The ATBI in the Smokies: An Overview

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Introduction

There is a fundamental flaw in how most parks and other natural reserves have been managed. In general, we have ignored a basic principle that would be fatal in the competitive world of business: we have never attempted a comprehensive inventory of our resources. This is surprising since the clearly stated purpose of most governmental and non-governmental conservation organizations has always been to protect and preserve the natural and cultural resources entrusted to their stewardship. How can we be intelligent stewards if we do not even know what kinds of resources we have, where they are found, their rarity, or, in the case of natural resources, some inkling of their ecological role?

In the summer of 1997 these questions were lamented by a handful of U.S. National Park Service (NPS), U.S. Geological Survey (USGS), and university professionals involved in natural resources stewardship and science at Great Smoky Mountains National Park. It was noted that over the years we were increasingly being forced to make many resource-impacting decisions without an adequate basis to judge the impacts on native species and natural processes. What we knew about threats to our resources, although not unique to the park, was alarming: exotic insects, fungi, plants, and fish were devastating certain natural communities; some forest types were being entirely lost; some of the highest depositions of nitrogen and sulfur in North America were occurring here; and 24-hour ozone levels were higher than in major cities in the region. Additionally, the park's general locale was rapidly developing, which meant loss of integral habitat exterior to the park. Within the park, an increasing number of road, land-trade, utility corridor, and other projects were being proposed by politicians, other agencies, and/or corporations. The consensus among Smokies' staff was that some of these proposals had the clear potential to cause drastic and permanent losses of species, but which ones? Where were they? How many occurrences did we have? What was their most sensitive season? What other species or natural processes were the rare ones dependent upon? We needed to know most of the answers to

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these questions before the projects were planned, or even conceived. We needed a comprehensive, practical approach to discovering the biodiversity of the Smokies, and we needed to get the bulk of it accomplished in a relatively few years. We discovered we needed an All Taxa Biodiversity Inventory, or ATBI.

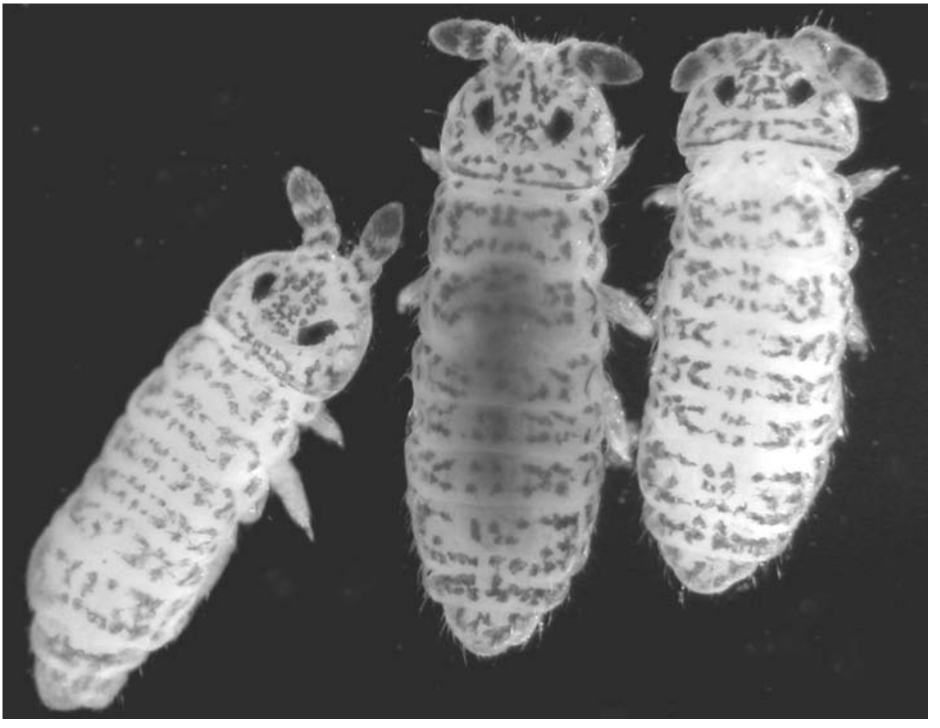
What is an ATBI?

Dan Janzen, the renowned ecologist, first conceived of the idea of an All Taxa Biodiversity Inventory, and coined the phrase, while conducting research in Costa Rica. Janzen's concern about rapid losses of tropical biodiversity prompted him to convene an international workshop to develop an approach for completing comprehensive inventories in a short amount of time (Janzen and Hallwachs 1994). However, an initial attempt at an ATBI in the Area de Conservación Guanacaste in northwestern Costa Rica was terminated in 1996 when the quasi-governmental organization responsible for receiving international funding and donations re-directed millions of dollars to other scientific endeavors.

Some of the words in the phrase "All Taxa Biodiversity Inventory" may be unfamiliar to the non-scientist. "Taxa" is the plural of taxon (taxonomic group); therefore, "all taxa" refers to all living things. "Biodiversity," though becoming a term more commonly used, is a relatively recent entry to the English language. The phrase "biological diversity" was first used in 1980 and the contraction in 1985. The simplest form of biodiversity is called species richness—the number of species found in a particular area—but that is just one component. While most people have an image of biodiversity as representing the biological variety across the living world, formal definitions include genetic diversity (on which each species depends) and ecosystem or habitat diversity (which provides the environmental setting and supports the lifestyle and interactions of those species).

An ATBI brings into focus the diverse worlds of all organisms, including species in more obscure groups. For example, of the more than 600 species new to science discovered since the ATBI began in the Smokies, many belong to the following categories: algae, lichens, mollusks, worms, spiders, crustaceans, pauropods, springtails, flies, moths, and beetles. The word "all" therefore represents the essence of this new thrust in research. Taxonomists often become specialists on a particular group of organisms, and so they rarely have the opportunity to work with taxonomists who are outside of their own area of interest. ATBIs, including the Smokies project, have created a context and forum for these specialists to reconnect to a more inclusive view of the tree of life and the diversity of organisms that have evolved and proliferated across the earth.

It is important to understand that the goals of an ATBI include compiling species lists, but lists by themselves are of little direct conservation value. An ATBI collects information on habitat, distribution, time and date of occurrence for the species observed, abundance, and where possible, life history information. All groups are included and eventually targeted for research, but no one is under the illusion that every single species will be found. This is impractical even for a smaller reserve, and not a primary goal of an ATBI (see Parker and Bernard, this volume). An ATBI should seek also to document and understand the ecological interactions and roles of the species that are found, such as para-



Cosberella lamaralexanderi, one of the springtail species new to science found by the ATBI. Photo courtesy of Ernest Bernard / DLIA.

sites, hosts, pollinators, or seed dispersers. The project must also incorporate approaches that lead to better understanding of conservation threats. In essence, an ATBI is about the discovery and taxonomic identification of species and the creation of museum specimens and data that document those species, but it seeks to develop taxonomic information in an ecological, conservation, and educational context.

The inventory in the Smokies

Great Smoky Mountains National Park is known for its biological diversity, especially in some familiar, charismatic groups, such as salamanders and vascular plants. But with its physical and geographic characteristics, it seemed probable that most of the park's natural wealth of species had yet to be discovered. There have been many past scientific efforts in the park which have provided excellent information on resources, but many of these were often sporadic and serendipitous, providing only minor relevant data for stewardship purposes, since that was ancillary to the research hypothesis being tested. At the rate we were accumulating inventory data in the past, it was roughly estimated that it would take about 150 years to complete a basic inventory of species in all groups of life. Clearly we did not have nearly that much time.

In the fall of 1997 a call was issued to interested scientists and others to attend a hastily convened, multi-day conference on the possibility of conducting an ATBI at the Smokies. It was scheduled for December

1997. Over 120 people, mostly from the sciences and especially the taxonomic community, participated—almost entirely on their own funding. Costa Rica had already been organizing centralized efforts at conducting biodiversity surveys for selected biological groups, and several biologists who work in Costa Rica, including Dan Janzen and Winnie Hallwachs, attended the initial ATBI conference as advisors. Several key points emerged from this intensive workshop:

- All agreed that a second attempt at an ATBI was imperative and that the Smokies was a good venue for that attempt.
- This project was too large for any one park, university, or museum to plan and manage. A new, private, non-profit organization, Discover Life in America (DLIA), was created and eventually incorporated. Membership and the board were drawn from the scientists and educators involved in the ATBI.
- There were to be three major thrusts or beneficiaries of the project: stewardship, science, and education. These three foci were to be integrated into operations as much as practical and the science focus had to be the lead. Biopharmaceutical activities were not a goal.
- The most effective and efficient approaches needed to be designed and tested as a pilot for other ATBI projects that hopefully would follow.
- Scientists identified their needs as: housing, a place to work, minimal bureaucratic "entanglements," "seed grants" to act as catalysts for other funding, and greater access and involvement with park staff. The park agreed to push for better facilities for visiting scientists, and to complete planned mapping of geology, soils, and vegetative communities to facilitate sampling design.

Superintendent Karen Wade and especially Assistant Superintendent Phil Francis became deeply involved in the planning aspects of the ATBI. In a ceremony on Earth Day, 1998, NPS Deputy Director Deny Galvin officially sanctioned the Smokies ATBI effort. No funding was made available to the project by the agency, however, beyond the part-time efforts of several biologists. A series of DLIA organizational meetings, internal agency meetings, scores of presentations to various civic, environmental, educational, and governmental groups—including to the White House Office of Science and Technology Policy—ensued over the next two years. These discussions reinforced the consensus that the Smokies effort had to be designed as a pilot for other follow-on projects.

Fortunately, funding and organizational support was provided initially by the Friends of Great Smoky Mountains National Park, an organization that seeks donations on behalf of the park. Eventually the Great Smoky Mountains Association, which is an official cooperating association of the park, also became a reliable supporter of the project. Total annual donated amounts averaged about $150,000. This allowed DLIA to hire a full-time director and eventually two part-time employees to plan and conduct operations. Park staff filled in gaps where tasks could not be performed by the non-profit or the many volunteers that the DLIA staff trained.

Park staff, USGS staff, educators, and especially scientists started to submit proposals for funding from other sources, and have been increasingly successful for short-term projects on specific topics, but the core administration and coordination of the project are supported primarily by donated funds. The National Science Foundation has recognized the merit of the project and has funded ATBI scientists on several projects aimed at specific species groups (see Langdon, White, and Nichols, this volume); however, the largest source of support has always been the donated time of the approximately 200 cooperating scientists, many educators, and volunteers.

The Science Plan

The Science Plan for the ATBI in Great Smoky Mountains National Park (White et al. 2000; http://www.dlia.org/atbi/quarterly_newsletter/pdfs/science_plan.pdf) was written to outline the goals, approaches, and structures for this large project. Five themes were articulated: (1) coordination across all taxonomic groups; (2) the Taxonomic Working Group, or TWIG, structure; (3) taxonomic inventory in a conservation and ecological context; (4) Geographic Information Systems as an organizational and analysis tool; and (5) involvement of the public and students of all ages. The Science Plan also lists questions to be addressed in the ATBI because these form the basis of how we can create an overall understanding that is greater than the individual field projects that are carried out. We briefly review those questions here under two headings from the Science Plan: (1) what explains patterns of diversity and distribution; and (2) how should the ATBI be done. We start with the first (and simpler) question, and then turn to a more complete discussion of the second question.

What explains patterns of diversity and distribution? Major factors that determine species distributions are the physical environment (warmth, moisture, geology, and soils), disturbance history (human and natural), and spatial properties (how large or isolated a habitat is, and the spatial location of habitats relative to other terrain features). Species with different niche characteristics, vagilities (the tendencies and abilities of species to move to different areas), and rates of gene flow will react differently to the park's environments, histories, and spatial characteristics so that the answers to these questions will differ in interesting ways among taxonomic groups. Examples of questions that address these issues include: Does diversity increase with warmth, moisture, and productivity, and decrease with elevation? Is diversity higher in old-growth compared with second-growth areas? Are some species limited to old-growth or second-growth areas? Is diversity higher in areas of large contiguous habitat than in small isolated habitats? How do environment and geography contribute to species diversity patterns in groups with different inherent vagilities and rates of gene flow? How do we use known occurrences to predict complete distributions from computer map data? Is diversity correlated among groups and can we use diversity in one group (e.g., plants) to improve the predictions of diversity in another group (e.g., insects)?

Answers to questions like these help conservation managers because they expand the understanding of the factors that influence the occurrence of species and create observations that provide evidence about such threats as exotic species invasions, air pollution, and habitat loss and fragmentation. Information from large wilderness areas can also help us develop an understanding of past human effects. For example, exploitive logging in the southern Appalachians caused severe soil erosion in many watersheds. The old-growth forests in the Smokies reveal soil organisms that may play an important role in forest productivity—and which are now missing from the formerly logged lands, both inside and outside the park.

How should an ATBI be done? In the Science Plan we describe two approaches to building taxonomic knowledge: traditional collecting and observing, and structured collecting and observing. We briefly describe these approaches here (see Parker and Bernard, this volume, for a more in-depth discussion).

Traditional taxonomic exploration. "Traditional collecting and observing" is the title we use for the typical field work of taxonomists. Based on their knowledge and experience of where to find new species, taxonomists explore the landscape intuitively. Because their work is inherently experience-driven, it tends, depending on that level of experience for each scientist, to be an efficient way to build a species list and to add knowledge about the occurrences (locations, time) of individual species. However, it is difficult to evaluate the completeness of the lists generated—the relationship of the species list to the amount of effort and habitats covered is often left implicit rather than made explicit.

Structured sampling, ecological zip codes, and accessibility. By contrast, structured collecting and observing adds a systematic sampling approach in which biodiversity reference areas or plots are arrayed

Hanging a flight intercept trap during a 2006 beetle blitz at White Oak Sink. Photo courtesy of Laura Childers / DLIA.

against the environmental factors that correlate with species distributions. The work of USGS researcher Chuck Parker in developing and testing passive structured sampling protocols has sharpened our understanding of the value and difficulty of this approach (see Parker and Bernard, this volume). It is difficult to develop protocols that aim to maximize collection of taxa, while minimizing collection of specimens and impacts, for the least effort and expense.

We are also developing sampling designs based on environmental gradients. One of our research teams (Peter White, Todd Jobe, Dean Urban) is exploring the concept of "ecological zip codes" which uses computer map data to assign an "ecological address" to every 30x30-m location in the park. In the current iteration, the ecological zip codes represent the temperature, moisture supply, and insolation (the amount of solar radiation an area receives). Other factors (e.g., soil, vegetation, fire history, and old-growth vs. second-growth forest) can be incorporated through direct contrasts of areas that cover the same range of other physical environmental factors. The zip code map can be used to select plots and reference areas in order to ensure that the observations cover the environmental variation of the park, but it can also be used to model the environmental habitat of species from location data and to find the extreme habitats (e.g., the coldest and wettest places in the park) for carrying out targeted surveys.

Graduate student Todd Jobe has also modeled the accessibility of each 30x30-m location in the park by calculating the amount of human energy required to reach that location by foot. This information can be used in two contrasting ways: first, to estimate the bias associated with accessibility (e.g., the most accessible locations have received the most inventory effort) and, second, to design sampling strategies that are efficient with regard to resources because they return the greatest information per unit effort (whether measured in time, area covered, or funds spent).

In carrying out an ATBI in the Smokies or elsewhere, the same issue arises; namely, that the total number of species that occur is not known before the start. We are reminded of a remark made by Phil Francis, then the park's assistant superintendent, at one of the annual ATBI meetings. He said that the question of how many species are in the Smokies brought to mind a frequent question from visitors to Mammoth Cave National Park: "How many miles of unexplored caves are there?" This, in fact, is the ultimate question that an ATBI grapples with. The number of species is unknown, and the rarest species often make the prediction of total diversity uncertain. But it is also important to realize that completeness is not the only goal of an ATBI: our goals also should be to advance knowledge as far as we can and to understand where we are on the knowledge-versus-effort curve. In striving to achieve these goals, we not only increase the adequacy of our databases for conservation decisions, but we also build a firm foundation for those who come after us to continue scientific work in a wide variety of disciplines.

Summary

ATBIs build libraries of information that are useful even beyond the borders of the conservation areas where they are carried out. They support the development and survival of taxonomic knowledge for society as a whole, test new protocols, and help us enthuse and train new generations of field scientists—in this sense, ATBIs are carried out for science. But ATBIs also build the knowledge base needed to ensure that biological diversity is conserved in specific reserves. They provide a deeper level of understanding about species and the natural processes that perpetuate them than is possible to achieve by any other means. They allow us to be the most intelligent stewards possible of our parks and other reserves—so in this sense ATBIs are carried out to protect nature reserves. However, our society is steadily diverging away from actually experiencing nature, let alone developing an intimate knowledge and appreciation of it. This is especially true of our children (Louv 2005). ATBIs could stand on their own for science and reserve protection reasons, but with the many pressures facing today's societies, the long-term survival of natural systems inside and outside of reserves is probable only if the public and especially youth have those connections. So ATBIs are also carried out for educational purposes, to share that sense of discovery.

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