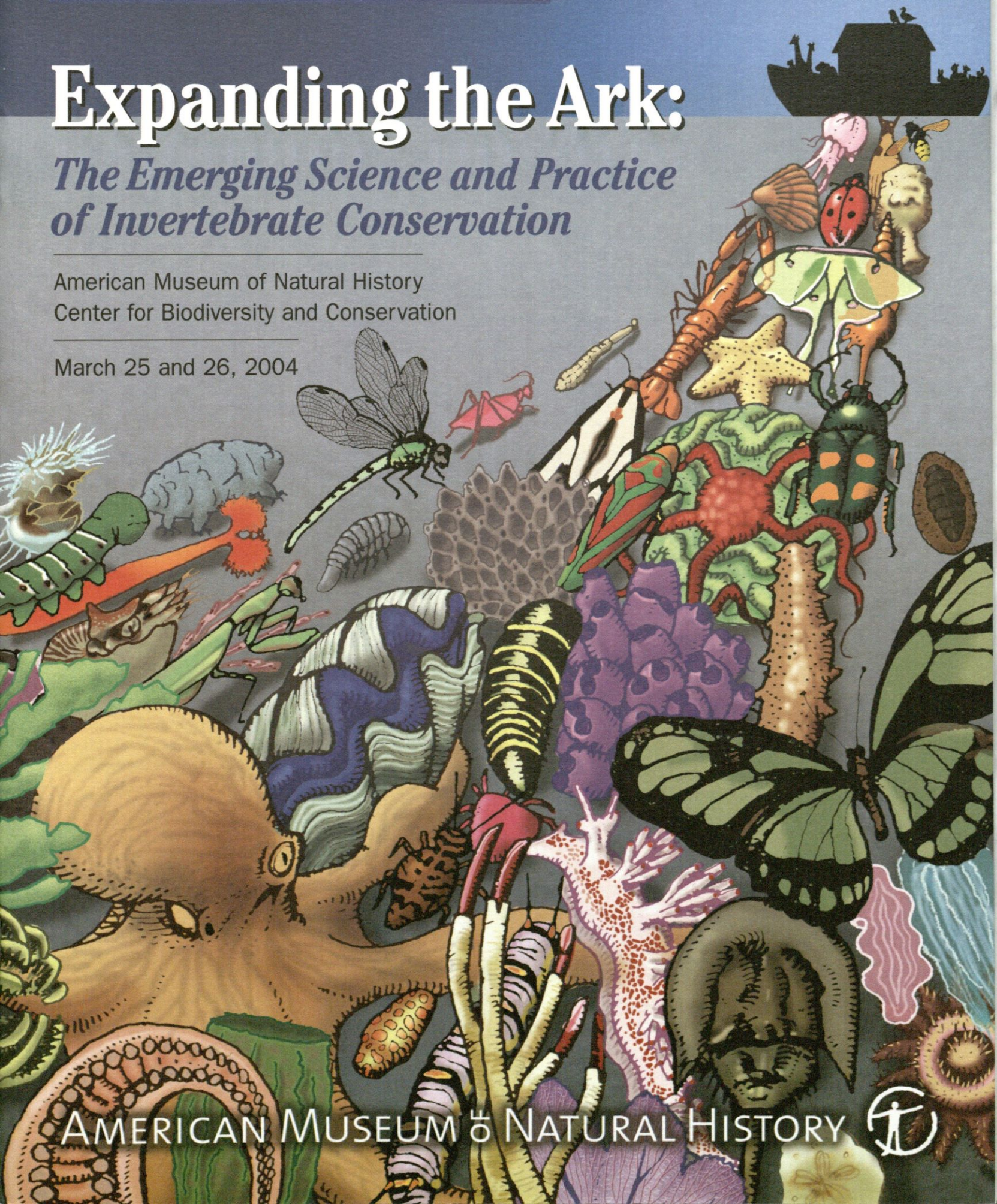
SPRING SYMPOSIUM

Expanding the Ark:

The Emerging Science and Practice of Invertebrate Conservation

American Museum of Natural History
Center for Biodiversity and Conservation

March 25 and 26, 2004



AMERICAN MUSEUM OF NATURAL HISTORY

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For their significant role in shaping the form and content of this symposium we especially wish to thank the members of the symposium steering committee, Dan Ashe, Scott Hoffman Black, Dan Brumbaugh, Jonathan Coddington, Rosemarie Gnam, Elizabeth Johnson, Larry Master, Scott Miller, Piotr Naskrecki, Mike Soukup, Eleanor Sterling, and David Wagner.

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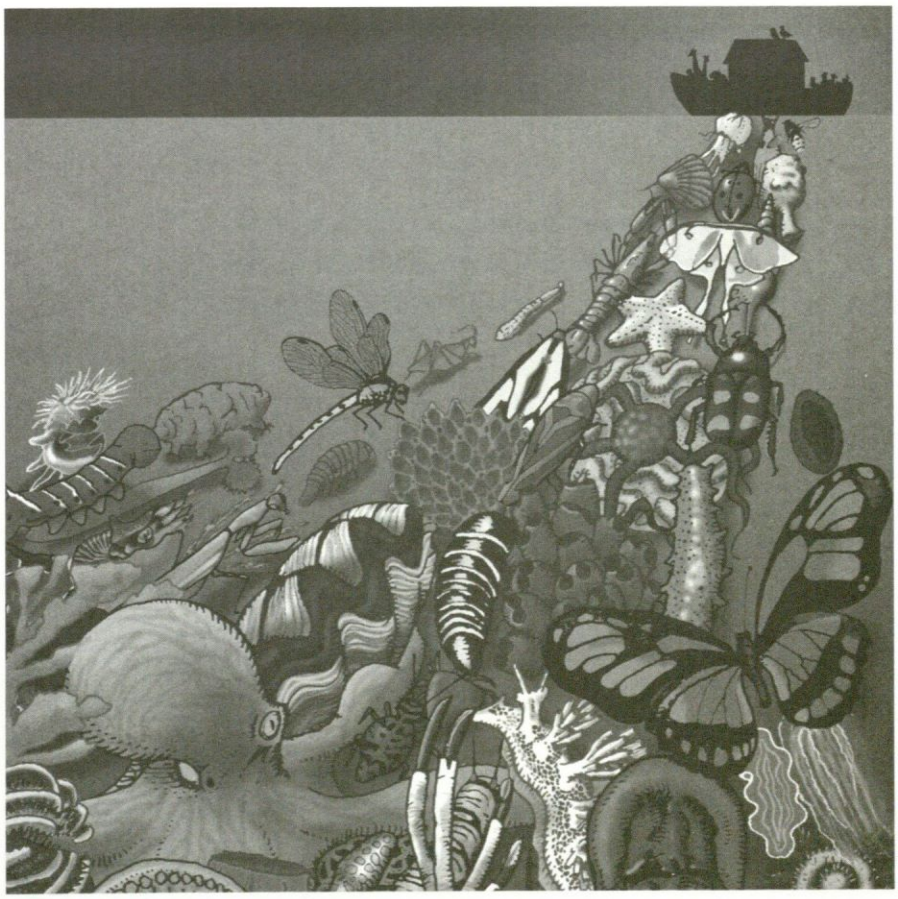

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EXPANDING THE ARK: THE EMERGING SCIENCE AND PRACTICE OF INVERTEBRATE CONSERVATION

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American Museum of Natural History

EXPANDING THE ARK: THE EMERGING SCIENCE AND PRACTICE OF INVERTEBRATE CONSERVATION

SPRING SYMPOSIUM

Identifying, conserving, and managing invertebrate biodiversity is one of the greatest challenges facing the conservation community today. Widespread threats to invertebrate biodiversity, such as habitat loss, introduced species, overexploitation, and pollution are rapidly driving many invertebrate species to the edge of extinction. In the U.S. the three most endangered groups of organisms — freshwater mussels, crayfish, and stoneflies — are all invertebrates. Almost 70% of all freshwater mussel species are in need of conservation measures, compared to just 16% of mammals and 14% of bird species. The imperilment of invertebrates is not solely a crisis in the U.S. — some 22% of Austria's invertebrates are considered threatened or endangered, as are almost 1,600 species of Britain's insect fauna. And in most other countries, we can as yet only speculate on the numbers of invertebrates at risk.

Invertebrates constitute the vast bulk of biodiversity on Earth and dominate virtually every global ecosystem in terms of species richness and ecological function. Invertebrates are pervasive elements of every food chain, as herbivores, predators, parasites, and decomposers. They are food for mammals, birds, fish, reptiles, and other invertebrates. Ecosystem services provided by invertebrates — such as pollination, soil creation and aeration, decomposition, and seed dispersal — are estimated to be worth trillions of dollars to the global economy each year.

Despite the importance and diversity of invertebrates, these poorly described and misunderstood animals are disproportionately absent from the majority of conservation planning and management strategies. Efforts to conserve invertebrates are also seriously hampered by a lack of public understanding of the positive values of invertebrate biodiversity.

But the tide may be turning. In the past decade, invertebrate conservation has emerged as an exciting component of the broader conservation world. Information technology is making it more feasible than ever to keep track of the incredible diversity of invertebrates. New scientific journals now showcase research that explores the needs of invertebrates and challenges the assumptions that conservation strategies designed for endangered megafauna or plants is sufficient to assure the persistence of the "other 99%" of biodiversity. New organizations and programs around the world are spreading the word of invertebrates' importance and providing the public with ways to lighten our impact on our spineless neighbors.

The American Museum of Natural History's Center for Biodiversity and Conservation, in collaboration with Conservation International, the National Park Service, NatureServe, the U.S. Fish and Wildlife Service, and the Xerces Society, has convened this symposium to examine the status of invertebrate biodiversity and our progress toward conserving it. Participants from around the world will consider a broad range of perspectives on how best to advance an invertebrate conservation agenda. *Expanding the Ark* provides a venue for engaging the scientific community, conservation practitioners, policy makers, and the public in a dialogue on the fate of invertebrate biodiversity, and to map concrete approaches for future action.

DAY ONE March 25, 2004
DEVELOPING AN INVERTEBRATE AGENDA: CONSERVATION STATUS, THREATS, AND SCIENCE TOOLS

8:50 am–12:50 pm **SESSION I: PLENARY REPORTS ON INVERTEBRATE CONSERVATION**

Introductory Remarks
MICHAEL J. NOVACEK, *Senior Vice President and Provost of Science, American Museum of Natural History*

ELLEN V. FUTTER, *President, American Museum of Natural History*

Moderator: **SACHA SPECTOR**, *Manager, Invertebrate Conservation Program, Center for Biodiversity and Conservation, American Museum of Natural History*

Plenary: The Importance of Invertebrate Biodiversity
CLAIRE KREMEN, *Assistant Professor, Department of Ecology and Evolutionary Biology, Princeton University*

Plenary: Toward a Conservation Agenda for Terrestrial Invertebrates
TIM R. NEW, *Reader/Associate Professor, Department of Zoology, La Trobe University, Australia*

Plenary: Hidden Diversity: Invertebrates in Caves
DAVID C. CULVER, *Professor of Biology, American University*

Break (20 minutes)

Plenary: Overview and Status of Freshwater Invertebrates
DAVID STRAYER, *Freshwater Ecologist, Institute of Ecosystem Studies, Millbrook, NY*

Plenary: Habitat Destruction and Ecological Extinction of Marine Invertebrates
JEREMY B.C. JACKSON,
William and Mary B. Ritter Professor of Oceanography, Scripps Institution of Oceanography, University of California, San Diego

Panel Discussion **(CULVER, JACKSON, KREMEN, NEW, STRAYER)**

Lunch Break

2:10–3:40 pm **SESSION II: THREATS TO INVERTEBRATE BIODIVERSITY**

Moderator: **DAMAYANTI BUCHORI,** *Conservation Entomologist, Department of Pest and Plant Diseases, Bogor Agricultural University, Indonesia*

400 Million Years on Six Legs: The Evolutionary Success of Insects and Their Modern Challenges
DAVID GRIMALDI, *Curator of Invertebrate Zoology, American Museum of Natural History*
and
ROBERT R. DUNN, *Fulbright Postdoctoral Fellow, Department of Environmental Biology, Curtin University of Technology, Australia*

Pesticides As Threats to Biodiversity and Ecosystem Function
PETER G. KEVAN, *Professor, Departments of Environmental Biology and Botany, University of Guelph, Ontario*

Aliens From "Out of Place!" Managing Illegal Aliens on an Expanding Ark—Without Rocking the Boat
GEORGE BOETTNER, *Department of Entomology, University of Massachusetts-Amherst*

Panel Discussion **(BOETTNER, GRIMALDI, KEVAN)**

Break (20 minutes)

4:00-
6:00 pm

SESSION III: ASSESSING INVERTEBRATE BIODIVERSITY—BARRIERS, BOTTLENECKS, AND SOLUTIONS

Moderator: **ELIZABETH JOHNSON,** *Metropolitan Biodiversity Program Manager, Center for Biodiversity and Conservation, American Museum of Natural History*

Addressing the Needs for Identification of Invertebrates in Conservation Practices
PIOTR NASKRECKI, *Director, Invertebrate Diversity Initiative, Conservation International*

A New Century Dawns on Invertebrate Surveys: Lessons From 20 Years of Terrestrial Invertebrate Surveys
SCOTT E. MILLER, *Senior Biodiversity Advisor to the Director, National Museum of Natural History, Smithsonian Institution* and
JONATHAN A. CODDINGTON, *Research Entomologist, Department of Systematic Biology, Smithsonian Institution*

Effective Inventory of Cryptic Marine Invertebrates: RAP versus TAP
PAULA M. MIKKELSEN, *Assistant Curator, Division of Invertebrate Zoology, American Museum of Natural History* and
RÜDIGER BIELER, *Associate Curator, Department of Zoology, Field Museum*

Are Invertebrate Focal Taxa Fulfilling Their Promise?
SACHA SPECTOR, *Manager, Invertebrate Conservation Program, Center for Biodiversity and Conservation, American Museum of Natural History*

Keeping Tabs on the Little Things That Run the World: Information Management for the Conservation of Invertebrates
LAWRENCE L. MASTER, *Chief Zoologist, NatureServe*

Bioinformatics and Invertebrate Monitoring: Applications of the National Biological Information Infrastructure (NBII)
MICHAEL RUGGIERO, *Director, Integrated Taxonomic Information System, U.S. Geological Survey, Smithsonian Institution/NMNH, Washington, D.C.*

Conservation of Invertebrates in England, Using Beetles as an Example—A Partnership of Agency, Academic and Amateur
ROGER S. KEY, *Senior Invertebrate Ecologist, Terrestrial Wildlife Team, English Nature*

Monitoring Freshwater Invertebrates: Identifying Patterns of Biodiversity and Taxa at Risk by Mining Water Resource Agency Data
CHARLES P. HAWKINS, *Director, Western Center for Monitoring and Assessment of Freshwater Ecosystems, Utah State University*

6:00-
8:00 pm

POSTER SESSION AND RECEPTION

DAY TWO March 26, 2004
INTEGRATING SCIENCE, MANAGEMENT, POLICY, AND EDUCATION

8:50 am–11:10 am **SESSION IV: DESIGNING EFFECTIVE MANAGEMENT APPROACHES FOR INVERTEBRATES**

Introductory Remarks
ELEANOR J. STERLING, *Director, Center for Biodiversity and Conservation, American Museum of Natural History*

Moderator: **DAN ASHE,** *Science Advisor to the Director, U.S. Fish and Wildlife Service*

Plenary: Landscape Triage: Strategies for Managing Invertebrates
MICHAEL J. SAMWAYS, *Professor and Chair, Department of Entomology and Nematology, University of Stellenbosch, South Africa*

Multi-Species, Regional Habitat Conservation Planning and the Conservation of Listed Invertebrates Under the Endangered Species Act
JIM A. BARTEL, *Field Supervisor, Carlsbad Office, U.S. Fish and Wildlife Service*

Design Elements of Marine Protected Areas: The Necessary Ingredients for Success
GARY E. DAVIS, *Visiting Chief Scientist, Ocean Programs, U.S. National Park Service*

Lines on the Water: Ocean Use Planning and Zoning
JOHN C. OGDEN, *Director, Florida Institute of Oceanography, and Professor of Biology, University of South Florida* and
ELLIOTT A. NORSE, *President, Marine Conservation Biology Institute*

Insect Conservation in Changing Landscape: The Role of Agro-Ecosystem in Maintaining Insect Diversity
DAMAYANTI BUCHORI, *Conservation Entomologist, Department of Pest and Plant Diseases, Bogor Agricultural University, Indonesia*

Managing Vector-Borne Diseases so as to Minimize Negative Effects on Non-Target Invertebrates
HOWARD S. GINSBERG, *Ecologist, USGS Patuxent Wildlife Research Center, and Unit Leader, Patuxent Coastal Field Station, University of Rhode Island*

Panel Discussion **(BARTEL, BUCHORI, DAVIS, GINSBERG, OGDEN, SAMWAYS)**

Break (20 minutes)

11:30 am–12:50 pm **SESSION V: CHALLENGES FOR MANAGING DISTURBANCE REGIMES AND INVERTEBRATE SPECIES**

Panel Moderator: **DAVID L. WAGNER,** *Associate Professor, Department of Ecology and Evolutionary Biology, University of Connecticut*

The Persistence of Marine Reserves in the Face of Catastrophes
STEVEN GAINES, *Director, Marine Science Institute, University of California at Santa Barbara*

Sink or Swim: The Challenges of Conserving Freshwater Invertebrates in a World of Regulated Rivers
GEORGE E. SCHULER, *Director, Upper Delaware Program (NY), The Nature Conservancy*

The Role of Fire in Managing Habitat for At-Risk Invertebrates
CHERYL B. SCHULTZ, *Assistant Professor, School of Biological Sciences, Washington State University*

Karner Blue Butterfly Habitat Management Considerations at Necedah National Wildlife Refuge
RICHARD KING, *Staff Biologist, Necedah National Wildlife Refuge, Wisconsin*

Panel Discussion **(GAINES, KING, SCHULER, SCHULTZ)**

Lunch Break

2:10-3:15 pm **SESSION VI: ENDANGERED AND THREATENED INVERTEBRATES**

Moderator: **MACE VAUGHAN,** *Staff Entomologist, Xerces Society*

Invertebrates and the Endangered Species Act—An Assessment of Thirty Years Protecting the Spineless
SCOTT HOFFMAN BLACK, *Executive Director, Xerces Society*

Conservation and Recovery of Native Invertebrates Under the Endangered Species Act
GARY FRAZER, *Assistant Director for Endangered Species, U.S. Fish and Wildlife Service*

IUCN Red List Approaches and Criteria for Invertebrates
MARY SEDDON, *Section Head, Department of Biodiversity and Systematic Biology, National Museums and Galleries of Wales*

Panel Discussion **(BLACK, FRAZER, SEDDON)**

Break (20 minutes)

3:35-4:35 pm **SESSION VII: COMMERCIAL HARVEST MANAGEMENT**

Moderator: **ROSEMARIE GNAM** *Assistant Director, Center for Biodiversity and Conservation, American Museum of Natural History*

Protecting Marine Invertebrates and Building Oceanic Arks (Marine Reserves) >Maximizing Yield Sustaining Use
JACK A. SOBEL, *Director, Strategic Conservation Science and Policy, The Ocean Conservancy*

An Overview of U.S. Invertebrate Trade Data
LAURA NOGUCHI, *Biologist, International Affairs, U.S. Fish and Wildlife Service* and **ANNE ST. JOHN,** *Biologist, Division of Management Authority for CITES, U.S. Fish and Wildlife Service*

Beyond Butterflies: Insect Farming Expands to Serve Growing Foreign Markets
STEVE PRCHAL, *Founder and Director, Sonoran Arthropod Studies Institute*

Panel Discussion **(NOGUCHI, PRCHAL, SOBEL, ST. JOHN)**

4:35-5:35 pm **SESSION VIII: BUILDING PUBLIC SUPPORT FOR INVERTEBRATE CONSERVATION**
A PANEL DISCUSSION

Panelists
MAY BERENBAUM, *Head, Department of Entomology, University of Illinois*

DAMAYANTI BUCHORI, *Conservation Entomologist, Department of Pest and Plant Diseases, Bogor Agricultural University, Indonesia*

THOMAS EISNER, *Director, Cornell Institute for Research in Chemical Ecology, Cornell University*

ROBERT MICHAEL PYLE, *Founder, Xerces Society*

STEVEN K. WEBSTER, *Senior Marine Biologist, Monterey Bay Aquarium*

CONCLUDING REMARKS

Jim A. Bartel
Field Supervisor, U.S. Fish and Wildlife Service, Carlsbad, CA

Multi-Species, Regional Habitat Conservation Planning and the Conservation of Listed Invertebrates under the Endangered Species Act

With the listing under the Endangered Species Act (ESA) of the Delhi Sands flower-loving fly in 1993, Quino checkerspot butterfly in 1997, and various freshwater crustaceans in the mid-1990s, the challenges and often unique issues surrounding invertebrates became evident to the state agencies and local governments embarking on multi-species, regional habitat conservation planning (HCPs) in southern California. Under section 10(a)(1)(B) of the ESA and the State of California's Natural Community Conservation Planning Act of 2001 (NCCP), state agencies and local governments can be authorized to incidental take federally and state listed wildlife resulting from urban development on a multi-species, regional scale with the U.S. Fish and Wildlife Service's and California Department of Fish and Game's approval of a similarly scaled HCP and NCCP. Focusing on the proposed Western Riverside County Multiple Species Conservation Plan in Riverside County and the failed efforts to date in adjoining San Bernardino County, the biology of the Delhi Sands flower-loving fly and Quino checkerspot butterfly, and local politics and economics have significantly affected and largely determined the fate of these multi-species, regional habitat conservation planning efforts within the Inland Empire of southern California.

May R. Berenbaum
Swanlund Chair, Department of Entomology, University of Illinois at Urbana-Champaign

Panelist, Session VIII: Building Public Support for Invertebrate Conservation

Scott Hoffman Black
Executive Director, Xerces Society

Invertebrates and the Endangered Species Act—An Assessment of 30 Years Protecting The Spineless

What do the Kentucky cave shrimp, Delhi Sands flower-loving fly, Karner blue butterfly, and the Bruneau hotspring snail have in common? They are all invertebrates that are listed under the U.S. Endangered Species Act (ESA). The ESA is one of the United States' most important wildlife protection laws. This talk will review how effectively the ESA has protected invertebrates over its thirty-year history. The topics covered will include a look back at the first listings of invertebrates and the amendment to the ESA that allowed preferential treatment for vertebrates. The listing, recovery, and funding disparity between vertebrates and invertebrates will also be discussed, as will an unlikely ESA success story and why the ESA remains perhaps one of the most important laws in the world for protecting invertebrates. Contrary to what some might say, the ESA is not "broken," and with proper funding and management, can continue to protect species threatened with extinction.

George Boettner
Department of Entomology, University of Massachusetts-Amherst

Aliens from "Out of Place!" Managing Illegal Aliens on an Expanding Ark—without Rocking the Boat

Globally, one of the greatest threats to insect conservation is the introduction of alien invasive species. Yet countless numbers of new species change borders every year. In Massachusetts alone, 350 new species of invertebrates have been accidentally introduced in the past 100 years. During this same time, another 150 species of insects were purposely introduced as biological control agents to slow the spread of some of these new pest species. Evidence will be shown that some of these generalist biological control agents intended as "cures," may have also contributed to the decline of native species. Early attempts to eradicate alien pests have included burning habitat, as well as widespread use of poisons such as lead arsenate and DDT. More recent techniques include releasing species-specific pathogens, such as fungi and viruses. This talk will explore some of the successes and failures of these approaches, with an emphasis on how to control alien species, while managing for insect conservation.

Damayanti Buchori
Conservation Entomologist, Department of Pest and Plant Diseases, Bogor Agricultural University, Indonesia

Insect Conservation in Changing Landscape: The Role of Agro-Ecosystem in Maintaining Insect Diversity

Agriculture has traditionally been seen as a threat to conservation, primarily because of intensification in production and changes in landscape structure and composition. The predominating view is that agriculture has resulted in species decline due to the "simplification" it brings. In the last decade, however, many studies are starting to show the significance of agro-ecosystem as a reservoir for biodiversity, especially insects. Since agriculture is in itself a mosaic of land use types, different land uses may harbor different insect species. This paper presents studies on the role of agriculture landscape and agro-ecosystem management in maintaining insect diversity. The role of "complex" landscapes as

one factor that can maintain diversity is discussed. Several factors that can increase the complexity of a given landscape are the presence of common weeds in field margins, hedgerow, and open fields that are shown to enhance the role of different types of natural enemies, while intercropping has been shown to decrease pest populations. Integrated Pest Management (IPM) is also discussed as a management system that can enhance the practice of insect conservation. This paper also discusses the view of insect conservation as basically the utilization of insects to reach their full potential/functional role in nature.

David C. Culver
Professor of Biology, American University

Hidden Diversity: Invertebrates in Caves

Caves are not an uncommon habitat—more than 45,000 are known within the United States alone. Worldwide, nearly 10,000 invertebrate species (1,200 in the U.S.) are known exclusively from caves and other subterranean habitats, and at least several times that number remain to be described. Among aquatic species, there are more obligate cave-dwelling amphipods than any other group, but bathynellan and isopod species show a greater propensity to be limited to caves. Beetles dominate the terrestrial community, but proportionally, diplurans and several minor arachnid orders show a greater cave-dwelling propensity. Species richness is greatest in North Temperate areas, especially around the Mediterranean. Concentration in North Temperate areas is likely the result of Pleistocene effects, while the concentration in the Mediterranean is likely the result of greater available cave habitat. In the tropics, diversity is higher in Southeast Asian caves than elsewhere. Internationally, caves have been protected as Ramsar Wetlands and World Heritage sites, and in the U.S. the Endangered Species Act has been an important protection mechanism. Caves are always connected to the surface and protection of caves requires protection of surface habitats. Key contact points between surface and subsurface are cave entrances, sinking streams, and sinkholes.

Gary E. Davis
Visiting Chief Scientist, Ocean Programs, U. S. National Park Service

Design Elements of Marine Protected Areas: The Necessary Ingredients for Success

Science and society both play critical roles in restoring impaired marine ecosystems, and in integrating taxa-based and place-based conservation strategies. Deteriorating resource conditions triggered a community's desire to change public policy in Channel Islands National Park and National Marine Sanctuary, California. Protecting areas of the sea for conservation has been a very successful, modern, social endeavor for nearly a century. Channel Islands National Park, one of 40 marine protected areas in the U. S. National Park System, was proclaimed a national monument in 1938 and expanded substantially in 1980 by Act of Congress. Collapse of marine life populations and loss of 80% of the giant kelp forests in the park between 1980 and 1998 showed that habitat and water quality protection alone did not secure sustainable ocean ecosystems or fisheries. Failed taxa-based fishery management strategies and practices prompted formal community and agency requests in 1998 for a network of reserves protected from direct fishing impacts, to serve as marine recovery areas. A four-year attempt to build a science-based, community consensus for a reserve network successfully identified five recovery goals for fisheries, biodiversity, education, economic, and heritage values. Nevertheless, the appointed community group failed to find unanimous support for a specific reserve network to achieve those common goals. The group submitted a recommendation, supported by 15 of 17 members, to the U. S. Department of Commerce and to the California Fish and Game Commission in 2001 for action in their respective jurisdictions. California adopted half of the network in state waters in 2003, after extensive public review and comment. The relative influences of a wide range of scientific and social factors necessary for marine protected areas designation are described.

Thomas Eisner
Director, Cornell Institute for Research in Chemical Ecology, Cornell University

Panelist, Session VIII: Building Public Support for Invertebrate Conservation

Gary Frazer
Assistant Director for Endangered Species, U.S. Fish and Wildlife Service

Conservation and Recovery of Native Invertebrates under the Endangered Species Act

The Endangered Species Act (ESA) was signed into law in 1973, but it was not until 1976 that five California butterflies became the first invertebrate species to receive protection under the Act. Today, 189 invertebrate species comprise slightly more than 38 percent of all listed native animal species. Approximately 80 percent of these invertebrates, including mussels, snails, crustaceans, insects, and arachnids, are listed as endangered; the rest are listed as threatened. In addition, 87 invertebrate species are currently identified as candidates for ESA protection. Several conservation tools become available when a species is listed as endangered or threatened under the Act, including regulatory protections, focused attention to recovery planning and implemen-

tation, the potential for land acquisition funding, and protection through cooperative agreements with the states. Still, recovery of listed invertebrates presents major challenges. Although 137 listed invertebrates have approved recovery plans, basic life history information is incomplete for many of these species. Conserving the ecosystems upon which listed species depend — the fundamental purpose of the Act — is a critical and complex undertaking for terrestrial and aquatic species alike. Critical habitat has been designated for 11 listed invertebrate species, primarily insects. However, invertebrate species' conservation needs continue to outpace the resources that are available for the implementation of recovery actions. It is important to note that while biological recovery is the core goal of the ESA, the conservation of invertebrates often requires unique attention that goes beyond the province of science or the scope of regulatory and statutory authority. Public appreciation of the ecological and practical value of invertebrates, as well as their intrinsic worth, must be fostered in order to attain parity with the support shown for charismatic vertebrate species. In addition, the cooperative endeavors that emanate from shared concerns are key to ensuring the continued existence of our most imperiled invertebrate species in their wild habitats. The federal agencies charged with administering the ESA can bring administrative tools and scientific expertise to the table, but the specific expertise and resources that individuals and organizations bring to this critical area of conservation need are essential for success.

Steven Gaines

Director, Marine Science Institute and Professor of Ecology, Evolution, and Marine Biology, University of California at Santa Barbara

Catastrophes and Marine Reserve Design: Can We Buy Insurance?

When viewed across long temporal and large spatial scales, severe disturbances in marine ecosystems are not uncommon. Events such as hurricanes, oil spills, disease outbreaks, hypoxic events, harmful algal blooms, and coral bleaching can cause massive mortality and dramatic habitat effects on local or even regional scales. Although designers of marine reserves might assume low risk from such events over the short term, catastrophes are quite probable over the long term and must be considered in reserve design and implementation. Although some strategies can lesson the likelihood of catastrophes altering reserve success, declines in reserve performance due to catastrophic events are inevitable. This talk examines a number of approaches, including admitting defeat by buying "reserve insurance": a multiplier to calculate the additional reserve area necessary to ensure that functional goals of reserves will be met within a given "catastrophe regime." The characteristics of relatively well-studied disturbances from historical data will be analyzed to characterize catastrophe regimes within which reserves must function, and use these regimes to illustrate the application of the insurance factor.

Howard S. Ginsberg

Ecologist, USGS Patuxent Wildlife Research Center, and Unit Leader, Patuxent Coastal Field Station at the University of Rhode Island

Managing Vector-Borne Diseases so as to Minimize Negative Effects on Non-Target Invertebrates

Numerous methods are available to control arthropod vectors of human diseases. The level of damage to populations of non-target species depends on the type of control method, environmental conditions, the method of application, and the accuracy of targeting the intervention. Efforts to control vector-borne diseases have historically conflicted with efforts to conserve invertebrates, but highly efficient management can support both efforts. Environmentally-appropriate methods and efficient integration and targeting of management can benefit public health by minimizing the number of human cases per unit effort, and can simultaneously minimize non-target effects by avoiding relatively broadscale applications of nonspecific control agents. Highly efficient management requires knowledge of both vector ecology and pathogen transmission dynamics to develop accurate surveillance tools and well-targeted control methods, as well as theoretical advances on ways to efficiently integrate management techniques. Probabilistic models of pathogen transmission suggest that efficiencies of different management methods vary with initial vector abundance and pathogen prevalence. Therefore, management must be tailored to specific local conditions. The efficiencies of various techniques and of various combinations of techniques at lowering the number of human cases can be compared, and the most environmentally benign approach that protects public health can be applied.

David Grimaldi and Robert R. Dunn

Curator of Invertebrate Zoology, American Museum of Natural History; Fulbright Postdoctoral Fellow, Department of Environmental Biology, Curtin University of Technology, Perth, Western Australia

400 Million Years on Six Legs: The Evolutionary Success of Insects and Their Modern Challenges

By virtually every measure, insects are the most successful group of animals in the 3.5 billion-year history of life on earth. They are among the earliest known land animals, the most species-rich lineage ever known, and are critical to terrestrial ecosystems as the primary phytophages, detritivores, and pollinators. Salient episodes of their fossil record are reviewed, which indicate resilience of insects to mass extinctions that affected many other

groups of animals. The rich fauna of insects preserved in amber from the Miocene of the Dominican Republic, 20 million years ago, provides particular insight into the dynamics of insect extinctions. We also discuss modern extinctions of insects, difficulties in documenting them, factors affecting their survival and susceptibility, and prospects for the future.

Charles P. Hawkins
Director, Western Center for Monitoring and Assessment of Freshwater Ecosystems, Utah State University

MONITORING FRESHWATER INVERTEBRATES: IDENTIFYING PATTERNS OF BIODIVERSITY AND TAXA AT RISK BY MINING WATER RESOURCE AGENCY DATA

The vast majority of freshwater invertebrate monitoring in the United States is conducted by water quality agencies. These monitoring programs were designed to meet the biological monitoring requirements of the Clean Water Act and not to assess aquatic biodiversity per se. Therefore, unless more financial resources become available, biodiversity information must be extracted from data collected by these agencies — data that vary greatly in quality, scope, and method of collection. Fortunately, there are ways to mine this extensive collection of data to provide estimates of the general status of freshwater invertebrate faunas within a state or region. In these programs, two types of waterbodies are typically sampled: reference sites, which represent the least-disturbed waterbodies in a region, and non-reference sites, which have been altered to some degree by human activity. Analysis of reference site data can identify the location of intact biodiversity hotspots and the environmental factors associated with natural spatial patterns in biodiversity. Analysis of non-reference sites can identify certain taxa at risk and the types of landscapes most vulnerable to taxa loss. To carry out more extensive and comprehensive biodiversity analyses will require better data sharing among local, state, and federal programs and the implementation of more appropriate sampling designs.

Jeremy B. C. Jackson
William and Mary B. Ritter Professor of Oceanography, Scripps Institution of Oceanography, University of California, San Diego

HABITAT DESTRUCTION AND ECOLOGICAL EXTINCTION OF MARINE INVERTEBRATES

The oceans contain the greatest phyletic diversity on earth with approximately 35 phyla. Most invertebrate species are undescribed but the total is likely somewhere between 1 to 10 million. Whatever their number, the vast majority of marine invertebrate species live on the sea floor. Most of the 3-dimensional structure and habitat complexity that support this high benthic diversity is provided by a comparatively small number of invertebrate species and plants that grow large and form reefs, mats, and burrows. The number of species of these "ecosystem engineers" is probably no more than 5 to 10 thousand, but each of them provides the habitat for 100s to 1,000s of smaller associated species, many of which are habitat specific. We have no idea whether these associated species are decreasing or increasing, for lack of data. But there is little doubt about the fate of the ecosystem engineers that are disappearing due to trawling, fishing, mining, displacement by introduced species, pollution, and climate change. The sea floor is being flattened at a scale that resembles global clear cutting of old growth forests with the concomitant ecological extinction of the great majority of species. The only question barring a radical change in ocean policy is how few decades it will take for ecological extinction to become total extinction.

Peter G. Kevan
Professor, Departments of Environmental Biology and Botany, University of Guelph, Ontario

PESTICIDES AS THREATS TO BIODIVERSITY AND ECOSYSTEM FUNCTION

Pesticides comprise the biocidal weaponry aimed at pests. The notion "pest" is anthropocentric, but real. Pests are organisms that interfere with human environmental exploitation. Pesticides are abused and overused, but needed for modern living. As selective toxins, they kill some organisms at lower doses than they kill others. Thus, insecticides applied in agriculture, agroforestry, and forestry kill non-targets, such as pollinators. The consequences are reduced pollination, seed and fruit-set, food for birds and mammals, and plant reproduction. Insecticides also kill soil animals. Reduced soil porosity, nutrient cycling, carbon accumulation, and fertility ensue. Predators, insects and vertebrates, are also unfortunate victims and again environmental problems result. Biodiversity and ecosystem function are inextricably linked, stressed, and altered by pesticides, and may be eroded enough that major downward shifts result.

Roger S. Key
Senior Invertebrate Ecologist, Terrestrial Wildlife Team, English Nature, UK

CONSERVATION OF INVERTEBRATES IN ENGLAND, USING BEETLES AS AN EXAMPLE — A PARTNERSHIP OF AGENCY, ACADEMIC AND AMATEUR

There is a wealth of data on England's beetles that has been collected by amateur coleopterists over two centuries. Those data are now being compiled so as to be useful for conservation work.

336 species of beetles are Red-Listed in Britain, out of a total fauna of about 4,200 species. Fifty-four are targeted for specific

action under the "Biodiversity Action Plan," our response to the Rio International Convention on Biodiversity. English Nature, the state conservation agency, is charged with implementing "species action plans" for most, so far with various degrees of success.

We are now funding Ph.D. research on the conservation ecology of various plant-feeding beetles, and have contracted projects coordinating amateurs and professionals working on carabids and water beetles.

Most of our beetle conservation work, however, concentrates on influencing the managers of protected areas to ensure that the areas are managed in an "invertebrate friendly" way. We concentrate on aiding insect dispersal, creating heterogeneity, and influencing microclimate and mainly monitor habitat features as a surrogate for all but the rarest species.

Richard King
Staff Biologist, Necedah National Wildlife Refuge, Wisconsin

Karner Blue Butterfly Habitat Management Considerations at Necedah National Wildlife Refuge

Necedah National Wildlife Refuge contains the largest known populations of Karner blue butterflies. All of these populations except two occur on restored savannas that have been frequently burned over in the past four decades. When this species was listed as endangered, the Refuge was asked to revisit its prescribed burn operations as they were assumed to harm Karner blue butterflies — despite the fact that nearly all of the Refuge's known populations occurred on frequently burned habitat. A literature review revealed that no peer-reviewed studies measuring the effects of prescribed burning on adult Karner blue butterflies existed. The Refuge developed a study that incorporated controls and replicates to determine the effects of prescribed burning on the highly mobile Karner blue butterfly. Two years of pretreatment and three years of post treatment monitoring revealed that adult Karner blue butterflies were unaffected by the prescribed burns. These results can be explained by the following: 1) prescribed fire does not cause Karner blue butterfly mortality, or 2) adult colonization of burned sites compensates for mortality.

Claire Kremen
Assistant Professor, Department of Ecology and Evolutionary Biology, Princeton University

The Importance of Invertebrate Biodiversity

Invertebrates represent the majority of animal diversity and conduct many critical ecological functions, including pollination, decomposition, herbivory, seed dispersal, predation, water filtration and, "ecosystem engineering." This talk explores the importance and value of invertebrates for ecosystem functioning, for ecosystem goods and services critical to humanity, and for their utility in conservation planning to protect global biodiversity.

Lawrence L. Master
Chief Zoologist, NatureServe

Keeping Tabs on The Little Things That Run the World: Information Management for the Conservation of Invertebrates

In order to practice on-the-ground conservation, it is necessary to know what species are at risk of extinction, where precisely they are located, what factors threaten their existence, and what their habitat and other requirements are. For the past 30 years, The Nature Conservancy and now NatureServe in collaboration with a network of state, provincial, and country natural heritage programs and conservation data centers in the Western Hemisphere have worked to develop this information and inform the conservation of at-risk species. In contrast to vertebrate and vascular plant taxa, only a small percentage of invertebrate taxa are sufficiently well known to be effectively targeted for conservation information development, but more than 14,000 North American invertebrate taxa are now tracked in NatureServe's databases. Growing numbers of amateur and professional biologists are developing information on the status and distribution of these species, particularly those thought to be at some risk of extinction. As a result of these efforts and the centralization and dissemination of key information, conservation organizations and government agencies are increasingly devoting resources to the conservation of invertebrates.

Paula M. Mikkelsen and Rüdiger Bieler
Assistant Curator, Division of Invertebrate Zoology, American Museum of Natural History; Associate Curator, Department of Zoology, Field Museum of Natural History, Chicago, IL

Effective Inventory of Cryptic Marine Invertebrates: Rap versus Tap

The application of Rapid Assessment Protocols (RAP) and Thorough Assessment Protocols (TAP) to inventories of cryptic marine invertebrates is discussed in context of a 10-year survey of marine mollusks in the Florida Keys National Marine Sanctuary (FKNMS). Original sampling employed a wide variety of methods (e.g., rock washing, scuba, bottom grabs deployed from research vessels) in a similarly wide variety of habitats (e.g., intertidal rocks, sand flats, seagrass beds, coral reefs, mangroves, offshore sediments to 215 m). A baseline was established for bivalve mollusks by combining original collection data with those

from museum specimens and a detailed survey of verifiable published/gray literature. Analysis of the resulting 12,000-record database shows actual species richness underestimated by 250% over the FKNMS inventory (1995), and also reveals faunal relationships along length/breadth of the island chain. Species accumulation curves show consistent "spikes" when new methods or habitats/areas are added, validating the use of TAP in such a setting. RAP methods applied to selected sites within FKNMS illustrate substantial shortfalls in recovering TAP-expected taxa, especially when limited to live-collected specimens. The importance of TAP (including physical samples, live/dead shells, literature/museum data, and trained systematists to process samples) in researching a large often-sampled area is emphasized despite the added resources required.

Scott E. Miller and Jonathan A. Coddington

Senior Biodiversity Advisor to the Director, National Museum of Natural History, Smithsonian Institution; Research Entomologist, Department of Systematic Biology, Smithsonian Institution

A New Century Dawns on Invertebrate Surveys: Lessons from 20 Years of Terrestrial Invertebrate Surveys

The huge diversity of terrestrial invertebrates is both a challenge and an opportunity. Well designed invertebrate surveys can be cost-effective sources of novel information, but poorly designed surveys can be rapidly overwhelmed by huge quantities of very sparse data whose interpretation is ambiguous.

The two main problems with invertebrate surveys are the diversity of the fauna in the field and the taxonomic impediment in the lab. Surveys usually fail in the field because the focal taxon is too diverse, sampling methods are too few, or sampling intensity is too low. Successful inventories of tropical diverse faunas are few. The 'modal' survey is still a faunal list. Most surveys do not sample enough to be meaningful, but some surveys based on common species can be successful. Due to the advent of species-richness estimators, the role of and explanation for rare species (singletons) is receiving careful attention. Perhaps the worst consequence of undersampling bias is that it cannot be distinguished from interesting biological signal, e.g. endemism, habitat specificity, or phenology. In most cases, well-designed surveys of terrestrial invertebrates do not damage populations, although some invertebrate populations need to be treated with special care.

The 'taxonomic impediment' is serious, but can be overcome. The existing taxonomic framework is fairly robust at the family and genus level. Some taxa are even reasonably well known at the species level, although the information can be hard to find. Quality of identifications is important and 'morphospecies' can mean many things. Efficient and accurate protocols for processing material are vital—parataxonomists and bioinformatics tools can help, but quality control remains important.

Piotr Naskrecki

Director, Invertebrate Diversity Initiative, Conservation International

Addressing the Needs for Identification of Invertebrates in Conservation Practices

The taxonomic impediment in invertebrate biology is one of the major stumbling blocks in a wider use of these organisms in conservation practices. Very frequently, invertebrates are not included in conservation decision-making because of the lack of resources to survey and identify them. However, recent developments in information technologies make it possible to simplify the process of species identification and provide tools for training of a new cadre of taxonomists. Global, comprehensive databases that address taxonomists' needs for free access to primary literature and type information are the prerequisite of a more efficient and inexpensive identification of invertebrate species. Online availability of type information can reduce the time necessary to identify new faunas by 50%-90%, and the cost to almost zero. An initial investment and a wide participation of major natural history collections is necessary for a success of this approach, but examples of a few major institution who adopted it show its great potential in reducing the taxonomic impediment.

Tim R. New

Reader/Associate Professor, Department of Zoology, La Trobe University, Australia

Towards a Conservation Agenda for Terrestrial Invertebrates

The current state of terrestrial invertebrate conservation interest and practice is summarised, and the twin approaches of focusing on single species as targets and of using these and assemblages as tools in wider conservation assessment appraised as strategies for the future. Problems and opportunities for conservation that arise from the massive diversity of terrestrial invertebrates are addressed, including the need for conservation over vast areas of the world where such activities have very low local priority and where communication of the value of invertebrates must be pragmatic. The value of adopting ecologically complementary suites of flagship taxa, and of ecologically informative focal groups to facilitate such communication, have potential to overcome some of the conceptual barriers between land managers and conservationists. Landscape-level management, particularly involving agroecosystem management, is a critical theme in working toward holistic management for

wellbeing of both primary production systems and wider invertebrate biodiversity in terrestrial and riparian environments.

Laura Noguchi and Anne St. John
Biologist, International Affairs, U.S. Fish and Wildlife Service; Biologist, International Affairs, Division of Management Authority for CITES, U.S. Fish and Wildlife Service

An Overview of U.S. Invertebrate Trade Data

Although many invertebrate taxa are traded in significant numbers, much of the global trade is unregulated and unreported because relatively few invertebrate species are protected by national laws or international treaties. The United States is unique in collecting information on wildlife shipments entering and exiting the country, regardless of whether the species involved are protected. With some exceptions, shipments of wildlife being imported to or exported from the United States must be declared and are subject to physical inspection by the U.S. Fish and Wildlife Service. We will present an overview of recent U.S. trade in invertebrates. These data are grouped into the following categories: annelids, arachnids, corals, crustaceans, echinoderms, insects, mollusks, and 'other invertebrates.' Detailed information is collected on taxa covered by various wildlife protection laws (including the Endangered Species Act and the Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES]) and certain species of special concern. Data on non-protected species, while broader, nonetheless provide important information on the scope and trends of international trade.

John C. Ogden and Elliott A. Norse
Director, Florida Institute of Oceanography (FIO) and Professor of Biology, University of South Florida; President, Marine Conservation Biology Institute

Lines on the Water: Ocean Use Planning and Zoning

Almost 30% of U.S. land area is federally owned and under some form of management. In the oceans, only fractions of a percent of our Exclusive Economic Zone (EEZ), in total approximately 120% of the land area is under comparable management in spite of manifest human disturbances including over-fishing, pollution, global climate change, and increasingly contentious user conflicts. The failure of fisheries management policy has created an intense interest in marine protected areas, but over more than a decade we have made little progress. We need a more comprehensive framework for scientific input to management and conservation. Ocean use planning recognizes that we must use the oceans, but we can't afford to use them up. It broadens the stakeholders from fishers to society as a whole. There is sufficient data and information encompassing the EEZ to begin a decade-long national planning process. There are excellent examples of ocean use planning schemes that work, such as the Great Barrier Reef Marine Park, the Florida Keys National Marine Sanctuary, and the Meso-American Coral Reef, to name a few. As recommended by the Commission on Ocean Policy, ocean use planning may be implemented within defined ecoregions merging state waters (shoreline to 3 nautical miles) with federal waters (3 to 200 nm). A proposed National Ocean Council may resolve state-federal conflicts and overlapping agency mandates.

Steve Prchal
Founder and Director, Sonoran Arthropod Studies Institute

Beyond Butterflies: Insect Farming Expands to Serve Growing Foreign Markets

Robert Michael Pyle
Founder, Xerces Society

Panelist, Session VIII: Building Public Support for Invertebrate Conservation

Michael Ruggiero
Director, Integrated Taxonomic Information System, U.S. Geological Survey, Smithsonian Institution

Bioinformatics and Invertebrate Monitoring: Applications of the National Biological Information Infrastructure (NBII)

Monitoring of invertebrates and other animal populations requires four major categories of standards for useful exchange and aggregation of data: taxonomic, collecting, design, and information management. Taxonomic standards are critical in identifying the organisms of study and in naming, referencing, cataloging, and archiving specimens. Collecting and design standards provide guidance on the appropriate methodologies for acquiring, enumerating, and analyzing organisms and data. Information management standards allow exchange of data between and among studies, institutions, and networks with necessary documentation and interoperability. Consistent application of these standards will allow the data from single studies to be aggregated at different scales. Various examples are given to demonstrate how the federated databases of the NBII can be used as resources for applying taxonomic and information management standards to invertebrate monitoring data. Additional examples are given to demonstrate the application of aggregated NBII data.

Michael J. Samways
Professor and Chair, Department of Entomology and Nematology, University of Stellenbosch, South Africa

LANDSCAPE TRIAGE: STRATEGIES FOR MANAGING INVERTEBRATES

Estimates are that many tens of thousands of invertebrates may go extinct over the next few decades. The pressures and impacts upon them are vast and multifaceted. Some of these impacts are local and others global, with many synergisms between. These interacting impacts make predictions of outcomes uncertain. This means that we must adopt a precautionary management approach, and be selective in what we do with limited human and financial resources. Underpinning this, we must be clear on our conservation goals and their ethical foundation. This leads us to consider not just "where" we do good conservation management (i.e. prioritization), but also "how" (i.e. triage). Management principles from research in recent years are emerging that may enable us to slow the impending "Great Biodiversity Crisis." These management approaches give ecological flexibility yet maintain evolutionary potential. At least in this way we are giving invertebrates and other biodiversity the best chance of pulling through the demographic winter of the Homogenocene.

George E. Schuler
Director, Upper Delaware Program (NY), The Nature Conservancy

SINK OR SWIM: THE CHALLENGES OF CONSERVING FRESHWATER INVERTEBRATES IN A WORLD OF REGULATED RIVERS

Cheryl B. Schultz
Assistant Professor, School of Biological Sciences, Washington State University

THE ROLE OF FIRE IN MANAGING HABITAT FOR AT-RISK INVERTEBRATES

Fire is a popular but controversial tool used to manage habitat for at-risk terrestrial invertebrates. Many rare invertebrates live in early-successional habitats that were historically maintained by fire. Many suggest that the absence of fire is responsible for accumulation of thatch, invasion by non-native species, and succession to woody habitat. Unfortunately, invasion by non-native species may have altered ecological processes such that historic disturbance regimes no longer maintain habitat for at-risk invertebrates.

*The role of fire in managing at-risk ecosystems from the perspective of rare invertebrates is reviewed, focusing on issues that managers can influence, such as timing of fire, frequency of fire, and portion of the habitat that is burned. The questions are asked, what kinds of data do we need to make conclusions about the effects of fire (e.g. the number of years of post-burn data, the direct effects of fire on sessile lifestages, and dispersal behavior of mobile lifestages), drawing on experimental investigations with the Fender's blue butterfly (*Icaricia icarioides fenderi*), an endangered butterfly in Oregon. In addition, the use of alternative management strategies is reviewed, such as mowing and grazing.*

Mary Seddon
Section Head, Department of Biodiversity and Systematic Biology, National Museums and Galleries of Wales

IUCN RED LIST APPROACHES AND CRITERIA FOR INVERTEBRATES

Jack A. Sobel
Director, Strategic Conservation Science and Policy, The Ocean Conservancy

PROTECTING MARINE INVERTEBRATES AND BUILDING OCEANIC ARKS (MARINE RESERVES)>MAXIMIZING YIELD SUSTAINING USE

Commercial and recreational extraction of ocean life, including fishing activities, severely alter, destroy, and threaten the continued survival of marine invertebrate species, communities, and the ecosystems on which they depend and support. Even artisanal, indigenous, and scientific taking and collecting can have significant impacts. Overfishing, habitat destruction, bycatch, ecosystem alteration, and synergies with other impacts and disturbances are among the principal threats to invertebrates from such extractive activities.

Severe, serial overfishing of abalone species along North America's Pacific Coast illustrates this impact to vulnerable species well. Historic North Atlantic trawl and dredge fisheries and more recently developed deepwater trawl fisheries targeting seamounts represent gear damage to fragile habitats. The Gulf of Mexico shrimp trawl fishery documents bycatch impact. Coral reef and kelp system degradation globally; related ecological changes; and the high impact of even single species removal reveal cascading and synergistic effects.

Successfully addressing threats from fishing and protecting marine invertebrates, invertebrate communities, and the ecosystems with which they interact and on which they are interdependent will require more than eliminating "overfishing" and achieving "sustained/sustainable use." More effective ecosystem-based management, a full range of marine protected areas, and larger and more representative no-take marine reserve networks will also be required.

Sacha Spector
Manager, Invertebrate Conservation Program,
Center for Biodiversity and Conservation, American Museum of Natural History

ARE INVERTEBRATE FOCAL TAXA FULFILLING THEIR PROMISE?

Pervasive scarcities of data on the distribution, taxonomy, and population status of invertebrates have seriously impeded the inclusion of invertebrate diversity in the conservation process. For nearly two decades, the development of invertebrate focal taxa has been suggested as a means to pry conservation-relevant information out of this hyper-diverse, poorly known invertebrate realm. A review of our progress toward establishing such focal taxa reveals decidedly mixed success. While there have been hundreds of studies debating the criteria for selecting focal taxa and detailing the effects of anthropogenic disturbances and ecological changes on dozens of different invertebrate taxa, they have resulted in a fragmented and often incomparable dataset. As a result, virtually none of the many proposed invertebrate focal taxa have been universally embraced, though a slate of promising candidates has been identified. However, we have developed a clearer understanding of the informational, methodological, and taxonomic infrastructure needed to support fully functioning focal taxa, and the coordinated effort necessary to produce it. Information technologies that are continually improving, together with more focused efforts by collaborative networks of taxonomists, ecologists, and conservation biologists has the potential to rapidly develop a suite of invertebrate focal taxa with utility in a variety of conservation contexts.

David Strayer
Freshwater Ecologist, Institute of Ecosystem Studies, Millbrook, NY

OVERVIEW AND STATUS OF FRESHWATER INVERTEBRATES

The earth's fresh waters contain more than 70,000 described species of invertebrates, and tens of thousands of species remain to be discovered and described by scientists. This diversity is not spread evenly over the surface of the globe, but is concentrated in hot spots, usually geologically ancient lakes, streams, or ground waters, which contain dozens to hundreds of species of invertebrates that are found nowhere else. Because fresh waters are such an important resource for people, and have been used intensively for water supply, power, irrigation, fisheries, navigation, waste disposal, and as sites for cities, environmental conditions in many of the world's fresh waters have been altered greatly from their original states. Habitat degradation, pollution, invasions of alien species, global climate change, and harvest all pose important threats to freshwater invertebrates. Especially where hot spots of diversity coincide with areas of intensive human development, many freshwater invertebrates have disappeared from their native habitats. Some invertebrate species already have become extinct, and thousands of others are in danger of disappearing from the earth. Careful management of fresh waters, especially in areas of high biological diversity, is needed to prevent catastrophic extinctions of freshwater invertebrates in the future.

Steven K. Webster
Senior Marine Biologist, Monterey Bay Aquarium

Panelist, SESSION VIII: BUILDING PUBLIC SUPPORT FOR INVERTEBRATE CONSERVATION

Center for Biodiversity and Conservation American Museum of Natural History

In 1993, the American Museum of Natural History created the Center for Biodiversity and Conservation (CBC) to enhance the use of scientific data to mitigate threats to biodiversity. The CBC develops strategic partnerships to expand scientific knowledge about diverse species in critical ecosystems and to apply this knowledge to conservation; builds professional and institutional capacities for biodiversity conservation; and heightens public understanding and stewardship for biodiversity. Working both locally and around the world, the CBC develops model programs that integrate research, education, and outreach so that people—a key factor in the rapid loss of biodiversity—will become participants in its conservation.

While many conservation projects have focused on the more "charismatic" forms of life, like birds and large mammals, the CBC strives to study and protect lesser-known organisms that are essential components of the world's biodiversity. Invertebrates, including insects, mollusks, and many other phyla of small, easily overlooked species, together represent the largest portion of the world's living things. Despite the fact that they are critical for maintaining healthy, functioning ecosystems, these animals are largely absent from the majority of conservation planning and biodiversity management strategies.

The CBC Invertebrate Conservation Program seeks to promote the incorporation of invertebrates into all levels of the conservation process. The program serves as a convener and forum, bringing researchers, resource managers, and conservationists together to discuss and develop principles and practices of invertebrate conservation; as a developer of scientific tools to address key obstacles to invertebrate conservation, drawing on the taxonomic strengths of the Museum; and as a clearinghouse, linking a broader user base to practical information and tools for invertebrate conservation.

Learn more about the CBC's invertebrate conservation work at:
http://cbc.amnh.org/center/programs/inverts.html

Raising awareness and promoting conservation action are also CBC imperatives, and through symposia, workshops, and publications we help to inform the public about biodiversity issues. To make the complex political and economic decisions necessary for the protection of global biological resources, people must have the scientific tools to identify and understand the mechanisms behind the threats to biodiversity. The CBC's role is to equip the world community to use these tools effectively.

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See back cover for listing of CBC Advisory Council.

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Conservation International

CONSERVATION INTERNATIONAL

Conservation International (CI) applies innovations in science, economics, policy and community participation to protect the Earth's richest regions of plant and animal diversity in the hotspots, major tropical wilderness areas and key marine ecosystems. With headquarters in Washington, D.C., CI works in more than 40 countries on four continents. For more information about CI, visit www.conservation.org.

National Park Service

The National Park Service, a bureau within the U.S. Department of Interior, is charged with the responsibility to preserve, unimpaired, the natural and cultural resources and values of our nation's National Park System for the enjoyment, education, and inspiration of this and future generations. The National Park Service administers over 385 designated units of the National Park System, oversees a National Trails System, and cooperates and assists partners in the management of National Heritage Areas, Wild and Scenic River Systems and other natural and cultural heritage sites. The National Park System includes 40 units with significant marine resources including coral reef, temperate kelp forest, glacial fjord, rocky inter-tidal, estuarine, and arctic marine ecosystems. The Service manages over 4,000 miles of marine and Great Lakes shoreline for a total of 71 coastal and Great Lakes park units. For more information about the National Park Service and its programs, visit www.nps.gov

NatureServe

NatureServe is a non-profit conservation organization that provides the scientific information and tools needed to help guide effective conservation action. NatureServe and its network of natural heritage programs are the leading source for information about rare and endangered species and threatened ecosystems. NatureServe represents an international network of biological inventories, known as natural heritage programs or conservation data centers, operating in all 50 U.S. states, Canada, Latin America, and the Caribbean. Together we collect and manage detailed local information on plants, animals, and ecosystems, and develop information products, data management tools, and conservation services to help meet local, national, and global conservation needs.

U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service is the principal Federal agency responsible for conserving, protecting and enhancing fish, wildlife and plants and their habitats for the continuing benefit of the American people. The Service manages the 95-million-acre National Wildlife Refuge System, which encompasses 542 national wildlife refuges, thousands of small wetlands and other special management areas. It also operates 69 national fish hatcheries, 64 fishery resources offices and 81 ecological services field stations. The agency enforces federal wildlife laws, administers the Endangered Species Act, manages migratory bird populations, restores nationally significant fisheries, conserves and restores wildlife habitat such as wetlands, and helps foreign governments with their conservation efforts. It also oversees the Federal Aid program, which distributes hundreds of millions of dollars in excise taxes on fishing and hunting equipment to state fish and wildlife agencies. For more information about the U.S. Fish and Wildlife Service, visit our homepage at http://www.fws.gov.

The Xerces Society

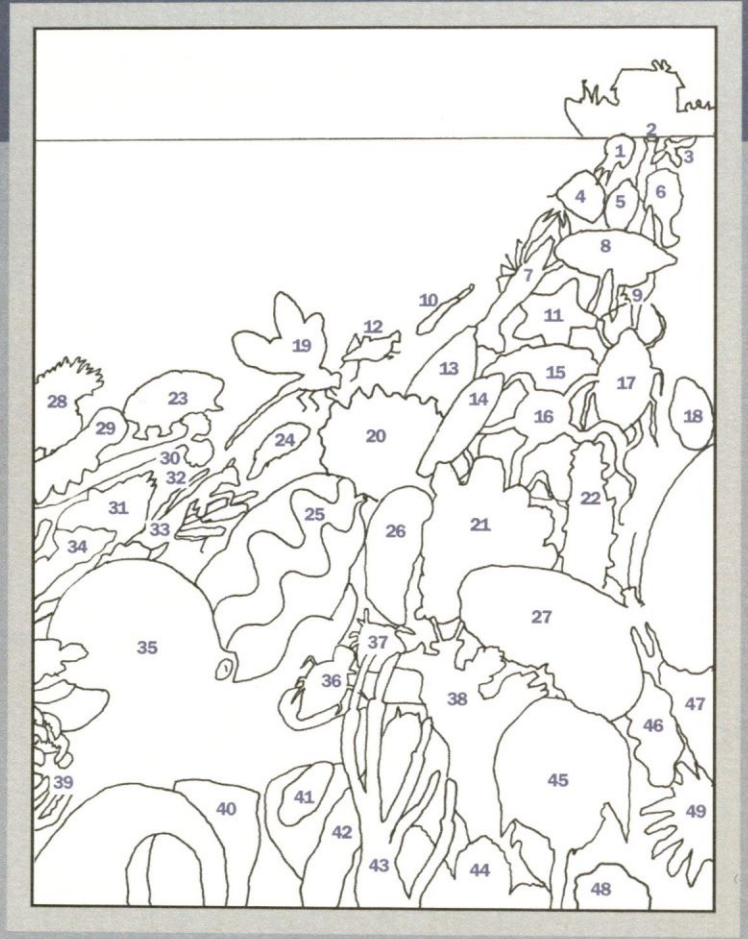
The Xerces Society

The Xerces Society is an international non-profit organization that protects the diversity of life through the conservation of invertebrates. For more than three decades the Society has advocated for invertebrates and their habitats by working with scientists, land managers, educators, and citizens on conservation and education projects. Its core programs focus on native pollinator conservation, watershed protection, publications, and protection of threatened, endangered, and vulnerable invertebrates and their habitat. For more information go to www.xerces.org.

AMERICAN MUSEUM OF NATURAL HISTORY

Visit the American Museum of Natural History online at:
www.amnh.org

Visit the Center for Biodiversity and Conservation at:
http://cbc.amnh.org



Key to Cover Illustration

1 Jellyfish *Chrysaora hysoscella*
2 Slug *Arion ater*
3 Scarab-hunter wasp *Campsomeris pilipes*
4 Cockle *Cardium* sp.
5 Convergent ladybug beetle *Hippodamia convergens*
6 Turkey-leg sponge *Poterion patera*
7 Norway lobster *Nephrops norvegicus*
8 Luna moth *Actias luna*
9 Tibia snail *Tibia fusus*
10 Peanut worm *Sipunculus nudus*
11 Cushion sea star *Oreaster reticulatus*
12 Round-winged katydid *Amblycorypha rotundifolia*
13 Colona moth *Haploa colona*
14 Scarlet-and-green leafhopper *Graphocephala coccinea*
15 Grooved brain coral *Diploria labyrinthiformis*
16 Brittle star *Ophioderma squamosissimum*
17 Scarab beetle *Jumnos ruckeri*
18 Chiton *Acanthochitona garnoti*
19 Western Mountain dragonfly *Ophiogomphus bison*
20 Bryozoan ("moss animal") *Cupuladria canariensis*
21 Bluebell tunicate *Clavelina puertosecensis*
22 Sea cucumber *Isostichopus badionotus*
23 Tardigrade ("water bear") Phylum Tardigrada
24 Sea roach *Bathynomus giganteus*
25 Giant clam *Tridacna gigas*
26 Pill millipede *Glomeris marginata*
27 Passion flower butterfly *Philaethria dido*
28 Brachiopods
29 Tobacco hornworm *Manduca sexta*
30 California horseshoe worm *Phoronopsis californica*
31 Chambered nautilus *Nautilus pompilius*
32 Bryozoan
33 Praying mantis ("European mantid") *Mantis religiosa*
34 Elkhorn coral *Acropora palmata*
35 Octopus *Octopus vulgaris*
36 Globular springtail Family Sminthuridae
37 Red freshwater mite *Limnochares americana*
38 Sea slug *Doto coronata*
39 Unstalked crinoid ("Benetti's feather star") *Oxycomanthus benetti*
40 Barrel sponge Phylum Porifera, Class Demospongiae
41 Flamingo tongue *Cyphoma gibbosum*
42 Queen caterpillar (Milkweed butterfly) *Danaus gilippus berenice*
43 Giant rift worm *Riftia pachyptila*
44 Sea fan *Gorgonia ventalina*
45 Horseshoe crab *Limulus polyphemus*
46 Polyclad flatworm Phylum Platyhelminthes, Class Turbellaria
47 Ctenophore ("comb jelly") *Euplokamis* sp.
48 Sand dollar *Encope micropora*
49 Crown-of-thorns starfish *Acanthaster planci*

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ADDITIONAL ABSTRACTS
Expanding the Ark: The Emerging Science and Practice of Invertebrate Conservation
March 25 and 26, 2004

Steve Prchal
Founder and Director, Sonoran Arthropod Studies Institute (SASI)

BEYOND BUTTERFLIES: INSECT FARMING EXPANDS TO SERVE GROWING FOREIGN MARKETS

Insect zoos and butterfly houses have been the most frequently constructed new exhibit in museums and zoos over the past 25 years. Since 1983 butterfly farmers in Costa Rica have supplied the glass houses of Europe and North America with a variety of species of butterfly and moth pupae to create engaging and educational displays for visitors. Insect zoos have had to wild collect and try to culture other arthropods, trade specimens, or purchase only Southeast Asian species. A collaborative effort between SASI and the Smithsonian Insect Zoo (SI) trained three accomplished butterfly farmers to expand their culturing activities to include other arthropod species. This presentation will review the Costa Rican butterfly farming industry and regulations, chart the progress of the one-year SASI/SI pilot study, and project future developments in insect farming for live exhibition.

George E. Schuler
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SINK OR SWIM: THE CHALLENGES OF CONSERVING FRESHWATER INVERTEBRATES IN AWORLD OF REGULATED RIVERS

Natural disturbances such as floods and droughts are integral parts of intact ecosystems. They play a significant role in determining the abundance and diversity of organisms across a range of spatial and temporal scales. In rivers and streams, the natural hydrologic regime, the magnitude, duration, frequency, timing, and rate of change of such disturbances defines patterns of freshwater biodiversity. Many freshwater invertebrates have habitat requirements and life history stages closely linked to the timing and patterns of the natural flow regime. Conservation practitioners and natural resource managers are faced with difficult choices in the current era of "ecosystem management," often having to balance the conservation needs of managing for many species against the requirements of an individual, and in some cases, endangered or imperiled species. In a world of regulated rivers with altered flow regimes, conservation often focuses on the impacts of the elimination of extreme events (floods and droughts) and overlooks those of the stabilization of the natural disturbance regime also resulting from such alterations. Examples from the Neversink River in New York and Green River in Kentucky, illustrate challenges faced by conservationists in places where human alterations of the natural flow regime negatively impact the ability of freshwater invertebrates to complete their life histories. The examples also highlight instances where alterations by human uses have moderated the natural hydrologic regime, reduced natural disturbances, to the advantage of one species and the detriment of others.