Scientific Findings, Success Stories, Lessons Learned, and an Alliance of ATBIs

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Scientific findings

The most frequently asked question about the All Tax Biodiversity Inventory (ATBI) is "How many species have you found?" This is to be expected, as the ATBI is an inventory. The answer is presented in the "taxa table" (Table 1) below, and, more currently, on the Discover Life in America (DLIA) website (www.dlia.org/atbi/new_science/discoveries.shtml). However, when we are asked this question we always qualify our answer by stating the last date the table was updated. This is because the numbers change so frequently that keeping up is a major difficulty, but one we are pleased to be faced with. Since this article was written, bio-quests have been held, scientists have visited the park independently to collect specimens, and additional samples have been processed from the pilot study backlog. So the answer has changed since the table below was produced—of that we can be certain.

Success stories

Professional recognition. The National Science Foundation (NSF) is the premier funding agency in the United States for scientific research. Traditionally, proposals submitted to NSF for funding have a success rate of less than 30%. ATBI cooperating scientists have received funding from NSF for five proposals specifically aimed at research in association with the Smokies ATBI. These proposals involve pyrenomycetes (wood-inhabiting fungi); agarics (mushrooms and their relatives); algae, diatoms, and cyanobacteria (blue green algae); beetles; and the tree canopy biota. These grants total more than $1,500,000. The willingness of NSF to fund proposals to conduct research associated with the ATBI indicates that the reviewers are impressed with the scientific credentials of the scientists and the quality of their research, and also recognize that the ATBI is a legitimate scientific undertaking deserving of financial support.

From the beginning, the ATBI has been an international activity. Scientists from Costa Rica and Canada attended the first organizational meeting in 1997, and since then scientists from around the world have worked with us in conducting the ATBI. In addition to Canada and Costa Rica, scientists from France, Italy, Norway, Russia, Spain, Sweden, and Ukraine have either visited the park to conduct studies, or have identified ATBI material we provided them.

Reducing the taxonomic impediment. As detailed in Parker and Bernard (this volume), the taxonomic impediment is the shortage of authorities to meet the world's needs for taxonomic services, not just in tropical countries with rapidly disap-

TAXON	New to Science	New To Park	Total New
Microbes			
Archaea	6	1	7
Bacteria	92	59	151
Microsporidia	1	4	5
Protozoa	2	14	16
Slime molds			
Dictyostelids	10	8	18
Protostelids	8	12	20
Myxomycetes	2	130	132
Algae	67	528	595
Plants			
vascular	0	47	47
non-vascular	0	9	9
Fungi	25	347	372
Lichens	10	83	93
Nematomorpha (horsehair worms)	0	5	5
Mollusks (snails, mussels, etc.)	6	111	117
Annelids			
aquatic oligochaetes	0	17	17
earthworms	4	7	11
leeches	0	8	8
Nematodes (roundworms)	1	6	7
Tardigrades (waterbears)	14	56	70
Arachnids			
spiders	40	237	277
mites	6	47	53
ticks	0	6	6
Crustaceans (crayfish, copepods, etc.)	27	65	92
Diplopoda (millipedes)	1	1	2
Pauropoda (pauropods)	20	27	47
Symphyla (symphylans)	2	0	2
Protura (proturans)	10	5	15
Collembola (springtails)	60	116	176

Table 1. Discoveries of the Great Smoky Mountains National Park All Taxa Biodiversity Inventory (ATBI), as of 17 August 2006. "New to Science" species have never been identified anywhere in the world before the ATBI. "New to Park" species have never been identified in the park before the ATBI (i.e., they are new geographic records). "Total New" is the sum of the "New to Science" and "New to Park" columns. It is the total number of species that were not known to exist in the park prior to the ATBI.

Table 1 (continued).

TAXON	New to Science	New to Park	Total New
Diplura (diplurans)	5	2	7
Microcoryphia (jumping bristletails)	1	2	3
Ephemeroptera (mayflies)	4	11	15
Odonata (dragonflies, damselflies)	0	29	29
Orthoptera (grasshoppers, crickets, etc.)	0	45	45
Blattaria (cockroaches)	0	6	6
Plecoptera (stoneflies)	3	5	8
Psocoptera (barklice)	0	24	24
Pthiraptera (lice)	0	21	21
Hemiptera (true bugs, hoppers)	4	148	152
Neuroptera (lacewings, antlions, etc.)	0	23	23
Megaloptera (dobsonflies, alderflies, etc.)	0	1	1
Coleoptera (beetles)	34	1,200	1,234
Mecoptera (scorpionflies)	1	8	9
Siphonaptera (fleas)	1	9	10
Diptera (flies)	50	158	208
Trichoptera (caddisflies)	5	72	77

Table 1 (continued).

TAXON	New to Science	New to Park	Total New
Lepidoptera (butterflies, moths, skippers)	72	688	760
Hymenoptera (bees, ants, etc.)	27	60	87
Vertebrates			
amphibians	0	2	2
reptiles	0	2	2
fish	0	4	4
mammals	0	1	1
birds	0	1	1
TOTAL	621	4,479	5,100

pearing rain forests, but also in temperate areas such as North America. More students need to be encouraged to study systematics, and more opportunities for professional careers in systematics need to be developed. Thus, we are extremely pleased that the ATBI has contributed to reducing the taxonomic impediment by directly influencing students to pursue advanced degrees in taxonomy. Currently, there are at least 12 students who have worked on aspects of the ATBI during their degree programs, and may eventually make the career choice of becoming taxonomists. Two examples are Ian Stocks and Matthew Petersen. Stocks served as the principal technician on the ATBI pilot study in the Smokies and was responsible for plot maintenance and sample retrieval and processing. Although he came to us with a Master's degree and a professed interest in technical work with no desire to pursue a Ph.D., his experiences with the ATBI ultimately led to a change of heart and he is now is pursuing a doctorate in insect systematics at Clemson University. Petersen began working in the park as a field technician in the inventory and monitoring program. Like Stocks, he professed no interest in pursuing an advanced degree; however, he worked in the park during the time that the ATBI was being formulated, and eventually decided to take advantage of the opportunities it presented. Petersen currently is studying crane fly systematics at Iowa State University for his Ph.D. These two students are likely to be involved for years in working out the systematics of their two groups, and assisting other reserves conducting inventories.

Protecting the park. As data are accumulating from the ATBI, it has become a standard source of information for environmental assessments and the several full environmental impact statements (EISs) that the park has been deeply involved with in recent years. Results from comprehensive species inventories were instrumental in keeping critical resource sites within the park during a highly controversial and political land trade. Results are also influential in other EISs that are still going through the National Environmental Policy Act (NEPA) process. Routine environmental compliance is also better informed, and we are becoming better able to craft viable alternatives to initial proposals.

Awareness. All methods of communication are important, but we have emphasized the utility of the DLIA website, www.discoverlifeinamerica.org. A wealth of information is now presented here, and recently the ATBI database has come on-line and is linked from this site. Accessing the public version of the database, which has had rare, sensitive, and commercially collectible species locations removed, allows people to find on-going reports of georeferenced data.

The thrill of new discoveries has helped encourage local and regional citizens and students to become involved in the ATBI. But beyond the adventure of field exploration, there is a sense that the surrounding communities value the park more now, perhaps because of species that they may have helped discover. There has always been a "pride of place" sentiment around the Smokies, and that uniqueness now has deepened. It is difficult to quantify that change in the public's valuing of the park, but other parks and reserve staff who have visited and experienced ATBI activities have been moved to initiate their own ATBI projects based on that perceived increase in support.

Lessons learned

When the Smokies ATBI began, then-Superintendent Karen Wade observed that the undertaking was overwhelmingly an exercise in social engineering. With over 200 scientists (often assisted by students and technicians) and even larger numbers of citizen-scientists working on every facet of biodiversity in the park over the past eight years, great attention to detail is required to ensure that everything goes smoothly. While many things have worked extremely well, not everything has. We have highlighted some of the difficulties encountered during the pilot study that led to changes in the manner in which the structured sampling will be conducted in the future. Below we reiterate those points, and provide some guidance based on other lessons learned at the Smokies and at other ATBI projects that we are aware of.

- Begin with data management. Develop a data management plan that your area and your cooperators will agree to use. Require that people populate the database with their findings. However much you devote to data management, it will not be enough. But your program will only be as successful as your data management strategy.
- Taxonomists are a scarce resource. Do not waste their precious time. They may be willing to donate their services, but it should not be expected of them. Your ability to secure funding will influence your ability to secure taxonomic assistance.
- Collaborating scientists face their own bureaucracy in their home institutions. Do what you can to reduce agency bureaucratic burdens on them when they agree to work with you.
- Make sure there are social opportunities for cooperators. Taxonomists normally work independently, unlike ecologists who often work tribally, and volunteers who work best when positive reinforcement is optimized. Much innovative collaboration will result if social opportunities are encouraged.
- It is easy to over-collect specimens (see Parker and Bernard, this volume), especially during bio-blitzes. It becomes expensive to handle, to ort, and, especially, to identify specimens,

and then to process them for museum use. Avoid collecting just because you can, or because it is part of a public event; it does no good to have specimens in unsorted lots in storage for years.

- It is important when relying heavily on volunteers to conduct critical aspects of a complex activity to match the right volunteer with the right position. In the beginning of the ATBI, several scientists volunteered to serve as Taxonomic Working Group coordinators, and in most cases, these individuals have worked well. However, some were poorly suited to the tasks of coordinating fellow scientists (an activity often compared with herding cats) and it was necessary to find replacements for them. Recruit broadly, and then check with folks you trust who know the person. Some personality types are great enthusiasts but may not be good coordinators, or do not have a good track record on finishing things. (Quote from the first ATBI conference: "90% of life's successes and failures is due to personalities, the other 10% is due to weather.")
- Bio-blitzes and other large, intensive field collection events are fun, generate a lot of involvement by scientists and volunteers, and create positive popular press. However, it is easy for such activities to result in very little useable data when all is said and done. Not all field scientists understand how important it is for stewardship purposes to have accurate map coordinates for all samples. Things may be too rushed, and too many logistical issues may come up in the day or two that most blitzes run that will ultimately prevent you from assuring that the results are meaningful. These difficulties can be prevented with sufficient planning.
- Plan much more than you think you need for quality assurance in the data stream.
- Have designated people serve as specimen and specimen lot labelers so that no material goes unlabeled.
- Provide staff or volunteers trained in global positioning system (GPS) use and who know your spatial data accuracy requirements to assist visiting researchers.
- Make interactive mapping programs available for collectors to use in order to ensure the accuracy of collection locations, or have topographic maps available on which collection locations can be verified.
- Place someone in charge of checking all data that comes in, throughout the course of the event.
- Scientists appreciate decent lodging facilities for themselves and especially for their students. It also is desirable to provide a central place where groups can work together. If you treat them well, they will tell their network of colleagues, and perhaps they, too, will want to help out the next time.
- Everyone needs to be involved in keeping costs down, and being alert for new funding opportunities.

An Alliance of ATBIs

What is the most ecologically diverse nation on Earth? The answer depends on how you measure diversity. When the 14 non-marine biomes of the world are mapped, the U.S., with about 6% of the world's land area, has 12 of the 14 biomes—more by far than any other country (Udvardy 1975). Similarly when Bailey's ecoregions are mapped world-wide, the U.S. again has the most number of regions (Bailey 1989). In addition, the U.S. contains about 10% of the world's freshwater wetlands (Aselmann and Crutzen 1989).

But these are coarse filters and the U.S. would presumably not fare nearly as well as many other countries when other measures, such as species richness are used—or would it? Again, it may depend on what you measure. Certainly at the Smokies we, and especially our cooperators, have been surprised by the number of species we have discovered so far. In some groups, the number of species in the park rival or exceed the numbers in tropical rain forest areas. But in a larger sense this kind of comparison is so superficial that it misses the point: almost all of the species in the U.S. are different from those elsewhere, and deserve to be discovered, identified and thereby be protected in their own right.

How will we ever know what is natively found if we never undertake to sample this country? We now briefly outline a plan to do just that. Imagine an array of national parks, state parks or reserves, and other permanently protected areas organized for the purpose of undertaking ATBIs, which are roughly stratified across some eco-regional classification. That is, the deserts of the Southwest, grasslands in mid-country, polar areas, tropical islands, marine and estuarine areas, temperate coniferous and deciduous forest areas, and all the other major and minor "eco-regions" of the U.S. (see Stein et al. 2000). The total area of the U.S. included in these intensively sampled sites would be far less than 1% of the land area, and, as we learn in other articles in this volume, actual field samples in each area will be far less than 1% of the reserves being sampled. Still, this would give us tremendous insight into the biodiversity of those reserves, those ecoregions, the country, and the Earth as well.

This is what the Alliance of ATBIs is about. At this time, 19 reserves have begun exploring formally creating such an alliance (Figure 1). This includes 12 national parks, five Tennessee state parks, New York's Adirondack Park, and Nantucket Island, a Nature Conservancy/Massachusetts preserve. This alliance has come about because of the many inquiries we have received about how the Smokies ATBI operates and how it may be implemented in other places. Each ATBI, although individually managed, would subscribe to a minimum number of common-sense standards in communications, data collection and management, results-sharing, joint fund-seeking, etc., and agree to actively participate in the governance of the Alliance. The professional staffs of each reserve must voluntarily buy-in to the core principles that guide the project.

An Alliance office will need to be created to coordinate regional and national funding proposals, set up mechanisms to increase scarce taxonomic resources, operate publications and communications links and outlets, and other tasks collectively assigned to it. Funding for each project could potentially start with a local or regional source of donated funds, and professionals and volunteers in the area can be recruited to help organize and conduct operations. Major funding from corporations, foundations, and agencies in the form of grants, cost-sharing, and other funding mechanisms will be sought for multiple projects by the Alliance office, and groups

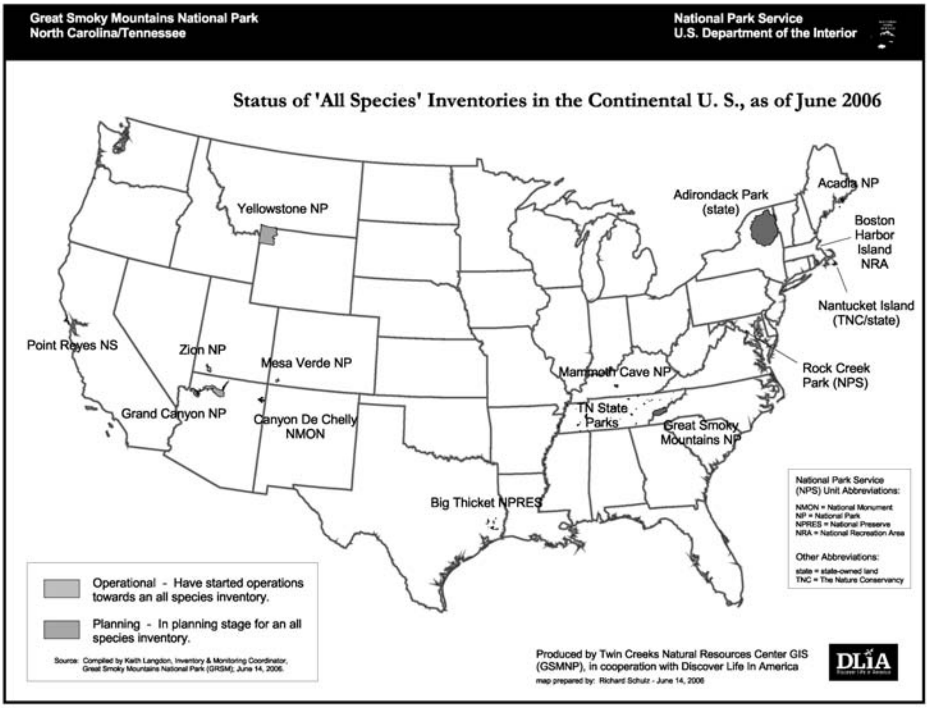

Figure 1. The Alliance of ATBIs.

of scientists should be encouraged to apply to their traditional grant sources, such as the National Science Foundation.

An ATBI is a comprehensive scientific inventory of biological diversity that includes citizen participation. It is more than a count of species, as it also highlights the relationships within an ecosystem and emphasizes how such relationships can inform and guide management decisions regarding the conservation of ecosystems. An alliance of regionally or locally based ATBIs takes the next organic step in understanding the ecology of unique ecosystems within North America and enhances local citizenship participation and stewardship of those systems. An alliance of ATBIs provides a viable means to share that understanding of organisms and their environments and to share lessons learned in developing, managing, and funding such inventory efforts. By getting the local and regional public involved in the science, the reserves each build stronger constituencies for their own long-term protection, and individually and collectively make a major change in America's connections with nature, and science.

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