CRITICAL ISSUES IN CAVE BIOLOGY

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Abstract

I shall discuss the most critical issues in North American cave biology, particularly those related to conservation and cave management. The major impacts on cave life have been caused by water projects, land development, quarrying, killing and disturbing animals, sedimentation, contaminants, and nutrient loss and enrichment. Less obvious impacts are trampling, cave invasions by exotic and pest species, and isolation of caves by various activities.

The most dramatic declines in macroscopic cave faunas were caused by the direct disturbance and killing of bats and massive kills of stygobites from water projects, sewage, and chemicals. Perhaps six cave species became extinct as a result of human activities, but other extinctions may have occurred. Many species of bats, cavefishes, and crustaceans cannot be found in their historic sites today. The subtle and inexorable decline of some cave communities over decades may go unnoticed because of a lack of baseline surveys and systematic monitoring.

Although many plans have been written and 36 cave species are under federal protection, many other cave species are threatened by human activities. We are hampered by a lack of scientifically-trained manpower, the Taxonomic Crisis, the Vertebrate Bias, and pressure on caves by increasingly mobile trespassers, looters, and uninformed recreators. We need better baseline data and census methods, regional and national surveys, and cave protection methods. Bats and groundwater are the most critical biological issues, while jobs for cave biologists and taxonomists are probably the most critical related human-resource issues.

Introduction

In this paper I shall discuss the most critical issues in North American cave biology, which are echoed in many parts of the world (Elliott 2000, Hamilton-Smith and Eberhard 2000, Juberthie 2000, Tercafs 2001). Although theoretical issues in biospeleology are interesting and challenging, I shall focus more on conservation and applied cave management.

The Critical Issues

The critical issues in cave biology, which I shall elaborate below, are (1) threats to biodiversity, (2) pressure on caves and cave life, (3) the Taxonomic Crisis, (4) the Vertebrate Bias, (5) the need for better census methods, (6) insufficient work force of cave biologists, and (7) insufficient funding.

Threats to Biodiversity: Caves have many endemic troglobites and stygobites (obligate cave dwellers), and cave-dependent species, such as certain bats. Cave biologists are still finding new species and there is a huge backlog of undescribed species. The first endangered species ever listed in the USA was the stygobitic Texas blind salamander, *Typhlomolge rathbuni*, in 1967. In 2000 there were 25 listed cave species. In 2005, 36 (3%) of the 1,155 worldwide animals on the federal endangered and threatened list were cave dwellers, and all the listed cave species were from the USA. More cave forms are listed every few years; none have been "de-listed." The gray bat, a key species in eastern caves, is being considered for "down-listing" from endan-

gered to threatened because of success in restoring some of its cave roosts, but a lack of good census data delays the down-listing. New listings tend to occur with rare, endemic forms endangered by urbanization. However, the latest listing, Tumbling Creek cavesnail, in 2001, is a species that is nearly extinct, probably because of sedimentation from a neigboring farm (Elliott *et al*., 2005). Perhaps six cave species became extinct as a result of human activities, but other extinctions may have occurred (Table 1).

Pressure on caves and cave life: The major cave impacts were reviewed by Elliott (2000):

(1) hydrological threats, (2) land development, (3) killing, over-collecting, and disturbing bats and other species, (4) sedimentation and contaminants, and (5) nutrient loss and enrichment. Less obvious are impacts caused by (1) exotic and pest species, (2) trampling, (3) isolation of caves by quarrying, mining, and land development.

The Taxonomic Crisis. If we do not know our biodiversity, we cannot conserve its components well. There are not enough taxonomists to describe new-found species to keep ahead of habitat destruction. Many think of this taxonomic crisis as happening only in the tropics, but it is affecting our temperate-zone caves and other habitats.

Wheeler, Raven, and Wilson (2004), three famous names in biology, published an important editorial on "Taxonomy: Impediment or Expedient?," from which I quote:

> Society has a growing need for credible taxonomic information in order to allow us to conserve, manage, understand, and enjoy the natural world. At the same time, support for taxonomy and collections is failing to keep pace. Funds nominally allocated to taxonomy go largely to reconstruct molecular phylogenies, while thousands of species are threatened by imminent extinction. Ecologists working in the tropics have felt this lack of taxonomic knowledge as an impediment that inhibits their ability to analyze community-level phenomena. It is time to evaluate the sources of this impediment and address them. Taxonomy must facilitate, not obstruct, biodiversity studies and conservation.

Some funding is available for biodiversity and taxonomic studies, including the U.S. Fish and Wildlife Service and states for recovering listed species, State Wildlife Grants (federal funding), National Science Foundation grants for training taxonomists and bioinventory, The Nature Conservancy, the U.S. Department of Defense's Legacy Resource Management Program, and others. Since 2003 the Legacy Program has co-sponsored the publication of 18 new cave species described from two Army bases in Texas. Currently, taxonomy is being done less in academia and more by natural history museum taxonomists and free-lance taxonomists supported by small grants and contracts from public agencies and private foundations.

The National Science Foundation offers **PEET** grants (Partnerships for Enhancing Expertise in Taxonomy) to support competitively reviewed re-

Species	Last Year Seen	Threats	Range
Crustacea			
Bactrurus n.sp., amphipod	1963	sealed spring, pesticides	Indiana
Stygobromus lucifugus (= *subtilis*?), Dubious Cave amphipod	1882	?	Illinois
Orconectes sheltae, Shelta Cave crayfish	1988	loss of nutrients	Alabama
Insecta			
Pseudanophthalmus krameri, Kramer's cave beetle	1973	?	Ohio
Amphibia			
Eurycea robusta, Blanco blind salamander	1948	hydrologic changes?	Texas
Eurycea troglodytes, Valdina Farms Sinkhole salamander	1985	recharge dam	Texas

Table 1. Possibly extinct troglobites in the USA.

search projects that target groups of poorly known organisms. This effort is designed to encourage the training of new taxonomists and to translate current expertise into electronic databases and other formats with broad accessibility to the scientific community. For example, some funding has been used for taxonomic work on millipedes (Milli-PEET project) and amphipods. In the USA, four new professional systematists (taxonomists) are working on these groups, but only about half of the graduate students who entered these programs are still working taxonomists; the others shifted fields to more lucrative positions.

National Science Foundation's grant program, **Biodiversity and Inventory**, is not sufficiently funded for the number of qualified applicants. An important proposal for cave biology work in eight Appalachian states, involving a group of cave biologists and invertebrate taxonomists, was rejected twice, despite favor from state Natural Heritage programs (John Holsinger, pers comm).

Many invertebrate taxa have few or no taxonomists, and American cave biologists increasingly seek collaboration with scattered experts worldwide. Examples of taxa with few taxonomists are:

Platyhelminthes (flatworms), primitive insects (springtails, diplurans), Orthoptera (crickets), Chilopoda (centipedes), Diplopoda (millipedes), Arachnida (spiders, mites, scorpions, pseudoscorpions, and the like), and many crustacean groups.

The Vertebrate bias: The Taxonomic Crisis is supported in part by the Vertebrate Bias. Federal and state agencies have spent more on studying and protecting vertebrates, like bats and cavefishes, than on invertebrates. Thirty years ago the U.S. Fish and Wildlife Service was reluctant to list cave invertebrates. Now cave and spring species are among the most prominent invertebrates on the list because of their high endemism and vulnerability (Figure 1).

The Vertebrate Bias is obvious to biologists like me, who were trained in entomology, arachnology, invertebrates, and vertebrates. This bias is the unfortunate tendency by some to show more interest in the conservation of vertebrates, especially mammals and birds, than of invertebrates. The basis for the Vertebrate Bias bias is partly educational, partly aesthetic, and sometimes is based on the false assumption that ecological importance is related to body size or relatedness to humans. Probably 99% of animal species, and thus much of the web of life,

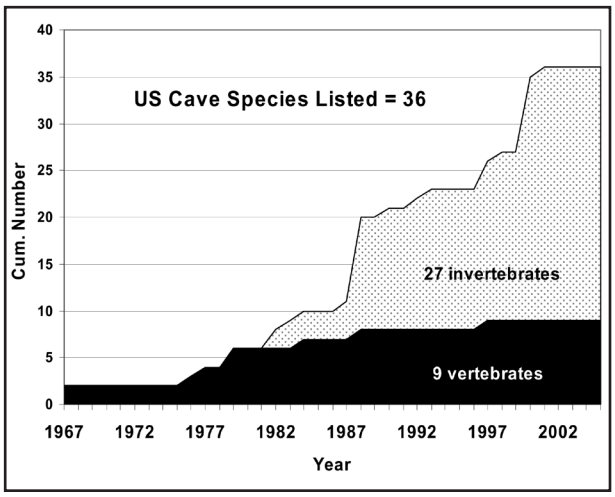

Figure 1. Comparison of endangered species listings of cave vertebrates and invertebrates.

are invertebrates, but we too often concentrate our conservation efforts on vertebrates. Native plants get even less respect.

The Vertebrate Bias appears to be declining in the listing process for endangered species, but the funding of wildlife preserves is still vertebrate-oriented (Elliott 2000, Figure 1). Nine cave-adapted vertebrates (not including bats) have been listed since 1967, none since 1997. Cave invertebrates were listed starting in 1982, and continue to be listed until now we have 27. This increase is despite a recent trend to toughen listing requirements and require more scientific documentation before listing, which indicates a real environmental crisis developing.

In the late 1970s many government biologists were old-school "wildlifers" with a strong vertebrate bias, in my opinion. I worked in California under a contract for the U.S. Army Corps of Engineers to rescue a tiny species of cave harvestman, *Banksula melones*, from extinction, thought to be imminent from quarrying and the newly constructed New Melones Reservoir (Elliott 1978, 2000). The Corps wanted to avoid a listing of this arachnid. A representative of the U.S. Fish and Wildlife Service was quoted in the press as saying that listing a "spider" was not worth the Endangered Species Act. (This statement was doubly ignorant because harvestmen are not spiders, but they are arachnids. His gaffe was as unschooled as calling a bat a rodent.) However, by 1988 six cave invertebrates were listed from the Austin, Texas, area, and soon nine more cave invertebrates were listed from the San Antonio, Texas, area. These listings were ini-

tiated by concerned conservationists, cavers and speleologists, and they were not resisted by the U.S. Fish and Wildlife Service (Elliott 1978, 2000). In 2002 the Tumbling Creek cavesnail was listed from Missouri, and this time the process was initiated by a Fish and Wildlife Service scientist (McKenzie 2001).

The need for better census methods: Baseline cave biology surveys are needed to assess impacts on caves and their wildlife. We also need bioinventories led by professional cave biologists, bat surveys using improved census methods, cave life databases, heritage databases and state cave surveys that collaborate with qualified researchers, cavers and conservation planners. In this Symposium, see Elliott *et al*. for a paper on the "Missouri Department of Conservation Method" for counting bat emergences from caves, page 147, (also see Elliott 2005). We need new technology and reliable methods, with statistical estimates, to monitor population trends in cave species, especially bats, which may be keystone species in providing nutrients to cave communities. If we are having success in restoring and stabilizing gray bats, we need at least five years of good data before the U.S. Fish and Wildlife Service can make a case for down-listing them from endangered to threatened status (Paul McKenzie, pers comm). Censusing cavefishes and invertebrates is difficult because of limited access and low numbers; we wish for better technology to solve this problem, such as down-hole video cameras, small sensors and data loggers, and cheap, reliable photography.

Insufficient work force of cave biologists: Currently we have a fair number of young bat biologists in the marketplace, who are needed in universities, environmental consulting, wildlife agencies, nonprofit conservation groups, and other organizations. However, we have relatively few young cave biologists because of the few jobs. Academic cave biologists must do a variety of teaching and research tasks, and their jobs usually are not billed as "cave biologists." We still have many undescribed invertebrate cave species, but few young biologists are being trained in invertebrate taxonomy so they can identify or describe them. Federal and state land resource agencies hire bat biologists and cave specialists, but few full-time cave biology jobs have been created. However, such agencies need cave biologists for applied research and resource management. In the last 20 years a small number of consulting cave biologists have gone into business, but it is difficult to make a living from sporadic projects. We need more federal and state emphasis on hiring cave biologists, not just cave specialists and bat biologists.

Insufficient funding: Low funding for cave biology is apparent in the problems outlined above. Funding is adequate for some projects, ironically at some military bases. About $1 million has been spent over 12 years to find and research caves and cave fauna at two Army bases in Texas (George Veni, pers comm). I participated in this work (Elliott 2004). There is an ironic trend in the USA, that military bases are now some of the last bastions of endangered species, simply because they are often the only remaining large tracts of wild land in many regions. Despite the fact that they may be used for infantry training grounds, small arms fire, tank fire, artillery, and bombing ranges, somehow endangered species like the black-capped vireo and certain cave beetles survive there. Perhaps urbanization is more damaging to our natural heritage than soldiers. We know more about cave fauna on some Army posts than on many national forests, conservation areas, and private lands.

Final Thoughts

We need regional and national biogeographic research, biodiversity analyses of caves, and rating of caves for multiple natural resources and threats against them. General cave biology and cave microbiology would be part of the whole mix. Wildlife agencies put more emphasis on biological resources, but they can work with other organizations to consider all cave resources. For example, the Missouri Cave Protection Working Group is using a spreadsheet method for rating caves for protection based on multiple resources.

Cave protection methods are increasingly sought by landowners and managers. In Missouri and other states, cave owners are increasingly asking for assistance to protect, restore, and gate caves (Elliott 2004b). A demographic change is occurring as baby-boomers retire and buy land; many of them are more conservation-minded than the previous generation.

Cave microbiology may or may not be a useful indicator of human impacts on a cave because

(1) many caves are already well traveled, have surface organic inputs, or are contaminated, (2) many caves have endemic cave animals, but few known, unusual, or endemic cave microbes, (3) cave microbes cannot be seen or identified by most cave visitors, and (4) no cave microbes are protected by law (yet).

Many cave animals are vulnerable to overuse, disturbance, pollution, and the like. Cave microbes may or may not be so sensitive. However, certain telltale microbes are useful for gauging visitation rates by humans and as indicators of pollution.

Bats and groundwater are highly critical biological issues. Bats have high economic and ecological value because they consume night-flying insects, some of which are pests. Corn earworm moths are consumed by several species of bats, most notably the Mexican free-tail. About half of the 42 species of U.S. bats use caves during their life history. In major karst areas, like the Edwards Aquifer of central Texas, the Ozarks, the Appalachians, and the Interior Lowland Plateaus of Kentucky and Tennessee, karst groundwater resources have major economic and health importance (even for those uninterested in caves *per se*). Bats and groundwater are also critical to the health of cave ecosystems.

In the final analysis, jobs for cave biologists and taxonomists probably are the most critical human-resource issues related to the problems discussed above. Important as they are, only so much work can be accomplished by volunteers and generalists. A scientifically trained, professional work force is needed to carry out the biological work that needs to be done.

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