



Great Smoky Mountains National Park, Great Smoky Mountains Association, Friends of the Smokies, and Discover Life in America

Nematodes – Little Wonders and Lots of Them

Ernest C. Bernard

Wherever you go in this world you are likely encountering nematodes. These tiny animals are the most abundant multicellular organisms on the planet; in temperate forests and agricultural soils there may be billions per acre feeding on fungi, plant roots, bacteria, and each other. The oceans teem with nematodes from beach sands to the deepest trenches. Nearly every species of invertebrate and vertebrate has its own suite of parasitic nematodes, and nematodes are second only to protists in the misery they cause to humanity. Many scientists believe there may be over 1 million species of nematodes, second only to arthropods, but only about 12,000 have been formally described. These organisms comprise the Phylum Nematoda, and common names for the group are nematode, roundworm, or eelworm. They are not related to true worms (Annelida) and should not be called worms. The common name is derived from the Greek word *nema* (thread), and refers to the threadlike appearance of these animals when seen with the naked eye.

Nematodes can be vertebrate or invertebrate parasites, plant parasites, bacterial or fungal feeders, or predators on other nematodes and microfauna. All of these types exist in abundance in Great Smoky Mountains National Park, but their presence has not been well documented. The best understood nematodes are the vertebrate parasites, some of which are more than 30 cm long (the longest nematode is a parasite of whales – 6 m long, and as thick as a pencil). Nematodes such as intestinal roundworms, guinea worms, and heartworms are familiar to most biology students; however, the vast majority of nematodes are much less than 10 mm long, and most soil species average about 1 mm in length. All nematodes feed on living organisms; contrary to popular opinion, there are no truly saprophagous nematodes.

The study of nematodes requires the use of stereo and compound microscopes, and specialized techniques for collecting and preserving them. They are not amenable to bio-blitzes, since collected soil, plant, or animal material must be returned to the laboratory for nematode extraction and processing to the point where they can be identified. Nematodes generally have few prominent external features, and so are differentiated by internal characteristics, some of which are visible with light microscopy. These difficulties have slowed our understanding of the diversity of free-living nematodes (predators, and bacterial, fungal, and plant feeders) with the exception of certain groups of economically important plant parasites, and also have slowed the ability of nematologists to conduct comprehensive



Fig. 1. Juvenile of a bacterial feeder (Rhabditida). Most nematodes lack color and appear translucent white in reflected light. Length 0.5 mm.



Fig. 2. With transmitted light, internal organs, and eggs are distinctly seen. Thelastomatidae (Oxyurida), female from millipede, length 2 mm.

All photos - Ernest C. Bernard

surveys.

Soil nematodes reach their greatest abundance in temperate deciduous forests (>3,000,000/square meter), therefore, the southern Appalachians should be among the best places to find high nematode diversity. However, surveys of free-living Smokies nematodes have been rare, with only three significant efforts of which I'm aware. Virginia Ferris of Purdue University sampled some soils in the 1960s-1970s during an extensive survey of leptonchid nematodes for her world revision of this family, and described two new species from the Park. In the late 1980s, during a structured survey of dogwood diseases in

Continued on page

A Note From Nancy Finley, Chief of Resource Management and Science

While being relatively new to Great Smoky Mountains National Park, I am not that new to the concept of an ATBI. Having been stationed at another prototype Inventory and Monitoring National Park for seven years and having served with the U.S. Fish and Wildlife Service for another seven years, I understand the value of biodiversity and more accurately the importance of knowing the breadth of the resources I am are charged with protecting. While my focus as Chief of Resource Management and Science for the Smokies is different than that solely of the ATBI, I clearly want and need the type of information the ATBI provides in carrying out my mission for the National Park Service. Plugging the specific resource information gathered by the ATBI into the Park's daily decision making is critical. That level of detail is not normally available to the federal government.

The task of organizing, planning and implementing the ATBI is no small one and all of those involved to-date should be commended for their persistence and hard work over the years. It has surely been a learning experience and one that is important to relay to emerging ATBI programs across the country. I look forward to the development of an alliance of ATBIs and believe this concept to be important for the future of the program. I would gladly assist in facilitating that process.

For the future, I look towards having ATBI data more readily available for Park managers and staff, as well as the general public. We currently are working on a divisional data management plan, which will assist in interfacing ATBI information with other Inventory and Monitoring data. It will be a good day when you can pull up amphibian data (collected through the ATBI) and overlay it with water quality data (collected through the Inventory and Monitoring program) and be able to determine species tolerances to acidic waters specific to the Park. Relational databases are necessary for this type of analysis and will optimize our programs.

I also look towards "completing" the ATBI project. We are a leader in this program but we also need to be able to demonstrate its importance in integrated decision making. I am told that if we can secure sufficient funding, a three to five year window is estimated to complete the main phase of the project and that implementation of structured sampling protocols will greatly assist in achieving this "completion." I recognize that some elements of the ATBI will continue long past the declaration of an "essentially complete ATBI" and appreciate the continued scientific and educational opportunities that the ATBI will provide for the community and future generations. That may be the most important legacy of the program; the idea of exposing those who have never thought much about science to a rare and important angle of science that most may never see.

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We are purging our email list! In order to stay in touch about training programs and ATBI activities, please email Jeanie Hilten (jeanie@dlia.org) a request to join the Yahoo! Group, DLIA Volunteers.



The ATBI Database is Now On-line!

Thanks to the efforts of many individuals and organizations, the 200,000-plus records in the ATBI Database so far can now be accessed on the internet at: http://www.discoverlifeinamerica.org/atbi/science/atbi_database.shtml. This URL is the introductory page for the program that serves up the database, and from here you can link directly to the database pages. This new site will provide various ways for users to search for distribution and specimen information at various taxonomic levels. Geo-referenced distributional data from ATBI research is displayed in the form of phenology charts (very useful for arthropod information) and maps showing where selected Park species have been found. Locations of endangered and otherwise sensitive species, of course, are not displayed.

We hope to have a separate domain name for this site later this summer. There may be a few "glitches" and some fine-tuning that still needs to be done on this new web project, so we encourage you to explore its current contents and send us your comments and suggestions for improvements and/or additions, especially if there are specific features you would like to see. Please respond to Chuck Cooper, Database Technician, at chuck@dlia.org.

the Park, Mary M. Dee of the University of Tennessee collected soil samples for extraction of nematodes. These nematodes are permanently mounted and maintained at the University of Tennessee, and have been partially identified. In the near future they will be entered into the ATBI database. One new species from that collecting effort has been described, but many other specimens represent undescribed species. The third and most recent effort has been the detection of insect-parasitic nematodes (Roberto Pereira and Ernest Bernard) and the diversity of nematodes in millipedes (Bernard). In the ATBI, internal parasites are covered by one TWIG, while free-living species and invertebrate parasites are included in the nematode TWIG.

Once one gets to the microscopic level, nematodes become extremely interesting. Nearly all species lack color, so with reflected light, they appear white and not very exciting (Fig. 1). With transmitted light, however, internal structures and organs are revealed (Fig. 2), especially the mouth region, digestive system, and reproductive organs. The mouth area, or anterior region, is an important key to understanding the many roles of nematodes in soil environments. Species of Mononchida prey on other nematodes, and have large, sturdy buccal (mouth) cavities and teeth for engulfing and ripping prey (Fig. 3). Three different orders of nematodes independently have evolved needle-like stylets, which are used for plant feeding or predation. Plant and fungal-feeding Tylenchida have stomatostylets (Fig. 4); Dorylaimida have odontostylets (Fig. 5); and plant-parasitic Triplonchida have onchiostylets (Fig. 6). These three stylet types form in a different way in each order.

Many nematodes are internal commensals or true parasites of arthropods. The intestine of every large millipede contains one or more species of oxyurid or rhigonematid nematodes (Figs. 2, 7). These nematodes usually are commensals, not parasites; they consume bacteria and protists inhabiting the millipede. However, they often have elaborately developed fringes, hooks, or sharklike teeth (Fig. 8) that enable them to grasp the intestinal wall and keep from being eliminated with digested food. Millipede commensals are easily obtained and are large enough to see internal organs with a stereo microscope. A truly parasitic order is Mermithida. These nematodes parasitize many different arthropods and kill their hosts when they emerge from the body (Fig. 9). Usually, mermithids are found incidentally emerging from trapped insects or insect colonies. So far during the ATBI, mermithids have been found incidentally in ants, spiders, springtails, caterpillars, caddisflies, and symphylans.

The study of GRSM nematodes is still in its very early stages, but most assuredly there are at least several hundred species, many of them undescribed, that eventually will be added to the Park inventory over the next few years.

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Fig. 3. Anterior end of a predacious nematode (Mononchida). Total length 1.5 mm.



Fig. 4. Anterior end of a plant-parasitic tylenchid, *Hoplolaimus* sp. Total length 1 mm.

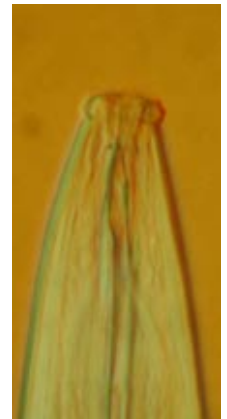


Fig. 5. Anterior end of a predacious dorylaimid, *Aporcelaimellus* sp. Total length 2 mm.



Fig. 6. Anterior end of a plant-parasitic triplonchid, *Trichodorus elefjohnsoni*. Total length 0.7



Fig. 7. Anterior end of a millipede commensal, *Rhigonema* sp. (Rhigonematida). Total length 4 mm.



Fig. 8. Jaws of *Rhigonema* sp., used for grasping millipede intestinal wall.



Fig. 9. Mermithid nematode emerging from spider.

Mike Ferro

Nancy Headlee



Round fungus beetle,
family Leiodidae.



Sap beetle, family Nitidulidae.



Short-winged mold beetles,
family Staphylinidae,
subfamily Pselaphinae.



Mike Ferro checking
containers of wood for
beetles.

Chuck Cooper

Dead wood represents an important habitat for many types of organisms, including salamanders, woodpeckers, mice, shrews, voles, fungi, bryophytes, vascular plants, spiders, pseudoscorpions, millipedes, centipedes, mites, and many insects. Surveys of European forests have shown that nearly half of all forest species are in some way dependant on dead wood. About one third (600 species!) of all beetles known from Great Smoky Mountains National Park are dependant during some part of their life-cycle on dead wood. Outside of protected areas, human activities such as logging often lead to drastic reductions in the amount and size of available dead wood habitat available for this diverse assemblage.

Dead wood can be large, small, fresh, not quite as fresh, a little rotten, and very rotten. In this study I collected rotting wood of different sizes and decay classes from old-growth and second-growth forests in the Park. Wood was then placed in large plastic tubs which have collecting jars attached to them. Adults and larval beetles that were already in the wood will "collect themselves" by falling into the jar when they emerge. I want to see which species use which type of wood, when they emerge, and if there are any species that are only found in old-growth forests, or only in second-growth forests. This is the first large-scale beetle rearing experiment of its type that I know of!

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The University of Tennessee's Educational Talent Search (ETS) is a program that works with student participants to inform them about specific areas where career opportunities abound. Science, technology, engineering, and math, known collectively as STEM, are career areas that have been identified as a top priority for development in the U.S. The goal is to double the number of STEM graduates with bachelor's degrees by 2015 (Source: The Education for Innovation Initiative, 2005). ETS high school participants are getting hands-on scientific research experience by working on the All Taxa Biodiversity Inventory project.

Each month, a team of ETS students goes to Great Smoky Mountains National Park to collect specimens of beetles and other insects as part of a research study to determine the contribution of dead wood to the life of the forest. The research is being conducted by Ph.D. candidate Mike Ferro of Louisiana State University, who gave the ETS students a microscopic look at their findings during the June collection event. DLIA volunteer Carol Cranford is the coordinator of the "citizen science" aspect of this two-year study. More information about the project and pictures of the group are on the DLIA website at:

http://www.discoverlifeinamerica.org/dlia/volunteer/images/beetle_wranglers_2006/index.html

Over 1000+ students from 17 Knoxville area middle and high schools annually engage in career exploration and academic outreach activities through this Title IV U.S. Department of Education grant. Dr. Ernest Brewer serves as the Principal Investigator, and Leigh Ann Campell, a psychology graduate with a Masters in Education Administration, helps with the program. She notes that the young people involved are the first generation of college-bound students in their families. Most have not had the chance to visit Great Smoky Mountains National Park before, and several have already asked, "When can we come again?"

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Citizen Scientist: Carol Cranford



Charles Wilder

Beetle Wrangler (back row center) and her team of volunteers.

With a B.S. degree in Biology and a M.S. degree in Entomology, both from Auburn University, I spent many years as a biology instructor and counselor at a community college in north Alabama. I loved the association with my students, but I certainly could do without grading papers and some of the other tedious aspects of teaching. I recently retired in order to fulfill my life-long dream of being able to live, at least part-time, in the Smoky Mountains. Frequent trips to the Smokies during childhood began my love for these mountains, and now I spend my time learning more than teaching.

In conversation with a local artist in Gatlinburg, I first learned of DLIA and the possibility of volunteering with them. She gave me Jeanie Hilten's number and the rest is history. For almost two years, I have been a volunteer in the DLIA office. I started by helping with the annual meeting and doing office chores. Now I have taken on a project which involves coordinating monthly collections of invertebrates from various types of wood in different stages of decay. We call this the "Beetle Wrangling of Dead Wood" project, which is the dissertation research of Mike Ferro from Louisiana State University.

I have learned so much from Park scientists and also enjoy working with students and other citizen scientist volunteers. I love to see the students' amazement of what is found in the samples! By learning and helping others to learn about the biodiversity here, I feel I am contributing a small amount to the conservation of our Park.

Carol Cranford
DLIA Volunteer

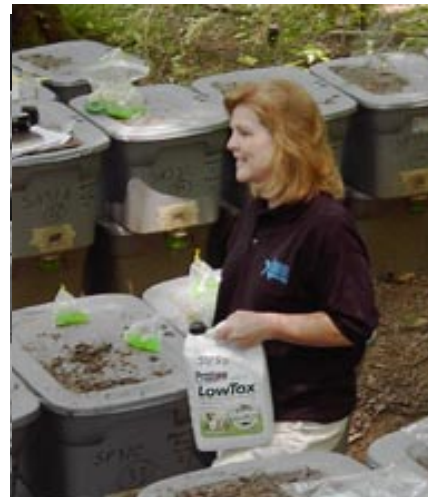
"As a volunteer on this project, I have learned so much from the professionals involved about the diversity of organisms in the Park and how they each affect the health of the Park. Since I am a former teacher, working with the students and watching them discover some of the Park's inhabitants has truly been exciting for me."



Charles Wilder



Charles Wilder



Chuck Cooper

Nancy Headlee directing Beetle Wranglers.

Scientist Profile: Pat Cox



Jeanne Hillen

Patricia (Pat) Cox is a Senior Botanist for the Tennessee Valley Authority Heritage Program, and is a DLIA board member. Her expertise is plant taxonomy and systematics, and plant anatomy. She has 30+ years experience as a field botanist with 13 years spent in academics at the University of Tennessee, where she taught

I have been interested in the outdoors since I was three. My dad would take me fishing in Louisiana bayous, lakes, and rivers, but I was only allowed to go if I baited my own hook - so began my love for anything that lived outdoors.

While in college at Northeast Louisiana University (NLU) I took a course in plant systematics, and my professor was Dr. Dale Thomas. The first class field trip was to a cemetery, where Dr. Thomas and his assistant got down on their knees with their hands behind their backs and had a contest as to who could eat the most *Viola rafinesquei* (wild pansy). Just as I was wondering what I had gotten myself into, they made us all get down on our hands and knees and start searching for a little fern, *Ophioglossum* (adder's tongue fern). Looking back now, it was THAT day that changed my life. I was hooked!!! Over the next three years I took every botany field class Dr. Thomas taught (aquatic plants, dendrology, field botany, and several special topic classes). He took us on field trips to places I had never been and I learned plants I had never seen before. After undergraduate school, I started my Master's degree at NLU with Dr. Thomas.

Most of Thomas' students had been doing flora projects for their degrees. I had asked to do the flora of my home Parish (Rapides); he told me no, because it was an important Parish and he needed a man to do it just in case I ended up getting married, quitting school, and not finishing the project (you have to remember that this is in the mid-70's before many women were in biology). So for my research project I did the flora of Morehouse Parish. It didn't really matter to me because it was an incredible way to learn plants and of course in hindsight he regretted not letting me do what I wanted.

During my master's program, I became very interested in ferns, especially the little *Ophioglossums* that tended to prefer cemetery life. However, for my doctorate I ended up working with the family Asteraceae with Dr. Lowell Urbatsch at LSU. My research centered around the systematics and taxonomy

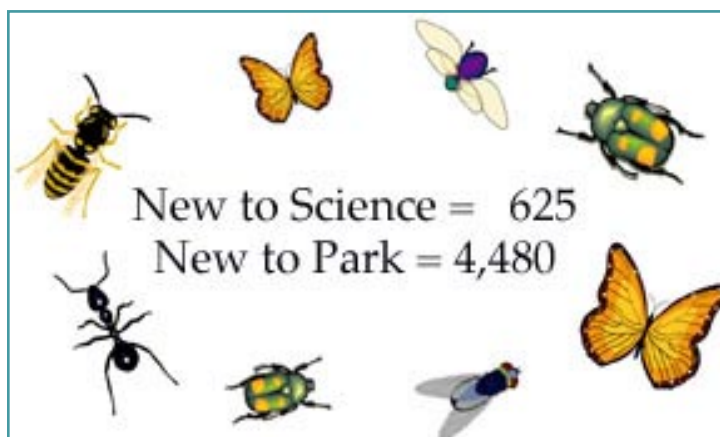
of *Rudbeckia* subgenus *Macrocline*. Just before graduation, I accepted a teaching post-doc at the University of Tennessee (I finally made it to east Tennessee and FERNS).

After 13+ years in academics it was a big step for me to leave UT and begin my new career working as a Botanist for the TVA Heritage Program. I miss teaching, but I love this job and I feel we are doing our part to help protect the natural resources of this area. Since coming to Tennessee, I have grown to love the Smokies and am proud to be part of the ATBI, working both as a volunteer and a researcher. My research for this project involves using the trails as transects to map the fern species in the Park. Over the past five summers, with the help of volunteers, over 200 miles of 50+ trails have been mapped for ferns. This past spring at the annual meeting of the Association of Southeastern Biologists, I organized a symposium entitled "ATBI: a search for species in our own backyard." Twenty-two ATBI scientists and Park staff gave presentations about their research and the proceedings of the symposium will be published as a special issue of the Southeastern Naturalist. This will be an excellent venue to expose the project to the scientific community.

Someone once told me that my job was being a botanist, but that it wasn't who I was. I didn't agree. Being a botanist is WHO I am; it's a passion, and a part of me that can't be separated out. I can't imagine doing or being anything else.

Pat Cox
TVA Heritage Program
pbcox@tva.gov

Taxa Tally



Becky Nichols
Park Entomologist

Teachers Trained in ATBI Science Methods

Susan Sachs

"Thanks for putting us side by side with researchers and other science educators."

"All of these topics are in the North Carolina biology curriculum. I will use the information either directly or indirectly to improve my classes and introduce various topics."

These quotes, from two teachers who participated in the 2006 Science Teacher Institute held at the Great Smoky Mountains Institute at Tremont, sum up why we offer a week-long experience using ATBI field researchers as instructors. Each day was set up to focus on a different habitat and to highlight some of the unique research in the Smokies. The planning team for the workshop specifically picked researchers whose field methods can be easily replicated in a schoolyard or nearby natural area. The goal is to give teachers first-hand field experience to take back to the classroom; and often what goes along with this experience is enthusiasm.

The workshop, now in its fourth year, was funded by the North Carolina GlaxoSmithKline Foundation through a grant obtained by Friends of the Smokies. Participants were primarily middle and high school science teachers from throughout North Carolina. Investigations for creatures were held in various habitats, including moss beds, slimy rock walls, creeks, high elevation spruce-fir forest, and even the sewage pond near Tremont. Teachers reported that highlights of the week were snorkeling for hellbenders with Michael Freake, searching for snails with Dan and Judy Dourson, scraping algae with Paula Furey, sucking up insects with Mike Ferro and Matt Grimmell, investigating the creek for aquatic insects with Becky Nichols, navigating through GIS with Mark Ethridge and being amazed by fireflies and bees with Adriean Mayor.

The workshop will be held again next year, and the planning team is exploring the idea of expanding into a second week for alumni that will focus more in-depth on how to use data in the classroom once it has been collected in the field. Several of our studies have internet databases and other on-line opportunities that teachers can use to incorporate more math and GIS mapping into the classroom.



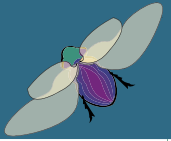
Snorkeling for hellbenders in Little River.



Matt Grimmell assists teachers with insect identification in the field.

A special thank you goes out to the workshop planning team, which consists of members of the DLIA education committee, Tremont staff, and NPS Resource Education staff. If you would like to be involved in next year's workshop, please contact Susan Sachs at 828-926-6251.

Susan Sachs
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Susan_Sachs@nps.gov



Mark these events on your calendar and stay tuned for more details and other programs. See the website at www.discoverlifeinamerica.org or www.dlia.org. For more information, to add an event to our calendar, to learn about DLIA's volunteer "project teams," or to sign up for activities, contact Jeanie Hilten, 865-430-4752 or Jeanie@dlia.org.

Saturday, August 12 - Wednesday, August 16: Lepidoptera Bio-Blitz. As the Lepidoptera list approaches completion we hope to add a large number of species to our DNA barcoding database. The bio-blightz will target late summer species. Contact Brian Scholtens, scholtensb@cofc.edu for more information.

Monday, August 14 - Tuesday, August 15: Geology Investigations, Appalachian Highlands Science Learning Center. Rob Young from Western Carolina University will lead the activities. Contact Susan Sachs, Susan_Sachs@nps.gov or 828-926-6251.

Friday, August 18 - Saturday, August 19: Discover Life in America Board Retreat and Meeting, Balsam Mountain Preserve. RSVP to Jeanie Hilten.

Saturday, September 2: Fern Foray #4. Contact Patricia Cox, pbcoc@tva.gov.

Friday, October 27 - Sunday, October 29: "Fall Research in the Smokies" Seminar, Appalachian Highlands Science Learning Center. Held in conjunction with the NC Museum of Natural Science, this seminar for educators will include participation in the ATBI snail inventory and long-term monitoring of lichens, elk, and possibly salamanders. There is a \$45 fee, which covers lodging and some meals. To sign up, contact Mike Dunn, Mike.Dunn@ncmail.net.

Monday, December 4 - Tuesday, December 5: "Biodiversity Data Interaction for an Alliance of ATBIs" Data Workshop, Holiday Inn Sunspree, Gatlinburg, TN. Sponsored by a grant from NBII/SAIN. Contact the DLIA office.

Wednesday, December 6 - Friday, December 8: 10th Annual ATBI/DLIA Conference, Holiday Inn Sunspree, Gatlinburg, TN. Contact the DLIA office.

The deadline for submitting articles for the Autumn issue of the ATBI Quarterly is October 10th.

The ATBI Quarterly is available on the DLIA web site at: www.dlia.org/atbi/quarterly_newsletter/quarterly.shtml or, to continue to receive a hard copy, consider sending a \$10.00 donation to Discover Life in America.



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