) 1991. *The Conservation of Insects and Their Habitat*. Academic Press, London, England.

Deyrup, M. 2001. Endangered terrestrial invertebrates. In *Encyclopedia of Biodiversity*, Volume 2 (Simon A. Levin, Ed.). Academic Press, New York, NY..

Deyrup, M. and Eisner, T. 2001. Interviews at the edge of a cliff. *Wings*, Fall. The Xerces Society.

Hoffman Black, S.C., Shepherd M., and Mackey Allen, M.. 2001. Endangered invertebrates: the case for greater attention to invertebrate conservation. *Endangered Species Update.* 18: 41-49.

Kellert, S. R. 1993. Values and perceptions of invertebrates. *Conservation Biology* 7:845-855.

Opler, P. 1995. Conservation and management of butterfly diversity in North America. In *Ecology and Conservation of Butterflies* (A. S. Pullin Ed.). Chapman and Hall, London, England.

Pyle, R. M., Bentzien, M., and Opler, P. 1981. Insect conservation. *Annual Review of Entomology*. 26:233-258

Samways, M. J. 1994. *Insect Conservation Biology*. Chapman and Hall, London, England.

Stein, B. A., Kutner, L. S., and Adams, J. S. (Eds.) 2000. *Precious Heritage. The Status of biodiversity in the United States*. Oxford University Press, Oxford, England.

Wilson E. O. 1992. *The Diversity of Life*. W. W. Norton Company, Inc., New York, NY.