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Forum

Creating Encyclopedia of Life's species pages for ants (Hymenoptera: Formicidae): What we have done and what remains to be done

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Abstract: In the current era of the internet, sharing information has reached dimensions never before imagined and greatly impacts daily life, education, and science. The Encyclopedia of Life (EOL) aims to make knowledge about all the world's living organisms available to anyone at anytime. With over 12,500 described species that constitute 15 - 20% of the animal biomass in most terrestrial areas, ants (Hymenoptera: Formicidae) are one of the most abundant groups of organisms on the planet. At a recent meeting held at the Field Museum of Natural History, ant biologists from around the world came together to discuss how the Global Ant Project will contribute to the greater mission of EOL to benefit both the scientific community and the public. Specifically, the ant community will improve and expand freely available online taxonomic resources including a complete taxonomic catalog, specimen images, distribution data and general biological notes, making all this available to EOL via AntWeb. These readily available World Wide Web resources, which rely heavily on basic taxonomic research and training as well as on research collections, facilitate all aspects of ant biology from taxonomy to conservation. In this meeting review, we highlight areas that will be impacted by an informative Encyclopedia of Life, and also address the key challenge of incorporating the many readily existing resources in this enterprise.

Key words: Encyclopedia of Life (EOL), internet, Global Ant Project (GAP), collaborative taxonomy, meeting review.

Introduction

"Imagine an electronic page for each species of organism on Earth, available everywhere by single access on command" (WILSON 2003). With this bold vision and by helping facilitate fund raising from several agencies, E.O. Wilson placed the cornerstone for the Encyclopedia of Life (EOL; <http://www.eol.org>). EOL was launched in May 2007 a couple months after Wilson was awarded the TED (Technology, Entertainment, Design) Prize, with support from the Sloan and MacArthur foundations. E.O. Wilson, a myrmecologist himself, stated his wish *"to help create the key tools that we need to inspire the preservation of Earth's biodiversity"* (WILSON 2007).

EOL is an online-encyclopedia with the goal to provide web pages for every known living species on Earth. Content can be in the form of audio and video material, figures, graphs and text. The first version of the website went online February 2008. To date, the EOL website hosts over

180,000 content pages as well as 1.2 million stub pages. Their 10-year goal is to have content-informed pages for 90 percent of the 1.8 million currently known species. To support EOL's greater mission, the Biodiversity Synthesis Center (BioSynC) hosted at the Field Museum of Natural History in Chicago, IL, USA brings together researchers to discuss ways to contribute to EOL. The second Global Ant Project (GAP) synthesis meeting was held on 5 - 7 November 2009 at the Field Museum. In this meeting review, we will describe past accomplishments and future goals of the myrmecological community to make data available to EOL. We aim to illustrate the importance of an informative Encyclopedia of Life and by this encourage experts to take part in this endeavor.

Web-based resources on ants

Ants (Hymenoptera: Formicidae) are among the most abundant terrestrial life forms and often comprise more than 80% of the arthropods in tropical rain forests (HÖLLDOBLER & WILSON 1990, DAVIDSON & PATRELL-KIM 1996). Approximately 12,500 ant species are described to date (BOLTON & al. 2007, <http://antbase.org>), but the evolutionary history of the earliest living lineages is not yet fully resolved (WARD 2007, MOREAU 2009) and astonishing new species are still being discovered (RABELING & al. 2008). A wide range of excellent websites exist that share invaluable information on ant identification, ant blogs, literature, and other helpful resources. Listing them would be beyond the scope of this meeting review, but compilations are given on the GAP homepage (<http://gap.entclub.org/resources.html>) as well as by KLINGENBERG & VERHAAGH (2005) and NASH (2005). Plans to sequence eight ant genomes have recently been announced (SMITH & al. 2010; <http://www.antgenomics.org>) opening up a vast range of possibilities in the study of ant biology. Large scale DNA barcoding of ants is already being accomplished and represents a promising tool for biodiversity assessment (SMITH & al. 2005).

The Encyclopedia of Life represents powerful means to make all this knowledge of ants available to both the scientific community and the public. Information is acquired by assembling content from various online sources, which is then authenticated by specialists or by direct submission by EOL curators. Currently it is a debate as to whether EOL should just be a mash-up of readily existing online content or create highly informative species pages. Ultimately, it will be the decision of each taxonomic community of how informative EOL will grow.

The Global Ant Project (GAP) was created as a consortium of myrmecologists, who welcome new participants, with the goals of facilitating all forms of ant research and assisting the creation of species pages for each ant species. At this time, GAP has endorsed and promoted AntWeb (<http://www.antweb.org>) as the main repository of images and specimen data. AntWeb was founded in 2001 by Brian

L. Fisher and is hosted at the California Academy of Sciences, San Francisco, CA, USA. About 40 remote curators currently contribute images and specimen data to AntWeb on regional pages. As of 10 June 2010, AntWeb pages include 210,336 specimens, 14,095 extant valid taxa, 10,600 specimens imaged, and 4,674 species imaged (<http://www.antweb.org>). One goal set by the group of myrmecologists at the meeting was to help facilitate the inclusion of natural history data into AntWeb, which could then be shared with EOL. AntWeb is already serving content to EOL and Wikipedia (<http://www.wikipedia.org/>), based on software developed by AntWeb programmers. Distribution data for species is provided by Plazi (<http://plazi.org/>) and Antweb into GBIF (<http://www.gbif.org/>) and from there into EOL. An overview of the current contributors to the ant species pages on EOL is given in Figure 1.

Web-based identification tools

Identifying an ant specimen can be tricky even for experts, in part due to the fact that complete taxonomic keys containing all the known species are rare, comprehensive field guides are scarce and the original species descriptions are often buried in obscure journals. Web-based ant identification tools can help everyone from trained entomologists to schoolchildren by facilitating species identification. AntWeb features image comparison tools and enables mapping of specimens using Google Earth (<http://earth.google.com>). Users can also download field guides with images for specific regions and / or taxa. High-resolution auto-montage images of thousands of ant species, along with information included in traditional taxonomic catalogues of species are provided on the web via AntWeb and other online resources. Primary taxonomic literature is available through the Biodiversity Heritage Library (<http://www.biodiversitylibrary.org>) and Antbase (www.antbase.org). Recent literature is indexed in ZooBank (<http://www.zoobank.org/>), linked to Plazi and made available to EOL. Zoobank and Antbase also index all new described ant species thereby providing a current up to date number of described ant species available online. Since 2002, the taxonomic ant catalogue (<http://antbase.org>, Hymenoptera Name Server: <http://osuc.biosci.ohio-state.edu>) is constantly updated and feeds into EOL through ITIS (<http://www.itis.gov/>), Species 2000 (<http://www.sp2000.org/>) and the Catalogue of Life (<http://www.catalogueoflife.org/>) (Fig. 1).

The use of these technologies sets new standards for collaborative online taxonomy. Taxonomic descriptions are dependent on repeated examinations of type specimens and published literature. For the first time, type specimens can be illustrated by high resolution digital photographs, the anatomical detail and depth of field of which are beyond those often seen in specimens viewed by light microscopy. These online photographs can be accessed by anyone anywhere. The necessity for shipping type material will likely decrease dramatically as many morphological characters can be viewed online as type and other specimens are imaged. When the original diagnoses from print literature are added, experts can proceed with revisions at a speed and an economy vastly greater than enjoyed in the pre-digital era. The process of identification and description of new species will be accelerated with products accessible across a broad community of users (e.g., LONGINO 2009). Taxonomy can be globalized and democratized (WILSON 2003)

and online resources, such as EOL, can provide the framework to access all this information.

Ants in conservation biology

Correct species identification is fundamental for biodiversity assessment and conservation management. Ants are considered particularly useful for biodiversity monitoring. They are abundant and ubiquitous in both intact habitats and disturbed areas, they are easily collected and do not require enormous expertise to locate (MAJER 1983, CRIST 2009). Ants have proven sensitive and rapid responders to environmental variables (see AGOSTI & al. 2000 for an overview). An internet-based database of ant images is expected to help ecologists and conservation biologists study and preserve global ant diversity and make the public aware of species richness by providing the taxonomic tools to identify and document the planet's diversity. Evaluating how ants respond to environmental change at the species level has become increasingly feasible in regions such as North America and Madagascar, where web-based identification tools can help pinpoint geographic variations in morphology and distributions (UNDERWOOD & FISHER 2006, KREMEN & al. 2008).

Initial attempts to include ants in the IUCN red listing have proven difficult, because too little is known about the general biology and distributions of most ant species. With well maintained species pages on EOL and other databases this obstacle may eventually be overcome, especially if myrmecologists from around the world contribute to these databases with both published and unpublished records and observations. With this data available informed conservation decisions and assessing species threat status can then be accomplished.

Foundation for taxonomic research

Although online tools can be helpful in taxonomic research, they will never replace the careful research and countless hours of work done by well-trained scientists. Sampling, processing, identifying, properly storing and describing specimens are fundamental aspects for understanding biodiversity. Tropical remote regions are often biodiversity hotspots and many more species await description in these countries requiring training of local researchers. Training initiatives as for example ANT COURSE (<http://research.calacademy.org/ent/courses/ant>), which is independent of the GAP program, are great opportunities for ant biologists whose research responsibilities require a greater understanding of ant taxonomy and field research techniques. In addition to training future scientists, preserving and growing museum and university collections for future research is among the basic foundations necessary to support EOL's mission in the long term. Museum collections make innumerable contributions to science and society in various fields (SUAREZ & TSUTSUI 2004).

Challenges

Currently, the majority of information on ants is contributed via AntWeb to EOL and a large proportion of these pages contain high resolution z-stack images, but not much text. Experts on ants are needed to participate as EOL curators and provide content including basic natural history data to the pages for the groups they study. Biology students can create species pages with their mentors, as is be-

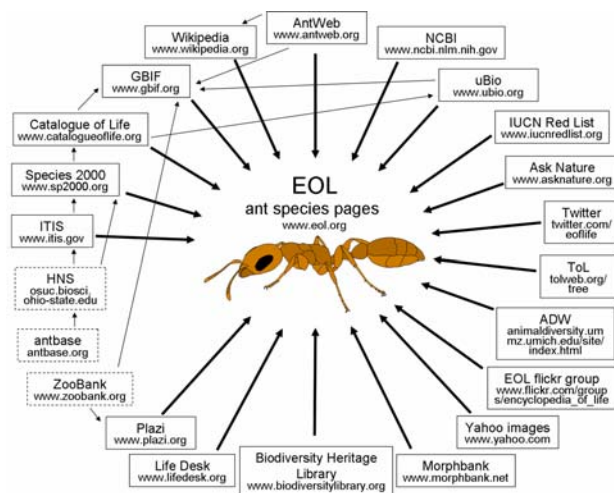


Fig. 1: Providers that contribute content on ants (Hymenoptera: Formicidae) to the species pages of the Encyclopedia of Life (EOL). Arrows indicate how the different web portals interact and direction of data flow with thick arrows indicating data flow directly to EOL and thin arrows indicating data flow between the respective contributors. Providers that contribute indirectly to EOL are indicated with dashed boxes. The URL of each website is provided.

ing done at the Field Museum as part of the NSF REU summer intern program. It is a key challenge to make all of the readily existing knowledge on ants available to EOL and unified efforts are required to fulfill the mission of EOL and at the same time reduce the duplication of results. One potential way to unify the numerous online efforts of myrmecologists would be to have EOL provide the framework to marry all of these separate efforts under a single umbrella, while still allowing the independent development and maintenance of individual ant websites. Anyone can take part in EOL's mission and detailed instructions can be found on their website (http://www.eol.org/content/page/help_build_eol).

Making content freely available online to the research community is a common trend with free access journals like the BioMed Central series or the Public Library of Science series. Data-sharing standards are now routine for scientists in molecular genetics (e.g., GenBank) and morphological research (e.g., Morphbank and Morphobank) and are of great benefit to the progress of science. EOL has great potential, but at the same criticisms and shortcomings of the EOL mission and implementation have been pointed out (e.g., blog by Roderic Page: <http://iphylo.blogspot.com/2008/02/encyclopedia-of-life-first-impressions.html>).

Developing the required software and imaging specimens is costly, while taxonomy and basic research in natural history require well-trained biologists and are time consuming. Funding agencies need to be made aware of this and must be willing to provide funds for data contribution, museum storage, and basic taxonomic research. Data sharing and public outreach should lie in the interests of such agencies. Providing online resources for entire taxonomic groups, as the ants, makes possible the scientific and conservation enterprise to anyone, anywhere on the planet. Our hope is that the notable efforts as already accom-

plished by the ant community and outlined here will be expanded and mirrored across the entire tree of life.

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Zusammenfassung

Im heutigen Zeitalter des Internets hat der Informationsaustausch zuvor nicht vorstellbare Dimensionen erreicht und beeinflusst Alltag, Bildung und Wissenschaft. Die Encyclopedia of Life (EOL) hat sich zum Ziel gesetzt, Wissen über alle lebenden Organismen frei zugänglich zu machen – für jedermann und jederzeit. Mit über 12.500 beschriebenen Arten, die rund 15 - 20 % der tierischen Biomasse in den meisten terrestrischen Gebieten ausmachen, sind Ameisen (Hymenoptera: Formicidae) eine der ökologisch und numerisch häufigsten Organismengruppen. Im Rahmen einer Tagung am Field Museum of Natural History haben Myrmekologen Möglichkeiten diskutiert, um das Ziel von EOL zu unterstützen, wodurch sowohl Wissenschaftler als auch die breitere Öffentlichkeit profitieren werden. Konkret wird das Global Ant Project die frei verfügbaren Online-Ressourcen erweitern und verbessern. Ein vollständiger taxonomischer Katalog, Automontage-Fotos, Angaben über Verbreitungen und allgemeine biologische Informationen sollen EOL durch AntWeb zur Verfügung gestellt werden. Diese bereits im World Wide Web verfügbaren Ressourcen, die auf grundlegender taxonomischer Arbeit, auf Ausbildung von Jungwissenschaftlern sowie auf Sammlungen basieren, werden alle Aspekte der Biologie erleichtern. Wir skizzieren hier vergangene Erfolge sowie Ziele und nennen Bereiche, welche durch eine informative Encyclopedia of Life profitieren werden. Gleichzeitig betonen wir die Herausforderung, bereits vorhandene Ressourcen für EOL zugänglich zu machen.

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