INVERTEBRATE MONITORING IN THE NATIONAL PARK SYSTEM

Howard S. Ginsberg, editor

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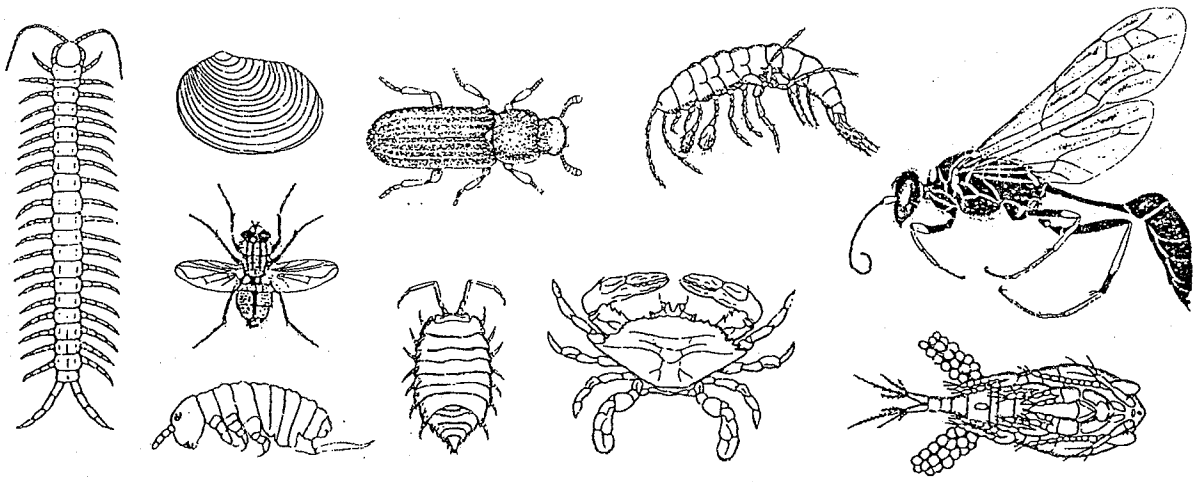

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IN THE NATIONAL PARK SYSTEM

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This report is a product of the National Park Service Invertebrate Monitoring Workshop, which was held on 22-24 April 1992 at the Whispering Pines Conference Center, W. Alton Jones Campus, University of Rhode Island. The report was written collectively by the Workshop participants, who sent draft sections to me for compilation and editing. I thank all of the participants for their hard work and thoughtful contributions. I also thank P.A. Buckley, Mary Foley, K. Elaine Hoagland, Dennis D. Murphy, Dale Schweitzer, Thomas Stohlgren, and several of the participants for constructive comments on early versions of the manuscript. The purpose of this report is to promote awareness of the importance of invertebrates in our National Parks, and to provide guidelines for inventory and monitoring of invertebrate faunas as a basis for invertebrate conservation efforts in the National Park Service.

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EXECUTIVE SUMMARY

Conservation of biodiversity is an important priority of the National Park Service (NPS). Most efforts to date have dealt with vertebrates and vascular plants, and have underemphasized invertebrates. In fact, invertebrates are among the least-well-studied elements of National Park biotas, and a large proportion of parks have little or no information about their invertebrate faunas. Considerably greater effort should focus on invertebrates because they constitute the vast bulk of the animal biomass and biological diversity in parks, are major movers of ecosystem processes, and have unique value for scientific study. Furthermore, they are useful as indicators of ecosystem processes and perturbations to natural systems, can be used to monitor succession and longer-term changes, and have major impacts on agriculture and public health.

Inventory and monitoring (I&M) programs for invertebrates should be based on the "Long-term programmatic goals" for NPS Inventory and Monitoring outlined in NPS-75. The goals of an I&M program for invertebrates should include setting up a national network of NPS biodiversity monitoring sites, assuring continual evaluation of data quality and refined methods development, and providing for continuity of knowledge at each park. Small parks should be included in invertebrate I&M programs because of their collectively high biotic and environmental diversity. Research should focus on assessing and improving inventory and monitoring methods and developing monitoring programs for taxa of special interest.

We recommend the following approach to inventory and monitoring of invertebrates in the National Park system. This program should be implemented at a nationwide series of parks designated as Invertebrate Monitoring Parks, and at other parks as determined by specific needs and by the interests and capabilities of park staff. The invertebrate I&M program should consist of:

1) Reviews and inventories of previous studies and collections of invertebrates at study parks
2) Inventories of current collection holdings, their extent, location, and level of curation
3) Compilation of reference materials on invertebrates at these parks (including literature and voucher specimens)
4) Research on inventory methods (including development and evaluation of inventory and monitoring techniques and selection of indicator taxa) and targeted inventories in parks
5) Development of policies and programs to foster the use of outside expertise and minimize disincentives to outside experts to work in parks
6) Standardization of data management conventions to allow coordination of efforts and pooling of information with other government agencies, museums, academic institutions, conservation groups, etc.
7) Establishment of educational programs to promote awareness and to educate the general public and park staff about invertebrates, and to provide special training for appropriate members of park staff and management.

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I. INTRODUCTION

Biodiversity refers to organismal variety on all levels of biological organization. It represents the kind, number, and frequencies of components of the living world, such as genes, populations, species, communities, ecosystems and landscapes. Thus, biodiversity can be conceptualized at three primary levels: 1) genetic diversity within species, 2) species diversity within habitats and communities, and 3) ecosystem diversity, including the variety of communities and processes, and diversity of landscapes (Soulé and Wilcox 1980, Norse et al. 1986).

Conservation of biodiversity is necessary to sustain the integrity of natural ecosystem processes and the viability of living resources and is currently a major national and international priority (McNeely et al. 1990, Lubchenco et al. 1991, Huntley et al. 1991). Efforts to conserve ecosystem processes begin with inventory and assessment of biological diversity. This baseline information is needed to effectively monitor the changing state of biodiversity in our National Parks.

The National Park Service is a crucial player in the national effort to conserve biodiversity, and has an important conservation mandate (Dottavio et al. 1990, Keystone Center 1991). However, most NPS conservation efforts to date have involved vertebrate animals and vascular plants with relatively little attention to invertebrates (see Section III). A large part of the effort to inventory, monitor, and conserve biodiversity should be directed toward invertebrates for a number of reasons:

1. **Most global biodiversity consists of invertebrates.** Invertebrates constitute far more than 70 percent of the roughly 1.5 million species of organisms that have been described to date (Wilson 1985, 1987; Kosztarab and Schaefer 1990, Schaefer and Kosztarab 1991). There are about 25 times more species of invertebrates than mammals, birds, and all other vertebrates together. Furthermore, insects and other invertebrates constitute the bulk of the biospheric faunal biomass. In a hectare (2.5 acre) of tropical rainforest at Manaus in the Brazilian Amazon, for example, there are roughly one billion invertebrates, mostly mites and springtails. This is about 93 percent of the 200 kg total dry weight biomass of animals present (Wilson 1987).

2. **Invertebrates are "movers" of ecosystem processes.** Invertebrates are important in the production and processing of energy and essential materials and in recycling and processing of nutrients in ecosystems. Invertebrates are found at all trophic levels (except primary producers), and by virtue of their bewildering abundance play a major role in nutrient flow through ecosystems. They are important both as consumers (e.g., herbivores and predators) and as secondary producers (e.g., prey items). The importance of herbivorous insects in forest systems, for example, is well appreciated. However, some invertebrate roles, such as that of decomposers, are often overlooked. A square meter of North American pasture soil (to a depth of 15 cm), for example, yielded about 43,100 mites and 119,800 springtails (Salt et al. 1948). The importance of decomposers to ecosystem function is obvious. Nevertheless, a large proportion of these soil arthropods remain undescribed (Schaefer & Kosztarab 1991).

3. **Invertebrates have unique value for scientific study.** Invertebrates are ideal study organisms because of the short generation times and rapid population growth capabilities of many species. Researchers can perform experiments in weeks that would require several years with longer-lived species. Invertebrates are amenable to experiments in a wide range of fields because they display such a tremendous diversity of life-history patterns, generation

times, and reproductive strategies. Some species produce only one brood of offspring in a lifetime while others have several. Generation times range from several generations per year to long-lived species that require several years to reach reproductive maturity. Reproductive methods include "cloning," parthenogenesis (offspring produced by females without males), hermaphroditism (each individual contains both male and female systems), and two-sex reproductive patterns. By virtue of this diversity, invertebrates offer tremendous potential to elucidate basic biological principles.

4. **Invertebrates can serve as sensitive indicators of ecosystem change.** Short generation times and high reproductive potential also make invertebrates excellent indicator and "early warning" organisms. A sudden population crash could be indicative of chemical contamination, disease, drought, and/or over-predation. Longer-lived animals might not display obvious effects of subtle environmental changes for years or even decades. Invertebrate populations, on the other hand, often respond rapidly to environmental degradation. There is already a substantial literature on the use of invertebrates as indicators of water quality and wetland conditions (e.g., as indicators of high oxygen vs. low oxygen content, acidity, presence of heavy metals or other contaminants).

5. **Invertebrates can be used to monitor succession and longer-term ecological processes.** Invertebrates are well-suited to monitor the recovery of ecosystems after large-scale perturbations, such as the fires at Yellowstone National Park (Christiansen et al. 1992) and hurricane Andrew at Everglades National Park. After a serious disturbance where a habitat has been destroyed (burned, covered with volcanic ash, bulldozed, flooded), invertebrates, because of their high dispersal rates via wind, water and macrofauna, are generally the first animals to colonize an area. They set up microhabitats, spread seeds, condition the soils, and otherwise act to initiate processes to reestablish viable habitats. Each stage in the development and succession of an ecosystem has its own suite of invertebrates that alter the habitat and pave the way for later successional stages.

Taxonomic and faunistic data on invertebrates are also of direct importance in long-term ecological studies, as demonstrated by the National Science Foundation's Long-Term Ecological Research Program (CEQ 1985).

6. **Invertebrate populations have important economic impacts.** Invertebrates influence human welfare in both positive and negative ways by their effects on agriculture and industry. They play important roles in soil development, crop pollination and fruit set, and themselves serve as food items of major importance on a worldwide scale (e.g., shrimp, lobsters, crabs, clams, scallops, squid; in many parts of the world various insects serve as dietary staples).

On the negative side, invertebrates have important destructive impacts on crops and domestic animals during growth, production and storage. Considerable effort is devoted to minimizing pest damage and detecting immigrant pests, and this requires comprehensive databases on native and introduced invertebrates. Effective biological control (involving introduction and release of alien biological control agents) with minimal negative environmental impact, also requires faunal data on invertebrates in the region where pest management is conducted (Kim and Knutson 1986).

7. **Invertebrates have major impacts on public health.** Invertebrates serve as vectors and reservoir hosts for diseases that have major impacts on human populations. For example, plague (caused by a bacterium transmitted by fleas), malaria (caused by protozoa transmitted by *Anopheles* mosquitoes), Lyme disease and Rocky Mountain Spotted Fever

(transmitted by ticks), and arboviral encephalitides (viral diseases transmitted by mosquitoes) pose important threats to human and animal health. Invertebrate diversity data along with geographic, geologic, biological and social factors, play an important role in zoonotic research to identify faunal elements and to predict possible epidemics of disease (Heyneman 1984).

Thus, given the major contribution of invertebrates to global biodiversity, and their importance to natural systems and directly to humans outlined above, they clearly require more attention in National Park Service programs than they presently receive. The mandate for preservation of ecosystems in the National Parks provides a major first step toward the goal of invertebrate conservation. The specific management actions taken in each park have important implications for invertebrate taxa, and these organisms should be considered in developing management programs on the park and servicewide levels. The first step in establishing a program for conservation of invertebrates is to describe the current status of invertebrate faunas in National Parks. The purpose of this report is to provide recommendations for specific steps that should be taken to initiate a program for inventory and monitoring of invertebrates in the National Park system, that will lay the groundwork for a Servicewide program of invertebrate conservation in the National Parks.

II. GOALS AND OBJECTIVES

The primary goal of this workshop is to identify the actions required to build a body of knowledge about invertebrates in National Parks so that resource managers can routinely incorporate information on invertebrates into the decision-making process. The NPS Inventory and Monitoring program provides the framework for this accumulation of knowledge.

The goals for inventory and monitoring programs in the National Park Service are stated in Draft NPS-75 (p.6):

Long-term programmatic goals

To comply with legal requirements, fully implement NPS policy, and guide management activities, the Servicewide Inventory and Monitoring Program will focus on attaining the following major long-term goals:

1. Establish natural resource inventory and monitoring as a standard practice throughout the National Park Service which transcends traditional program, activity, and funding boundaries.

2. Conduct baseline inventories to determine the nature, status, and condition of natural resources and park ecosystems under National Park Service stewardship.

3. Perform long-term monitoring studies to better understand the dynamic nature of natural ecosystems and to provide reference points for comparisons with other, altered environments.

4. Develop and implement specialized tools and techniques to effectively integrate natural resource inventory and monitoring information into National Park Service planning, management, and decisionmaking.

5. Pursue an aggressive outreach program to share National Park Service accomplishments and information with other natural resource organizations and to form partnerships for attaining common goals and objectives.

Similar objectives have been recommended in the report "Protecting Biological Diversity in the National Parks: Workshop Recommendations" (Dottavio et al. 1990) and in the Keystone policy dialogue report "Biological Diversity on Federal Lands" (Keystone Center 1991). Guidelines for designing and implementing I&M programs in the National Park system were reviewed by Silsbee and Peterson (1991).

In this context, the NPS Inventory and Monitoring program should include:

- **Biodiversity monitoring sites.** A national network of NPS sites (Invertebrate Monitoring Parks) should be established as monitoring stations for invertebrate diversity. Candidate parks for the initial phase of this program would include parks with particular biological interest (such as International Biosphere Reserves) or unique ecological features, and parks with existing invertebrate databases, as well as parks with scientific staffs or CPSU support.

This program will provide comparable data from numerous park sites that will allow assessment of regional and larger scale effects of global environmental change on natural systems.

- **Quality control.** Initial and ongoing assessment is needed of the quality of inventory data and analyses. Because of the great diversity of invertebrates, complete inventories are not feasible. However, statistical techniques exist to estimate the number of taxa not appearing in biological inventories and to assess the degree of uncertainty in monitoring data.

I & M programs should provide managers with assessments of completeness and uncertainty to allow optimal decision-making on natural resource issues.

- **Ongoing methods testing and development.** Numerous techniques exist to assess biological diversity. The applicability and efficacy of these techniques at NPS sites need to be assessed. NPS monitoring programs should be flexible enough to allow adoption of new techniques with demonstrated effectiveness.

- **Continuity of knowledge.** The value of long-term ecological studies has been repeatedly demonstrated. The NPS is uniquely situated to support monitoring and assessment of long-term changes in biodiversity. Mechanisms should be instituted to provide for continuity and consistency of effort and to accumulate knowledge about individual parks. Trends in resource quality can only be assessed with long-term time series of monitoring data.

- **Indicators of system "health".** The use of invertebrates as indicators of the condition of natural systems is well established in fresh water environments. Attributes such as high diversity, short generation time, and experimental tractability allow use of invertebrates as indicators in terrestrial and marine systems as well. Techniques that accomplish this

objective should be developed and validated. A variety of features of invertebrate faunas have been proposed as indicators of system health (e.g., see Noss 1990, Pimm 1991) but have not yet been adequately tested.

- **Remote sensing.** Monitoring capabilities can potentially be expanded by tying remote sensing data to invertebrate faunal patterns. Remote sensing methods can assess such parameters as productivity but have not generally been used to monitor population attributes. The NPS monitoring program offers the possibility of correlating remote sensing of physical features with ecological succession and biological diversity.

- **Species of special interest.** Monitoring programs should provide information on threatened and endangered species, exotic organisms, pests, and other species of special interest. These species can have profound effects on park biotas and biotas of surrounding regions.

III. CURRENT STATE OF KNOWLEDGE

Inventory and monitoring efforts and biological research in National Parks have traditionally emphasized vertebrates (especially birds and large mammals) and vascular plants. As such, little inventory information is available on invertebrates in most parks. A recent survey of parks in the Western Region (Stohlgren and Quinn 1991, Stohlgren et al. 1991) revealed that overall inventory data are considered less than 80% complete in the vast majority of parks (>73% of Western parks). Preliminary results from a Servicewide survey show similar trends (Stohlgren et al. 1991). These results are largely slanted toward vertebrates and vascular plants. More than half of the parks reported knowing less than 50% of their invertebrate species and essentially no research had been done on invertebrates in about half of the parks. Actual sampling surveys of parks would likely reveal that knowledge of invertebrate faunas is far less complete than these results suggest.

The only park with a reasonably comprehensive inventory of a large invertebrate group is Acadia National Park. William Procter (Johnson and Procter 1927, Procter 1938, 1946) surveyed the terrestrial arthropod fauna of Mount Desert Island, Maine, for three decades and listed 6,578 species. Even this exhaustive inventory was far from complete. Some major arthropod groups (e.g., soil invertebrates) were not included, and Proctor did not survey annelids, mollusks, nematodes, or other common invertebrates. Clearly, the amount of effort that would be required for a full inventory of the invertebrate fauna of any major park is far beyond our current capability.

A further problem associated with any large scale inventory of the invertebrate fauna of any park is the incomplete state of taxonomic knowledge of many major groups. A recent survey of the status of systematics of insects and arachnids (Schaefer and Kosztarab 1991) estimated that nearly half of the species in North America remain to be described! Some of the most ubiquitous and diverse groups (e.g., Acari, Diptera, Hymenoptera) have the highest proportions of species not yet described. In natural systems closer to the tropics (especially tropical rain forests) biodiversity increases markedly, but taxonomic knowledge declines dramatically (Wilson 1988). This dearth of knowledge would frustrate any attempt at complete inventory of an invertebrate fauna.

One observation of considerable interest is that total species richness in several small parks can be greater than that in individual large parks of comparable area. For example, six small to medium-sized parks in northern California had about 50% more species of vascular

plants, birds, and mammals than did Sequioa and Kings Canyon National Parks, which had roughly twice the land area of the combined smaller parks (Stohlgren and Quinn unpublished). Therefore, small parks should not be neglected in Servicewide inventory and monitoring programs for invertebrates. Small parks can be selected to represent a variety of biome-types, thus increasing overall diversity in samples (even though some of the natural communities sampled may themselves be low in biodiversity).

IV. RECOMMENDATIONS

A national network of NPS sites should be established as monitoring stations for invertebrate biodiversity (see **GOALS AND OBJECTIVES**). These should include large natural parks of national significance as well as smaller parks that represent diverse biome types. The data from this program will be most useful if the studies are coordinated with national ecological and systematic research efforts. National Parks provide natural systems that are unparalleled in terms of the careful management of human impact. They are, therefore, of great value to ecological researchers for studying the effects of global change on relatively pristine natural systems (e.g., see Murphy & Weiss 1992).

The following recommendations should be implemented at each of the designated NPS Invertebrate Monitoring Parks. Current funding levels would not permit implementation of these programs in all natural-area parks. Nevertheless, these recommendations can serve as guidelines for resource managers who wish to establish invertebrate I&M programs at any National Park sites.

Workshop Recommendations

1. **Review and inventory historical information and collections.**

Past research and associated collections are a foundation for invertebrate monitoring programs within the National Park system. To build on this foundation, information on existing invertebrate research and collection in parks must be consolidated and two questions addressed:

a) What is the extent of past research and collections of invertebrate fauna? Where are the collections housed?

b) What future research and collection are necessary to develop basic knowledge of invertebrate populations?

Searches of literature should include Park files and records, Park museum catalogs and files, and published and unpublished scientific literature. Researchers who have worked in the park should be contacted as part of this effort. Park files and records can include collection permits, annual investigator's reports, correspondence, and sighting reports. These sources should be summarized into a format that is readily available to researchers, staff, and the public. This summary can then be used to identify available databases in individual parks, and to determine information needs and guide future research efforts.

An annotated bibliography of published and unpublished research should be

appendixed to the summary report and should also be maintained on a computerized bibliographic data base for future reference. The location of specimens collected during these studies should be ascertained, if possible.

2. **Inventory current collection holdings.**

The location and status of all collections from the park should be determined, and the following information compiled:

a) What is the extent of the collection? How comprehensive is it and how many genera/species are represented?

b) Has the collection been verified? Do annotations include the verifier's name, and the date of verification?

c) Has the collection been accessioned and catalogued into the Automated National Catalog System (ANCS)? Is the accession complete?

d) How is the collection being housed and maintained? What are the costs associated with collection care?

3. **Evaluate availability of reference materials.**

a) Reference materials in parks.

Each park should have reference materials that are available to park staff, researchers, and managers. Reference materials include specimens, species lists, literature, slides and/or photographs of invertebrate species of concern to management. Reference collections should be stored in a manner that makes them easily accessible to users. Rare, threatened, or endangered species should not be collected for this purpose, but instead should be represented by photographs and slides where possible. Such materials are invaluable in promoting appreciation of the ecological role of invertebrates and can be used for interpretive presentations and training on pest management, invertebrate taxonomy, community ecology, biodiversity, and related topics. These materials should be made widely available.

b) Voucher specimens.

In addition to reference materials for general park use, voucher specimens are essential. These collections document species present at a given time. As such, they provide an inventory of park biodiversity and form the basis for the development of long-term monitoring programs. These should be used primarily by researchers and resource managers. They may include rare species, including species that are endangered or threatened.

Voucher collections are of great value and must be carefully protected. Due to the storage, expense, and staffing requirements for collection curation, it is not always practical to maintain voucher collections at parks. Cooperative agreements should be developed with local universities or museums that meet curatorial standards for voucher and type specimen care. The park should keep accurate records on the location of all voucher and type specimens, ensure accessibility to qualified users, and provide regular monitoring and support to guarantee care. We recommend that current regulations under 36 CFR 2.5g (1) be

revised and modified as necessary to foster this approach to handling and preserving voucher specimens.

4. Conduct targeted inventories and research on inventory methods

Considerable need exists for new information. Two areas of critical and immediate importance are a) the development/demonstration of improved inventory methods and b) the need for taxon and community-based surveys in parks.

a) Methods development.

Little information exists on the methods needed for maximally effective I&M programs. Development and demonstration of methods to address this lack is a major concern. Priority should be given to developing I&M techniques that contribute to the theoretical base for project design, or demonstrate applications of these designs.

Priorities for the choice of development programs should be:

1) evaluation of competing data collection methods for maximization of information content

2) development of statistical methods for interpretation of I&M program data, including data analysis, the handling of geographic information, risk assessment, and others

3) testing of methods for the assessment of degree of completeness of inventories

4) predictive models for assistance with project design in allocation of effort to competing sampling methods, choice of taxa or functional groups for a specific problem, and optimal size and number of sampling units

5) protocols for the identification of species or suites of species that can serve as indicators of ecosystem "health",

6) identification of I&M issues unique to the National Park environment.

Priority should be given to projects that:

- evaluate the utility, cost effectiveness and importance of invertebrate I&M data for in-Park decision making

- can help in developing system-wide standards

- assess the importance of invertebrate biodiversity in relation to both cultural and natural resources

- provide information on the role of invertebrates in ecological processes in ways amenable to public education.

b) Taxon and community-based surveys.

These projects are visualized as limited in scope, and unique to each Park in emphasis. They should provide baseline and monitoring data on invertebrate faunas that will be useful to park managers. This is an area particularly amenable to use of local experts for cost-effective small projects. Park-based managers are in a particularly excellent position to match management needs for I&M data on invertebrates with locally available talent, and this should be encouraged. Whenever possible, techniques should be used that will allow comparisons with other sites.

The studies recommended in a) and b) above can be performed at any park with appropriate natural areas, but should be concentrated at the designated NPS Invertebrate Monitoring Parks. The data should be stored so as to provide baselines for long-term invertebrate monitoring programs at these parks, and for comparisons across regions. Voucher collections should be maintained as outlined in Recommendation 3b.

5. **Foster the use of outside talent and expertise.**

a) Coordinate park needs with the interests of outside researchers.

No mechanisms exist to help researchers who want to work in a park learn of the park's most pressing research needs. Most parks do not have invertebrate specialists on their staff and can offer little guidance to incoming researchers as to the park's needs for inventory or other information on specific taxa. If a baseline inventory has been completed, including a survey of historical records for the park and a compilation of recent and ongoing research on invertebrate topics, the park should provide this inventory to scientists and ask them to consider how their collecting and other activities could be tailored to contribute to conspicuous gaps in the park's knowledge of specific taxa or habitats. Therefore, the Workshop recommends that:

- Each park develop a list of invertebrates known from the park (see Recommendations 1-3), and a list of unique habitats or other critical areas of interest to management. These lists should be made available to researchers when they apply for permits for research or collecting with the request that the researchers address gaps in the park's knowledge, and that they identify topics that need further study.

b) Minimize disincentives to outside researchers and collectors.

The Park Service has a very small pool of in-house experts on invertebrate biology, and must rely heavily on cooperators in universities, state agencies, and local interest groups. However, zealous application of current Park Service guidelines on collection, disposition, and curation of specimens has led to instances of frustration on the part of outside researchers. In some instances, researchers have been alienated to the extent that they refuse to work in National Parks, while others claim they are prevented from conducting research in National Parks. This situation compromises the Park Service's ability to accomplish its mission by hindering or excluding the research efforts of people who have the expertise and interest to assess the biodiversity and health of the parks. Researchers who work in National Parks often find the reporting requirements of the Automated National Cataloging System (ANCS) to be unreasonable and burdensome. These problems act as disincentives to researchers wishing to conduct studies in National Parks and thereby limit the ability of the

Park Service to obtain the expertise needed to inventory the biodiversity of parks. Therefore, in addition to the changes (regarding disposition of specimens) suggested in Recommendation 3b, the Workshop recommends that:

- The Chief Curator of the NPS work with members of the Invertebrate Workshop and other interested authorities, including the Association of Systematics Collections, to develop a modified version of, or compatible linkages to, the ANCS that reflect the needs of invertebrate researchers and meet the requirements of good systematic and curatorial practice. The modified version of the ANCS should be designed to be compatible with the goals of Recommendation 6.

- Park curators, especially those in natural area parks, be trained in biology, including systematics, and in the requirements of biological specimen curation.

- Individuals responsible for issuing permits for collecting or research be trained in the importance of invertebrates in park ecosystems, and the nature and purpose of invertebrate collecting techniques to permit them to better understand the reasons for issuing permits to invertebrate authorities.

6. **Standardize data bases for inventory information.**

a) Foster interagency/academic agreements

Data bases used to record invertebrate survey information in National Parks should be compatible with those used by other government agencies and by academic institutions (the Association of Systematics Collections is currently working on this issue). This will allow sharing of information and broader data bases for decision-making. Some features of currently-used data bases are more appropriate for archeological data or data from vertebrates or vascular plants, than for data from invertebrates. The existing ANCS system should be modified (as discussed in Recommendation 5) to be more suitable for invertebrate inventory. Sharing of information and expertise with organizations such as the Smithsonian Institution, USDA Systematic Entomology Laboratory, and the proposed National Biological Survey should be routine.

b) Coordinate with outside groups

A great deal of information on invertebrate diversity has been collected by outside groups, and much of this is relevant to resource management in National Parks. For example, the Nature Conservancy Natural Heritage Inventories have an information management system (Jenkins 1988) that is potentially of tremendous value to the National Park Service in developing its own invertebrate inventory and monitoring program. The current program of cooperation between the National Park Service and the various State Natural Heritage Programs should be encouraged and expanded to promote sharing of information on invertebrate faunas. Similar cooperation should be fostered with other organizations that represent special expertise in invertebrates (e.g., Xerces Society, Entomological Society of America) that can contribute to invertebrate inventory programs in the National Park Service.

7. **Assess needs and offer training on invertebrates.**

Education should be an important part of the NPS invertebrate management effort. The program should promote awareness of invertebrates in natural systems, educate park visitors and staff about invertebrate ecology, and provide special training for persons involved in invertebrate management. These goals address three different audiences: 1) general public, 2) park staff, and 3) park management.

a) Awareness

1) Public: Increase biodiversity awareness through park newspapers and interpretive programs on invertebrates and their roles in the ecology of each individual park.

2) Park staff: Plug into existing training such as seasonal interpretive training, or Introduction to Natural Resources training, to increase staff awareness of invertebrates as a park resource.

3) Park management: Review existing Resource Management Plans for invertebrate statements. Examine existing issues on invertebrates such as pest control, endangered species, or species of special concern. Create an action statement on invertebrates to be included in the park's Resource Management Plan.

b) Education

1) Public: Develop Visitor Center exhibits of invertebrates present in the park, and informational handouts or displays on trails and walkways.

2) Park staff: Offer one- or two-day courses on invertebrate ecology or basic curation techniques. Luncheon lectures should be given by researchers working in the park or from local universities.

3) Park management: Specific courses can be offered on areas of concern, i.e., endangered species, pests, and keystone species. Lectures and exchanges with local researchers and universities should be encouraged.

c) Training

- Park staff/management: Intensive training on curation, and on biology and ecology of invertebrate (pest and non-pest) species found in park areas should be provided to appropriate members of staff and management (e.g., Resource Management staff). Training should provide participants with a firm understanding of the role of invertebrates in ecosystem management.

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