Standing on the Shoulders of Taxonomists: Electronic Field Guides and User Communities in the Ecoinformatics Revolution

VERSION [1.50]

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What would Florence Merriam Bailey and Roger Tory Peterson have invented, if they had grown up with Personal Digital Assistants (PDAs) and the Internet?

Abstract

The recognition that taxonomy is central to the conservation of biodiversity has reestablished the critical role of taxonomy in biology. Taxonomists describe and name species, and curate collections. In addition they construct keys allowing others to identify species correctly. These keys, often of the dichotomous type, have been difficult to use and are largely ignored by the general public in favor of field guides, essentially browsable picture guides. We review the role of field guides for identification and discuss the application of electronic and digital technologies (scanners, digital cameras, color printers, GPS units, digital libraries, and the Internet) to produce user-friendly methods of identification. Substantial progress has been made in developing new approaches and it appears likely that new technologies will greatly enhance species identification in the field by non specialists. We advocate the use of empirical tests, cross cultural studies, and cognitive and human developmental frameworks for improving identification methods. We suggest that wider adoption of the citizen science model and use of electronic field guides to identify species will enhance public understanding and participation in biodiversity monitoring and assessment.

Introduction

During the last 20 years attention to the loss of our biological heritage and resources has moved from a largely academic concern to a mainstream policy issue at all levels of society. The term "biodiversity" came into widespread use in the late 1980's (Wilson 1989, Reid and Miller 1989, McAllister 1997, Read 1997) and, along with the term "nature's services" (Daily 1997), has come to symbolize these concerns. Activities by scientists, NGO's, educators and governments directed at the biodiversity crisis continue to grow. (For recent examples see Ricketts et al. 1999 or Stein et al. 2000 or sample some of the many internet sites beginning at http://www.sciencemag.org/feature/data/biodiversity2000.shl, http://www.geocities.com/RainForest/Vines/8695/, or www.biodiversity.uno.edu/). The sponsorship of the Global Biodiversity Information Facility (http://www.gbif.org/) by the Organization for Economic Co-Operation and Development (http://www.oecd.org/) testifies to the understanding that biodiversity conservation is a critical issue of global significance.

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At the core of biodiversity conservation efforts are the discovery and maintenance of knowledge about species and their distributions. For the last 250 years, since Linnaeus (Knapp 2000), this task has been the purview of taxonomists who work in collections where specimens are housed. Unfortunately knowledge of biodiversity is limited (Certainly less than 20% of the estimated species have received scientific names) and human and physical infrastructures for recording, cataloguing and identifying species are currently insufficient for the task (Janzen et al. 1993, Raven and Wilson 1992, Blackmore 1996, Wilson 2000). In addition, what knowledge we have is often difficult to access because it is only available in very specialized technical publications of limited distribution or recorded on file cards and specimen labels in museums. However, efforts to make changes are increasing (Day 1998, PCAST 1998, GBIF), especially with regard to sharing information over the Internet (Bisby 2000, Edwards et al. 2000).

Central to these efforts is the use of scientific names for species. For instance Alewife is the common name of a fish that migrates up rivers along the east coast of North America every spring to mate. It has been widely used by humans for food and bait. Alewives are also called Blear-eyed Herring, Wall-eyed Herring, Glut herring, Green Shad, Bang, Ellwife, Gaspereau, Grayback, Kyak, Mulhaden, Racer, Sawbelly, Skipjack, and Spreau. Everywhere in the scientific community, however, this anadromous herring is called *Alosa pseudoharengus* and its location in the taxonomic hierarchical is as follows PHYLUM - Chordata , SUBPHYLUM - Vertebrata, CLASS - Osteichthyes, SUBCLASS - Actinopterygii, ORDER - Clupeiformes, SUBORDER - Clupeoidei, FAMILY- Clupeidae, GENUS - *Alosa*, SPECIES - *pseudoharengus*. This formal designation allows the scientific community to communicate about individuals that occur in nature. While not a perfect system, the process of describing and naming species provides the community a rationale for the scientific name and allows us to trace the history of the names. In the case of *Alosa pseudoharengus,* the authority is Wilson (1811). This means the Wilson studied specimens in collections and concluded that this was a species that should be part of the family Clupeidae along with closely related species such as the Shad (*Alosa sapidissima* Wilson (1811)) and Blueback Herring (*Alosa aestivalis* Mitchell (1814)).

As in all scientific endeavors, standards are essential. Taxonomists clearly recognize the necessity of naming standards and three, slightly different, but well established International Codes of Nomenclature exist (Zoology, Botany and Bacteria). Furthermore, the Taxonomic Database Working Group (TDWG, www.tdwg.org) and Integrated Taxonomic Information System (IT IS, http://www.itis.usda.gov/plantproj/itis/standard.html) are working to establish electronic interchange standards. Minimum nomenclatural requirements include the species name and the ability to trace the origin and authority of the name. (See Species 2000 standards http://www.sp2000.org/Standarddata.htm).

Perhaps equally important to the preservation of biodiversity is the adoption of standard common names (Peter Alden, personal communication). For a few taxa, such as birds and butterflies, there are standards. However, common names can generate confusion, especially among plants. Consider the name "loosestrife." Mention it, and many people in New England immediately think of purple loosestrife, the invasive wetland species; but the USDA's plant database gives 43 species from three different genera (*Decodon*, *Lysimachia*, and *Lythrum*) and two different plant families (Lythraceae, Primulaceae) for the name loosestrife. Furthermore, the USDA database gives no results for the spelling " loose-strife" or "loose strife," while both alternative spellings produce results using the Google search engine. Having a process and standard rules for forming common names would be a great help for the professional and amateur user communities in finding information (Parkes 1978, Kartesz and Thieret 1991).

Once standards are accepted in a discipline, the community can usually move onto other business (Rumble 1999). In taxonomy, however, names change. Species are lumped or split depending upon the information available or the judgment of the authority involved. Changing names is a reflection of the infancy of the discipline and the fact that judgments are made without complete information. This flexibility is absolutely necessary, but it detracts from the notion of a standard and makes it more difficult for people, especially non-specialists, to communicate.

Finally, in addition to naming species, taxonomists provide keys to identify species. The traditional approach, following Linnaeus, has been to construct dichotomous keys. However, these keys are notoriously difficult to use (ask non taxonomists or beginning biology students) and sometimes dangerous (see Appendix 1 of examples culled from the net), so an entirely different approach was developed for the public – the field guide. In fact an industry of people, mostly non-scientists, who write and illustrate field guides (National Audubon, Golden, Peterson, Stokes guides) that translate taxonomic information into a form that the public can use.

These communication difficulties, combined with the fact that most biologists work on a few model species, led to the perception that taxonomy was an inward looking and arbitrary science, not a place to make a career. As a result, taxonomy was marginalized by the biological community. Now, as taxonomy moves into the bioinformatics age, the image of people relegated to dusty basements in monolithic museum buildings is being replaced by digital technologies including barcode labeling, imaging equipment, GIS equipment and WEB database. Along with this new outlook is a greater effort by the taxonomic community to share their expertise and information. As the indispensable role of taxonomy for biodiversity studies is acknowledged, taxonomists are rebuilding their support and status in biology.

Here we consider how taxonomic information can be more widely shared using electronic media and the "field guide" approach. We discuss the communities (mainly applied and recreational groups) that "consume" taxonomic information. We review the history of field guides and their impact, describe their essential elements and variety, and ask what kinds of field guides and elements of field guides are already being published electronically. Next we discuss the problems associated with helping people to identify an organism with the correct scientific name. We argue that a more scientific approach to developing keys and guides should be adopted. Finally we consider the "citizen science" paradigm and the implications that being able to label specimens with their correct scientific name would have for preserving biodiversity and monitoring the environment.

Consumers of Taxonomic Information

Who are the consumers of information about species? Who needs to get scientific names? Pankhurst (1991, chapter 7) provides a list that focuses on the professional disciplines. For the most part, it is not the mainstream biologist working at the lab bench solving problems in medical science, but rather a diverse set of people who might be called “applied and recreational field biologists and naturalists” (Table 1). Often their needs are very specific. They need help identifying species, and a field guide, with direct coaching from specialists, is often the method they use.

Field Guides

History of Field Guides

We can review the history of field guides by studying the history of field guides to birds. Florence Merriam Bailey, sister of C. Hart Merriam, the first chief of the U.S. Biological Survey (1885-1910) and wife of the well-known zoologist Vernon Bailey, is credited with writing the first field guide in 1889, entitled *Birds Through an Opera Glass*. (This book contains wonderful descriptions, but only a few black and white illustrations). Others readily adopted the non collecting approach. For instance, in the 5th edition (1895) of *Our Common Birds and How to Know Them*, first published in 1891, Grant (p. 14) writes, “But if the would-be observer looks forward to what may be called professional work, and intends to make an exhaustive study of ornithology, he must kill birds and learn to skin and preserve them…. In the present little work this branch of the subject will not be discussed, and only such familiarity with birds will be sought for as may be attained by direct observation alone and through the instrumentality of no weapon more deadly than the opera glass.”

In 1898 Bailey completed *Birds of Village and Field: a Bird Book for Beginners,* and later in 1902 came the *Handbook of Birds of the Western United States*. The handbook included information about the dimensions of birds, was arranged by taxonomic order, and gave clear descriptions of each species, its distribution, food and nest. Thus, it contained many elements of a modern field guide. Florence Bailey was a leading advocate for the protection of birds and a founding member of the Audubon Society. It is not surprising that she was an early advocate of using binoculars, rather than guns, to identify birds. (http://www.northnet.org/stlawrenceaauw/bailey.htm, http://www.audubon.org/chapter/ca/goldengate/EducationResourcesMerchandise/FirstFieldGuide.html, http://women.eb.com/women/articles/Bailey_Florence_Augusta_Merriam.html)

After Bailey, Chester Reed, among others, published books that are clear forerunners of the modern field guide. These efforts were part of the new conservation movement blossoming in America (Popular Ornithology, c.1850-1920. Additional Resources in the Library of Congress http://lcweb2.loc.gov/ammem/amrvhtml/consbib3.html).

The modern breakthrough came in the 1930’s when Professor Ludlow Griscom showed that it was possible to identify birds reliably without killing them (Peterson in Hill 1965). Then, based on his experiences with Griscom, the tradition initiated by Florence Bailey, and his wonderful skill as an artist, Peterson developed the first modern field guide (A Field Guide to the Birds, 1934). Essential to his system were color plates with paintings of similar species in which Peterson indicated field marks. People could easily compare species they saw in the field with the paintings and make an identification (Leahy 1982). This guide proved to be an essential tool for casual bird observers to become skilled "birders." Commenting on the impact of Peterson’s guide, Young (1998) writes “Wildlife watching, especially birding, has become one of the nation's most popular pastimes, the offshoot of a vast increase in environmental awareness since the hawk-shooting days before 1934, when Hawk Mountain was transformed from shooting gallery to wildlife sanctuary."

Field guides allowed the development of a large group of skilled amateur birders, which has had an enormous impact. Birding is a sport, an industry, and an educational tool. Birding encourages people to reconnect with nature and therefore to value it. Birders are the backbone of the environmental movement as evidenced by the well-established Audubon Societies and Rachel Carson's metaphor "Silent Spring. " Birders are growing in number, and birding may soon surpass hunting and fishing in popularity (Cordell et al. 1998, Cordell et al. 1999)

Components of Modern Field Guides

There is no strict definition of what constitutes a field guide, but, normally, it is taxon or life form specific, and covers a limited geographic area that can be defined by political or biogeographic boundaries. Common features include a book format that is divided into two sections. The first introduces the group and often subgroups within the taxon being presented, with a description of how species in the taxon are classified and named. It also includes information about the basic biology, illustrations labeled to teach morphological terms, ideas on how to observe and collect specimens, including the necessary equipment, tips for identification and recording observations, and a definition of what is to be found in each of the species accounts. Often simple keys that can be used in the field are provided. The keys are based on illustrated characters. In contrast to the normal dichotomous keys of taxonomy, these keys tend to be wide (3-15 choices at each level) and about three levels deep.

The second, and usually much larger, section of book contains the species accounts in a standard taxonomic order or perhaps organized by some critical morphological character, such as flower color, in the case of wildflowers. A central feature of the species accounts is the collection of photographs, drawings or paintings of each species, labeled with a name. The pictures present species in life-like postures and may include arrows to indicate field marks. The pictures allow one to compare similar looking species side by side. When variation within a species exists, such as between the sexes or between adult and juvenile forms that too may be illustrated. In fact, the illustrations can account for more than 50% of all printed material in the species account section. In some designs the illustrations are presented as a series of color plates, and naturalists are known to remove the plates and have them rebound for field use so as to minimize volume and weight. For the new "pocket" guides - small laminated foldouts or cards, this is all one gets – a picture with a name. These two observations support the idea that a picture of each species is the essential feature of a field guide.

The written accounts for each species contain a host of information, including names, identification tips (color, size, shape, similar species), habitats, behavior, life stages, ecology, range maps with information about seasonal movements, relationships to humans, and conservation. The amount and format of the information depends on the audience and taxon. Variation in field guide formats takes into account age and level of experience of the user and geographic coverage. For birding, field guide niche markets exist for beginner, standard, and advanced levels.

Identification Using Field Guides

How is this information used to identify species? The identification process employs a combination of simple keys, scanning the illustrations for a match, and a careful comparison between what is known about the specimen in view or in hand and pertinent text and graphical information provided in the guide. The keys help people focus their search in a section of the book in which the number of choices is relatively small. Usually one can scan the species illustrations adjacent to the tentative ID. Bird and butterfly guides often have little in the way of keys, while plant guides are much more likely to use two or three different characters to help users narrow their scanning efforts.

Particularly useful are guides that give similar species under each species account. Then users can make direct comparisons with similar species to increase the confidence of a positive identification. Sometimes one single taxon specific character among all of those given is enough to identify the species. For a tree this might be a leaf, a flower, a twig, a fruit, or a piece of bark. For a bird it might be a silhouette, a feather, a song, or a movement pattern along a branch.

Limitations to Commercially Available Field Guides

The economics of traditional publishing dictate that paper field guides must have commercial viability, so they tend to focus on popular taxa, cover wide geographic areas, and contain many species. A review of titles from the major series of field guides (Audubon, Golden Guides, Peterson, Stokes) in the US indicates more than 20 common topics for field guides, including animal tracks, birds, butterflies, edible wild plants, fishes, fossils, insects, medicinal plants, mushrooms, plants, pond life, reptiles & amphibians, rocks & minerals, seashells, seashores, stars, trees, weather, weeds, wildflowers, and venomous animals and plants. A search of Amazon.com in December of 2000 using "field guide" as a key phrase found 625 natural history guides, with more than 70% about birds (Fig. 1). One has the impression that bird guides exist for every corner of the world and that birding has become big business given the variety of specialized bird guides now available. The other five categories (non bird vertebrates, plants and mushrooms, invertebrates, habitats, and fossils, weather, and stars) each ranged from 3 to 8 percent of the total. In a guide with many species, it is not generally possible to show regional, seasonal, and developmental variation in forms because of constraints on size and cost. If the guides are produced for a regional area, the quality of the illustrations is usually not as good, in order to keep the price down for the smaller market.A recent exception is Sibley's new bird guide that has many illustrations, yet is still priced as other guides (Sibley 2000).

A plethora of modern field guides are in print, but aside from the standard categories listed above from major publishers, they may be difficult to find. For instance, a list of field guides for the Pacific Northwest (http://www.tardigrade.org/natives/fieldguides.html) totaled 84 and had a very different taxonomic emphasis compared to the Amazon list (Fig. 1). More than 55% were about plants (trees, wildflowers, poisonous, edible) and mushrooms, 20% about habitats, and slightly less than 10% about birds. Many of these books are from smaller publishers with regional coverage. (Note that we did not make any direct comparisons between this set and the Amazon set in terms of the number of species, costs, and quality of illustrations.) A second example concerns amphibians and reptiles. A search of Amazon.com turned up only 10 guides to amphibians and reptiles, but Livo (1998) lists 147 publications, including field guides, checklists, and handbooks, many of which are from academic presses. Clearly, more complete information is available in less popular and less commercially viable forms. At the same Internet site of the Colorado Herpetological Society, Arden (1999) reviews recordings of frog calls. Commercial book and music stores, whether traditional or e-stores, do not have such complete lists.

Electronic Field Guides

CD's

As with paper field guides, most electronic products are for birds. Commercial birding software (Table 2) includes more than 10 CD's with all the features for identifying birds found in paper guides, except that as yet they cannot be easily used in the field, as one would normally do with a field guide. The usual advantages of electronic documents are apparent in these products: hypertext links, more color photographs, greater amounts of information, such as the inclusion of both field marks and songs for IDing. Programs may allow users to search on shape, size, color, habitat, or unique behaviors. Games and quizzes featured in some software products help users learn the birds. More than half a dozen programs exist that allow birders to keep track of the birds they see (Table 2). These "listing" programs include a variety of options to output information such as life lists and maps of records. (Some of these products are reviewed by the New Jersey Audubon Society (1998) http://www.njaudubon.org/genlmenu/cdrom.html and Biosis Taxonomy and Nomenclature Software http://www.biosis.org/htmls/reviews/tn.html).

Examples of electronic guides exist for other taxa such as plants and butterflies (e.g. ETI's collection http://wwweti.eti.bio.uva.nl/Products/CD-catalogue.html). Sometimes these CDs are technically oriented and not intended for the general public.

On the more professional side, there is a host of high quality programs available commercially or for free that were conceived mainly for the storage and use of biodiversity information in more scientific settings. These include Biolink, Biota, Delta, Linnaeus II, and Lucid, which run in a variety of operating environments and platforms (for details, see Internet Directory For Botany: Software http://www.helsinki.fi/kmus/botsoft.html, Checklist of Software for Field Biologists http://www.euronet.nl/users/mbleeker/prog/soflis_e.html, Internet Resource Guide for Zoology, http://www.york.biosis.org/zrdocs/zoolinfo/software.htm).

Internet

A growing number of sites offer some information about species, but by far the largest and most complete is enature (http://www.enature.com). They have 12 field guides from the Audubon series online, totaling 4800 species (by their advertisement). One can search for species by name, or browse by thumbnail photos, or use an advanced search tool categorizing species by color, size, habitat and geographic region. For well-known vertebrate species, one can search a list of common species or a list that contains all species. The site also offers the ability to search within bioregion areas of states. With less well-known taxa, such as dragonflies, information is provided only for common species. For information about Lepidoptera, the Internet guide to North American butterflies by Opler, Stanford and Paluvann http://www.npwrc.usgs.gov/resource/distr/lepid/bflyusa/bflyusa.htm or of moths by Opler http://www.npwrc.usgs.gov/resource/distr/lepid/moths/mothsusa.htm might be better places to look than enature. Enature's additional features include the option to keep track of an individual's [individual bird or individual birder?] sightings, to have questions answered by an expert, and to get regular natural history notes by e-mail.

Many fine non-commercial sites for avian species offer features of paper field guides, such as species accounts with maps (Table 2). We also found a heterogeneous collection of more than 60 examples of electronic field guides unrelated to bird guides (Table 3). Some large sites, such as FishBase (www.fishbase.org) that contains all the world's fish species or An Online Guide for Amphibians in the United States and Canada, but most are small with a very specific focus. Examples include a Field Guide to the Psilocybin Mushroom Species Common to North America, A Field Guide For Your School Yard, A Field Guide to Economically Important Seaweeds of Northern New England, a Field Guide To Anemone Fishes And Their Host Sea Anemones, Species Identification of Intestinal Microsporidiosis in HIV-positive patients, and a On-Line Field Guide to the Diagnosis and Management of Potato Late Blight (Table3). These guides illustrate the diversity of applied fields that have published electronic guides.

One of most innovative approaches to electronic guides on the Internet, lets users build their own field guide (Royal Ontario Museum 1999). The software uses a three-step process in which the user picks from one of 54 areas in Ontario, Canada, selects one of three groups (birds or amphibians or fish), and finally selects either a field guide or checklist output format. This ability to construct guides to match user needs is one of the most significant advantages of electronic document processing.

Approaches to Species Identification

The identification problem

Radford et al. (1976, chapter 25) list four methods of identification: (1) expert determination, (2) recognition, (3) comparison, and (4) the use of keys and related methods (synopses, outlines, tables of characters). Clearly, careful expert determination would be by definition the most reliable method. However, either lack of access to experts or the long wait before experts can finish identifications makes this approach impractical. It is also tempting to think that we could build expert computer systems to do species identification. While a biodiversity "tricoder" modified from a Star Trek model has great appeal, and while it is true that that we understand generally the differences between novices and experts (Bransford et al. 1999 (Chapter 2), computer scientists are still struggling with how to engineer domain specific expert systems (see for example http://www.mip.sdu.dk/~risager/proship/public/ph.d.course/). Pankhurst (1991) devotes a chapter to the discussion of expert systems in species identification, but the approaches seem limited. The current generation of tools, such as Delta and Lucid, are more sophisticated than those described by Pankhurst.

Recognition is based on experience. Morse (1971) cited in Radford et al. (1976) says that this is also a reliable method. However, recognition depends upon being self-taught or having learned from some expert and, as stated above, because science is short on taxonomic expertise, this is not an approach that will work broadly. Comparison covers a broad array of approaches, including searching through museum specimens, reading descriptions, reviewing illustrations, and studying field guide plates. This is the basic approach taken by taxonomists to develop their expertise, but it is time consuming and requires access to specimens.

Keys and related methods are used successfully by scientifically trained people and, for all but the taxa covered by field guides, it is the most widely used approach. Keys offer a step by step approach to identifying a species. The classic key is a dichotomous hierarchical tree in which one character is used at each step to make a decision. One follows a sequential path to the end of the branch, at which time the species of interest is identified. However keys exist that use more than two choices at each step, use multiple paths to the correct answer (= a directed acyclic graph, not a tree in the strict mathematical sense), and use multiple characters at each step. Much has been written about keys and how to construct them (Radford 1976, Voss 1952, Pankhurst 1991). Despite their wide spread use in the scientific community, keys have some limitations discussed next.

Species Identification: Field Guides vs. Keys

We think it is telling that no one we know uses a key to identify birds. Clearly, this is because 1) field guides are based on pictures which are more intuitive for most people to use, whereas keys are usually based on verbal descriptions; 2) field guides for birds are of high quality for most locations in the world; 3) people have a good general knowledge about birds (common species are known, as are many life forms (ducks, hawks, woodpeckers, etc.) making it easy to reduce the number of possibilities to a small number for comparison quickly, and 4) people are trying to identify birds in the field, not with a specimen in hand. A comparison of the different approaches taken by field guides and keys (Table 4) suggest that field guides are easier to use for most people. This is because we normally identify objects intuitively, rarely making the process explicit. Think of the hundreds of things and people you can name, yet often we can only give cursory descriptions. It is possible to identify species with seemingly little information - a gestalt process. Even experienced birders sometimes find it difficult to explain the process and speak about the bird's "Giz." Keys may be written using characters that are not clearly evident, and if one comes to the end with the wrong species, it is not clear where the mistake was made. Keys often use a more technical vocabulary. Many people find keys frustrating to use because one gets lost or it takes too long (= too many steps). In addition, keys cannot be scanned or easily studied to learn about the species, whereas one can leaf through a field guide browsing the images. Fields guide impart a visual ordering that is helpful when trying to recall species.

It should be emphasized that Despite these differences, keys and field guides often share approaches and elements. For example, some keys contain pictures, and field guides often have an implicit hierarchical tree of 2-4 levels for identification (e.g., life forms and then groups). Most bird guides have ducks and geese as a life form and dabbling ducks as a group (Peterson 1998, Kaufman 2000). *Newcomb's Wildflower Guide* has three levels of questions (flower type, plant type and leaf type) to lead one to the right section of the book. Petrides's (1998) *Guide to Eastern Trees* contains broad life forms based on leaf type, and then each section contains a matrix of identification characters. In addition to an excellent series of photographs for each species that allows one to simply scan for an identification, Uva et al.'s (Date) *Weeds of the Northeast* contains a typical dichotomous key, as well as seventeen shortcut identification tables, seven of which help with specific characters and 10 of which help with specific taxonomic groups.

Species Identification: Electronic Options for Keys and Guides

Wilson (1994, p. 1-7, http://www.cinenet.net/users/velosa/thesis.html) and Edwards and Morse (1995) compare the variety of traditional approaches (field guide technique, dichotomous and synoptic keys) used to identify organisms and discuss the advantages of interactive keys. Computers can reduce some limitations of each and combine some of their strengths. In chapter 5, Pankhurst (1991) gives an account of the development of ideas about identification using computers. Dallwitz et al. (2000) have provided a list of desirable characteristics for keys (http://www.biodiversity.uno.edu/delta/www/interactivekeys.htm) and Dallwitz (2000) has made direct comparisons of features among existing software packages (http://www.biodiversity.uno.edu/delta/www/comparison.htm).

Despite these useful developments beyond traditional keys, we believe some essential issues of identification have not been discussed, especially in light of what we know about how people use field guides. Given that identification is often an unconscious process, software tools should try to mimic the way we identify objects naturally and help reduce the frustration when the process becomes more explicit. We suggest that software should: 1) provide training tools and games to let people become familiar with the "cast of characters" slowly, instead of being overwhelmed by a confusion of newness, 2) work to reduce the time necessary to identify a species by choosing likely possibilities from a line up approach, and 3) suggest further queries that will aid in making the final positive identification. For the first point, computer games can be used to introduce and quiz users. For the second point, computer programs can use basic data about the observation, such as time, location, and habitat, and specimen characteristics, such as size, color, etc., to form the line up. This process is similar to the one suggested by Wilson (1994, p. 37) and would bypass the traditional key approach. This approach may not be possible or as desirable as using a very simple key.

One example of a simple key is the computer-based guide shown for Orchids on page 123 of Pankhurst (1991). This key emphasizes flower shape. The best example of a user-friendly key we have found on the Internet is "An interactive key to the Katydids of La Selva, Costa Rica (Orthoptera: Tettigoniidae) (http://viceroy.eeb.uconn.edu/interkey/Titlepg) by Piotr Naskrecki. He presents a visual key for 60 species with simple point and click choices. Three levels in the identification tree are needed to reach a final choice. Naskrecki was able to take this approach because the number of species at La Selva is relatively small (about 65). He lists similar species at the end of his branches to help users make a positive identification.

Future of Electronic Field Guides: Design and Use

Grant (1895 p. 4) writes about using field guides “As for the advice, though of the simplest, its is believed that it will prove effective.

Study one bird at a time.

Begin with the commonest, that is the most abundant and most easily recognized ones; it is the province of this book to point such out.

Do not attempt, at the commencement, to identify any bird which presents puzzling characteristics, or rather any which does *not* present some striking mark either of song or plumage to serve as a sign for certain classification."

This quotation is included to remind us that all tools have limitations - a major one being the skill and knowledge of the user. While we believe that much better tools can be made, ultimately a user's knowledge, built by studying a taxon, will greatly impact his or her skill at identifying species. From conversations with field biologists and educators, it has become clear that many novice users will want to get a name at the expense of real certainty about their ID. Positive identification takes work and the inexperienced are likely to choose a name when they have not really proven to themselves that it is correct. Nonetheless, we believe that tremendous advances in tools to aid species identification are likely in the near future because of rapid developments in learning theory and knowledge representation, software design, and digital hardware.

Learning theory and knowledge representation

A neglected approach to designing field guides and keys is to build on what is known about how the human mind works. Psychologists, neurobiologists, educators, and computer scientists are rapidly advancing our understanding of human learning. At the center of these studies is cognitive science and its efforts to understand how knowledge is represented, stored and retrieved (Matlin 1994). Several theories, including the feature comparison model, network models, the exemplar approach, and the prototype approach (Matlin 1994, chapter 7), seek to explain semantic memory (= organized knowledge = not episodic knowledge), which is thought to be important in classification problems. A review of the extensive literature in cognitive science on classification problems is likely to help in the design of field guides.

More direct results come from cross-cultural studies. One specific thrust by several anthropologists has been to try to understand how people from different cultures represent information about species in their environment. Studies first initiated by Berlin et al. (1973, 1974) and summarized by Berlin (1992) indicate that there are some universals about folk taxonomies and biological classifications.

The following principles are quoted from http://www.anth.uconn.edu/classes/anth244_f00/week10.htm:

> "1) In all languages, ethnobiological domains are organized taxonomically (categories of organisms of varying degrees of inclusiveness = taxa).
>
> 2) Taxa can be further grouped into a small number of ranks (unique beginner, life form, generic, specific, varietal).
>
> 3) Ranks are hierarchically arranged; taxa of the same rank are mutually exclusive.
>
> 4) Taxa of same rank usually occur at same level of the taxonomy.

5) The unique beginner is often unlabelled (e.g., plant, animal).

6) Life forms are few in number (5-10), include most lower taxa, and are polytypic (e.g., tree, vine, bird).

7) Generics are the most numerous (~500). Most are included within life forms; some are unaffiliated. They are highly salient, most commonly referred to, the first learned by children, and are labeled by primary lexemes (e.g., oak, pine, robin, cactus, banana).

8) Specific and varietal categories are fewer in number, occur in small contrast sets, are often culturally important, distinguished by few features, and are labeled by secondary lexemes (e.g., live oak, valley oak, Ponderosa pine, Monterey pine, butter lima bean, baby lima bean).

9) Intermediate categories are found below the life form and above the generics, are often unlabelled, and are very rare (e.g., evergreen, deciduous, song bird)."

Atran (1998) reviewed these findings in an effort to understand the universality of folk taxonomies and their roles in culture. The universals he described include 1) living organisms are special kinds of objects that people recognize and organize in groups we know as species, 2) each species has an underlying constancy, even though it might change form (frog and tadpole), 3) these species can be grouped in hierarchical sets, and 4) these sets are useful for making inferences about the biology of groups.

Another specific approach is to use a development framework and examine how children see animals and plants. This would be critical for designing educational tools and experiences. In zoos and museums it is mostly anatomical features, rather than behavior or habitat, that are discussed by children (Tunnicliffe, 1995). Tunnicliffe (1999) finds that people at zoos spontaneously use everyday names for animals and usually refer to animals (= mammals) with generic names, such as cat, zebra, rhino and elephant, rather than more specific terms, such as African elephant or black rhino, unless the mammal is well known, such as the snow leopard. [sentence runs on a bit.] The term bird is used for any bird unless it is distinctive, such as an ostrich, vulture, eagle, or parrot. According to Tunnicliffe, children under the age of seven do not explicitly recognize hierarchical categories when naming animals: thus a shark is not a fish, and a ladybird beetle is not a beetle or a bug, but this may just be a matter of experience (Carol Smith and Susan Abruzzi personal communication). Children comment spontaneously on the shape, size, and color of animals and any unusual features such as horns. For plants, anatomical features, rather than habitat, function or form, was the most important class of variables in naming the plant, and children tend to learn plant names at home rather than at school or by direct observation (Reiss and Tunnicliffe 1999).

There are more fundamental studies about the development of conceptual change in children, such as Carey's (1985) investigation of the "alive" and "animal" concepts or the more descriptive observations by Myers (1998). The conclusions of these studies point to the critical ages of about 4 to 10 years old. Advances in learning theory more generally (Carey and Gelman 1991, Matlin 1994) should help to frame the design of developmentally appropriate field guides.

These folk biology and development studies suggest some useful perspectives about the design of field guides. Information should be arranged in a hierarchical way, and though the number of levels should not be deep (3 or 4 levels), they can be broad at the species level. After the kingdom level adults use life form as the next level to distinguish groups in the hierarchy. Appropriate characters include size, color and unusual features. Finally, there are important developmental stages in how children use names and can categorize organisms before they children reach age 10.

Software Design

In general, electronic publishing will continue to break down traditional publishing limitations. The Internet, object oriented programming, and the adoption of XML are three central technologies. They should facilitate collaborative efforts among computer scientists and biologists to build EFGs that are highly specific in their subject matter and are not restrained in either the amount of information or the number of quality photographs. Software will allow people to produce EFGs that have very specific taxonomic focus or geographical coverage, large clear photographs, and the ability to compare similar species side-by-side dynamically. Information display will depend upon the seasonal occurrence of each life stage and the skill, experience and age of the user. Better identification tools will provide options for multiple life stages and traits (e.g. adults, juveniles, sound recordings, feathers, nests for birds) to identify the same set of species. Programs will include built in learning tools, ecological relationships among species, and observed occurrences by the user or the user community (See Citizen Science approach below).

Hardware Use and Developments

New digital cameras, image processing software, software tools to build web sites and the internet have permitted individuals to publishing their own electronic guides with only a small capital investment. However, taking this information to the field in electronic form is still difficult. As a substitute, scientists and field naturalists are making their own miniguides by laminating plates of images created with ink jet printers on glossy paper. These custom-made pocket guides can be very helpful and meet the objectives of an easy to use, high quality, local guide (see Foster 1999, Smith 2001, Zuchowski 2001).

The most important advancement in the near future will be the ability of Personal Digital Assistants to store and display many high quality images. Then paper field guides will start to be replaced by digital equipment. The marrying of video cameras, PDA, and GPS technologies will go a long way towards producing a tool that can be used to identify specimens in the field and collect electronic vouchers. On the data collection side, the CyberTracker (www.cybertracker.co.za) shows how much information can already be gathered in the field using a Palm Pilot. In the electronics industry, the general trend is for speed and memory capacity to increase, and for cost and size to decrease. If the advances witnessed in the last 20 years continue at the same pace, species identification will be much easier in 2020.

Testing of identification tools

A crucial component of electonic guides are the identification components. We have argued above that field guides are good tools for species identification by the public and we supported our view with a variety of arguments. Furthermore, electronic versions offer more flexibility than paper guides. Nonetheless, there has been little scientific study of how successful field guides are as learning and identification tools. Two reports on the Internet, measuring peoples' ability to identify species correctly (Commission of the European Communities Shared Cost DGXIV FAIR PROJECT CT 95 0655. 1998, Haas, Montagne and Bergen 1996), suggest that results vary widely. Clearly a more concerted effort is needed to understand the issues, processes and needs of user communities.

Application of EFGs: Citizen Science

The bird model

The term "citizen science" was coined by Rick Bonney at Cornell's Laboratory of Ornithology in 1990's during the Lab's efforts to engage the public in bird population monitoring projects. Currently, the laboratory has a large number of projects that it has initiated or hosts in partnership with other groups (http://birds.cornell.edu/citsci/index.html).

A public knowledgeable in bird identification has permitted the involvement of tens of thousands of people in bird censuses, such as the Christmas Bird Count, the Breeding Bird Survey, and FeederWatch. The ability to identify birds reliably is the singular skill that has allowed public participation in these environmental monitoring and research projects. The scientific community has greatly benefited from public participation (for example Hochachka and Dhondt 2000). Without this legion of volunteers, scientists would not be able to gather data over the time periods and geographic regions now possible. Such data gathered over extended temporal and spatial scales are extremely valuable for monitoring the environment.

Because of the great public popularity of birding, public expertise is being put to use for scientific studies. People are enthusiastic about participating because it gives more purpose to their efforts, and they learn about the process of science. Scientists are enthusiastic about the projects because they can answer questions that would be impossible to approach without a network of volunteers.

Other community science applications

These same characteristics of citizen-scientist partnerships are evident in a number of other programs such as Mussel Watch http://state-of-coast.noaa.gov/bulletins/html/ccom_05/ccom.html, the Fourth of July Butterfly Count http://www.naba.org/4july.html, and Discover Life http://www.discoverlife.org/. Other programs at the USGS Patuxent Wildlife Research Center http://www.im.nbs.gov/ or at the Texas Nature Tracker's Office http://www.tpwd.state.tx.us/nature/education/tracker/index.htm, have government sponsorship.

Extensions of the Citizen Science paradigm

Two obvious ways to extend the Citizen Science paradigm are underway. We focus our attention on North American projects, though there are exciting citizen science efforts in other parts of the globe not discussed here.

The first is for scientists to team up with students as, is happening with the Monarch Watch project http://www.monarchwatch.org/, the Community science Connection http://www.arboretum.harvard.edu/csc.htm, the Journey North http://www.learner.org/jnorth/ , and the Globe Program http://www.globe.gov/ (see Student and Scientist Partnerships Conference http://www.terc.edu/ssp/conf_rep.htm for discussion). In the usual "citizen science" approach, rules and regulations are disseminated by a central group of scientists who might work with educators to present the rationale and procedure in layman's terms. The observers enjoy the activity, but are not often involved in the analysis or interpretation of data.

The second extension is to allow people to submit data about a topic or theme without a specific protocol designed by scientists. The North American Butterfly Association's Sightings page http://www.naba.org/sightings.html and the Hudson River Almanac (www.hudsonriver.com/almanac/welcome.html) are examples of this approach. Here, in this bottoms-up approach, the rules for participation were not defined by a scientific group, but, rather, grow out of the interest of the participants. It is also worth noting that sometimes methodologies have been proposed by volunteer/school monitoring projects, such as Lichens http://www.cciw.ca/eman-temp/research/protocols/lichen/part1.html, but there is no known mechanism or location for participants to record their data.

For Biodiversity studies, citizen science partnerships could include data about location, number of individuals of a species, specific individuals, life stage, condition, behavior, or ecological interactions. Such ecological data can be used to address many kinds of broader ecological questions, including population trends, species distributions, phenology, and the structure of food webs. The focus could also be applied if it addressed such issues as the distribution of invasive species or the phenology of plants for global warming.

A largely ignored component of publicly gathered data is the specification of the quality of data and metadata. Several approaches are possible, ranging from just filtering missing data to using quality assurance plans (BC Fisheries Information Services Branch for the Resources Inventory Committee 2000.).

Final Comments

Over the last ten thousand years, rapid technological developments have led to agricultural societies and large concentrations of humans in which individuals have taken on more and more specialized roles (Diamond 1997). The industrialization of agriculture in the last 100 years has separated people from direct experiences with nature. This lack of contact has contributed to our lack of interest in nature. Aldo Leopold (1949) wrote in Sand County Almanac, "There are two spiritual dangers in not owning a farm. One is that danger of supposing breakfast comes from the grocery, and the other that heat comes from the furnace." Field guides are a way for people to connect with the environment by putting a specific face on the term biodiversity. The ecoinformatics revolution should help biologists take advantage of the rapid advances in digital technologies to share their knowledge about biodiversity with non-specialists. The non-specialists, in turn, through citizen science projects, are showing that their knowledge of species can be used to help monitor ecological changes as they relate to evolutionary dynamics and more pressing issues, such as biodiversity loss, invasive species and global climate change.

Acknowledgements

Jennifer Forman and Susan Abruzzi provided comments on drafts of this paper.

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Table 1. Examples of categories and disciplines in which scientists and citizens need taxonomic information. Lower-bound order of magnitude estimates of the group size come from talking with experts in a discipline, looking at membership numbers for societies, or doing simple projections from the size of a group in Massachusetts to the entire USA.

Categories and Disciplines	Focus of studies	Estimated Size of Group in the USA
Applied		
Public health	Mosquito survey	>1,000
Agricultural	Integrated Pest management	>100,000
Biological survey	Endangered species	>1,000
Land managers	Invasive species	>5,000
Recreational		
Birder	Local birds	>1,000,000
Native Plant Societies	Wildflowers	>500,000
Gardner	Weeds	>1,000,000
Ecotourist	Fauna in tropical resorts	>10,000,000
Mushroom hunter	Edible mushrooms	>10,000
Fisherman	Aquatic insects	>100,000
Educational		
Schoolyard science	Plants on school grounds	>20,000,000?
Nature camp	Butterfly projects	>50,000?
Citizen science		
Project feeder watch	Local birds	> 50,000
4th of July Butterfly count	Local butterflies	> 1,000

Table 2. Categories of birding software with examples.

Software category	
Interactive Field Guides	
Natureware	
Birds of Europe	
Birder's Mate	
Birds of the World	
North American Bird Reference Book	
Birder's Mate	http://www.mis.co.za/birdersmate/home.htm
Birds of North America CD-ROM 2.5	From Thayer's, songs, photos, videos, quizzes, field guide and more! For PC's.
Birds of the World	Covers 9,946 birds of the world. For the PC.
LANIUS Software's North American Bird Reference Book	Instructional multimedia CD-ROM, with songs, photos, quizzes, maps, and more. For PC's.
Multimedia Birds of Southern Africa	Illustrations, text, distribution maps, photos, videos, sounds as well as a search capability.
North America Birds	Peterson Multimedia Guide of almost 1,000 birds with photographs, videos, bird songs, range maps and more. For PC's.
North American Birds by Sight and Sound	Games and an online manual to help you learn around 700 species of North America birds. For both PC's and Macs.
National Audubon Society Interactive CD-Rom Guide to North American Birds	
Listing software	
North American Bird Reference Book with Excalibur 2000	
BirdBase and BirdArea	
AviSys	
Birder's Diary	
Flying Emu.com	
Merlin species watcher	http://www.hyperscribe.org/merlin/
MacPeregrine 3.0	Life lists, custom lists, reports, species accounts. For Macs.
Internet sites with Field Guide Information	
Northern Michigan Birding	http://www.northbirding.com/
North American Rare Bird Alert	http://www.narba.org/
Rare Birds	http://www.rarebirds.com/
Northern Michigan Birding	http://www.northbirding.com/
Bird Identification Training Center	http://www.northbirding.com/idtraining/
Patuxent--Bird Population Studies	http://www.mbr.nbs.gov/
Cornell Laboratory of Ornithology	http://www.ornith.cornell.edu/
American Birding Association	http://www.americanbirding.org/
on line tips for birds	http://www.mbr-pwrc.usgs.gov/id/idlist.html
Identification of Eastern US	http://www.nuthatch.birdnature.com/identification.html

songbirds by color	
The Great Backyard Bird Count Bird Identification Guide	http://birdsource.cornell.edu/gbbc/birdid/index.html
Identification by Behavior and Location	http://www.nuthatch.birdnature.com/idbybehavior.html
Ducks at a distance	http://www.npwrc.usgs.gov/resource/tools/duckdist/duckdist.htm
Peterson On Line	http://www.petersononline.com/birds/perspective/fieldmarks.html
Surf birds advanced birding issues	http://www.surfbirds.com/
Birding Magazine and Kenn Kaufman	http://www2.birdersworld.com/fieldguide/fg_archive.html
Partners In Flight species accounts	http://www.partnersinflight.org/birdacct.htm#Table

Table 3. Examples of Electronic Field Guides Published on the Internet

Guide	URL
Field Guide to Common Western Grasshoppers	http://www.sdvc.uwyo.edu/grasshopper/fieldgde.htm
Wildflower Field Guide	http://www.desertusa.com/wildflo/FieldGuide/fieldguide.html
USGS site Wyoming Rare Plant Field Guide	http://www.npwrc.usgs.gov/resource/distr/others/wyplant/wyplant.htm
Field Guide to the Psilocybin Mushroom Species common to North America	http://nepenthes.lycaeum.org/Plants/shrooms/field.guide.html
A Field Guide For Your School Yard	http://world.std.com/~brd/field.guide.html 10
Field Guide To The San Gabriel Mountains: Natural History	http://tchester.org/sgm/links/nat_hist.html#animals
Field Guide to Noxious and Other Selected Weeds of British Columbia	http://www.agf.gov.bc.ca/croplive/cropprot/weedguid/weedguid.htm
Underwater Field Guide to Ross Island & McMurdo Sound, Antarctica	http://scilib.ucsd.edu/sio/nsf/fguide/
Rob's Field guide to the Faeires	http://www.avalon.net/~rob/english/
Plant Field Guide: Visual Guide	http://www.nps.gov/goga/parklabs/02_habitats/plant_guide/plant_html/0_visual.html
Grasses Field Guide	http://www.bio2.edu/visitor/home_disc_sav_grass_1.htm
Shorebird Identification Guide for the Field	http://www.fws.gov/r7enved/ftguide.htm
Indiana Dunes	http://www.geocities.com/RainForest/Vines/5262/
A field guide to economically important seaweeds of northern New England	http://www.noamkelp.com/technical/handbook.html
Field Guide To Anemone Fishes And Their Host Sea Anemones	http://www.biodiversity.uno.edu/ebooks/intro.html
Field Guide to Some North American Seals or Sea Lion	http://www.lifestories.com/Spring99/field-guide/seal-field-guide.htm
On-line field guide to the diagnosis and management of potato late blight	http://www.bcc.orst.edu/lateblight/
Field Guide To The Psilocybin Mushroom	http://www.erowid.org/plants/mushrooms/mushrooms_field_guide1.sh

	tml
A Field Guide for Ground Checking Southern Pine Beetle Spots	http://www.bugpeople.org/fieldguide/fieldguide.htm
Aquatic Invertebrates Illustrated Field Guide	http://www.wlu.ca/~wwwbiol/bio305/Database/Categories.htm
Salmon	http://www.tbc.gov.bc.ca/culture/schoolnet/pacific/teacher/species.htm l 5
An Online Guide for Amphibians in the United States and Canada	http://www.npwrc.usgs.gov/narcam/idguide/specieid.htm
Reef cheek	http://www.ust.hk/~webrc/ReefCheck/speciesid.html
World Billfish Series Species Identification	http://www.worldbillfishseries.com/local/reference/billfish.html
Timber Harvest	http://www.for.gov.bc.ca/revenue/manuals/scaling/Ch3.htm
Salmonid (trout-like) Adult Species Identification	http://www.pac.dfo-mpo.gc.ca/ops/biosample/chapt_1/chapt_1.htm
Meat Species Identification	http://www.arc.agric.za/lnr/institutes/aii/specid.htm
Species identification of intestinal microsporidiosis in HIV-positive patients using the polymerase chain reaction	http://www.aegis.com/pubs/aidsline/1998/jun/M9861835.html
An ACQUIRE® expert system application for whale identification	http://www.aiinc.ca/demos/whale.html
Search the Seafood List	http://vm.cfsan.fda.gov/~frf/seaintro.html
Mollusks Species Identification Keys	http://www.or.blm.gov/surveyandmanage/SP/Mollusks/aquatic/species keys/specieskeys.htm
Ax mans' Guide to Fish Species Identification	http://www.geocities.com/Yosemite/Falls/9974/speciesid.html
Turtle Identification	http://www.uct.edu.my/ehchan/turtlebio/taxonomy.html
Exotic species	http://www.cciw.ca/eman-temp/research/protocols/exotic/exotic7.htm
Bird feather for airplane bird interactions	http://www.tc.gc.ca/aviation/aerodrme/circulars/english/spec_ident_fo rm_e.htm
Nature mappers	http://www.fish.washington.edu/naturemapping/crabid.html
Globe program	http://ael.physic.ut.ee/globe/globe.UUS!/si1.html
Chestnut Identification	http://www.mindspring.com/~psisco/overview.html
Shrimp species identification	http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/shrimp/biology.htmcv
Salmon Species identification	http://jcomm.uoregon.edu/~josh/salmon/species.html
Fish identification	http://www.ust.hk/~webrc/ReefCheck/species_id.html
Forestry scaling manual	http://www.for.gov.bc.ca/revenue/manuals/scaling/Ch3-01.htm
Identification of Grasses	http://www.forages.css.orst.edu/Topics/Pastures/Species/Grasses/Ident ification.html
Identification of Neisseria and related species	http://www.cdc.gov/ncidod/dastlr/gcdir/NeIdent/Index.html
Salmon and Other fish	http://www.ddfishing.on.ca/facts.htm
Midwestern Wetland FloraField Office Guide to Plant Species List and Identification Key	http://www.npwrc.usgs.gov/resource/othrdata/plntguid/species.htm
Rapid assessment and Conservation Engineering	http://161.55.80.213/groundfish/speciesID.htm

Diagnostic Standards and Classification of Tuberculosis	http://aepo-xdv-www.epo.cdc.gov/wonder/prevguid/p0000425/p0000425.htm
The making of FishBase	http://ibs.uel.ac.uk/ibs/sp2000/fishbase/fishhis.htm
Methodology For Volunteer/School Monitoring :Projects Using Lichens	http://www.cciw.ca/eman-temp/research/protocols/lichen/part1.html
Growing *Fusarium* Species for Identification	http://res.agr.ca/brd/fusarium/growth.html
Commercially important fish	http://www.fishinfo.co.nz/clement/species/content.html
Turf grass Identification of *Steinernema* species	http://www.ifas.ufl.edu/~KBN/idspgu.htm
Identification And Comparison Of *Varroa* Species Infesting Honey Bees	http://www.nal.usda.gov/ttic/tektran/data/000009/38/0000093819.html
Butterfly Species Identification Guide	http://www.butterflyhouse.org/species/flight.html
Parrotlet Species Identification	http://www.shadypines.com/plets.htm
Endangered species identification:	http://midwest.fws.gov/la_cross/reports.html
corn and soy field guide	http://www.aes.purdue.edu/AgAnswrs/2000/2-1%20Field_Guide.html
Western Wetland Flora Field Office Guide to Plant Species	http://www.npwrc.usgs.gov/resource/OTHRDATA/WESTFLOR/WESTFLOR.HTM
A Field Guide To Aquatic Exotic Plants And Animals", 1995.	http://www.sgnis.org/publicat/mn-field.htm
Forests and timber: a field guide to exotic pests and diseases	http://www.aqis.gov.au/docs/border/fieldguide.htm
Fox Ridge State Park Online Field Guide to Central Illinois Mushrooms	http://dnr.state.il.us/lands/landmgt/parks/foxridge/olfguide/mushroom/seastour.htm
Field Guide to Freshwater Invertebrates	http://www.seanet.com/~leska/Online/Guide.html 16 groups
World of Dermatophytes: A Pictorial Laboratory Identification	http://bugs.uah.ualberta.ca/webbug/mycology/dermwho.htm
UL Butterfly guide for Europe	http://www.butterfly-guide.co.uk/regions/
A quick guide to Pythons	http://www.nafcon.dircon.co.uk/pythons.html

Table 4. Comparisons between taxonomic keys and field guides as identification tools

Characteristics	Systematic keys	Field guides
Identification strategy	process of elimination	comparison
Basis of identification	matrix of characters	pictures and field marks
Starting level of key	many taxonomic levels	life form
Implicit key type	narrow and deep	broad and shallow
Number of levels in key	5 -50?	1-6?
Location of Use	usually in the lab	field
Context	only the specimen	specimen, location, habitat, season
Specimen	often dead	living
Use	strictly identification	identification + basic information
Author	usually scientific expert	naturalist
Coverage	taxonomic	Taxonomic, regional and life form
Audience	normally skilled biologist	public
Language style	technical	limited technical usage
Species covered	all taxa	major groups of large organisms
Arrangement of material	hierarchical key with descriptions	book format with pictures
Key type	mostly dichotomous	Variable, not always present
Search mode	NA	scan
Field portable	yes	yes

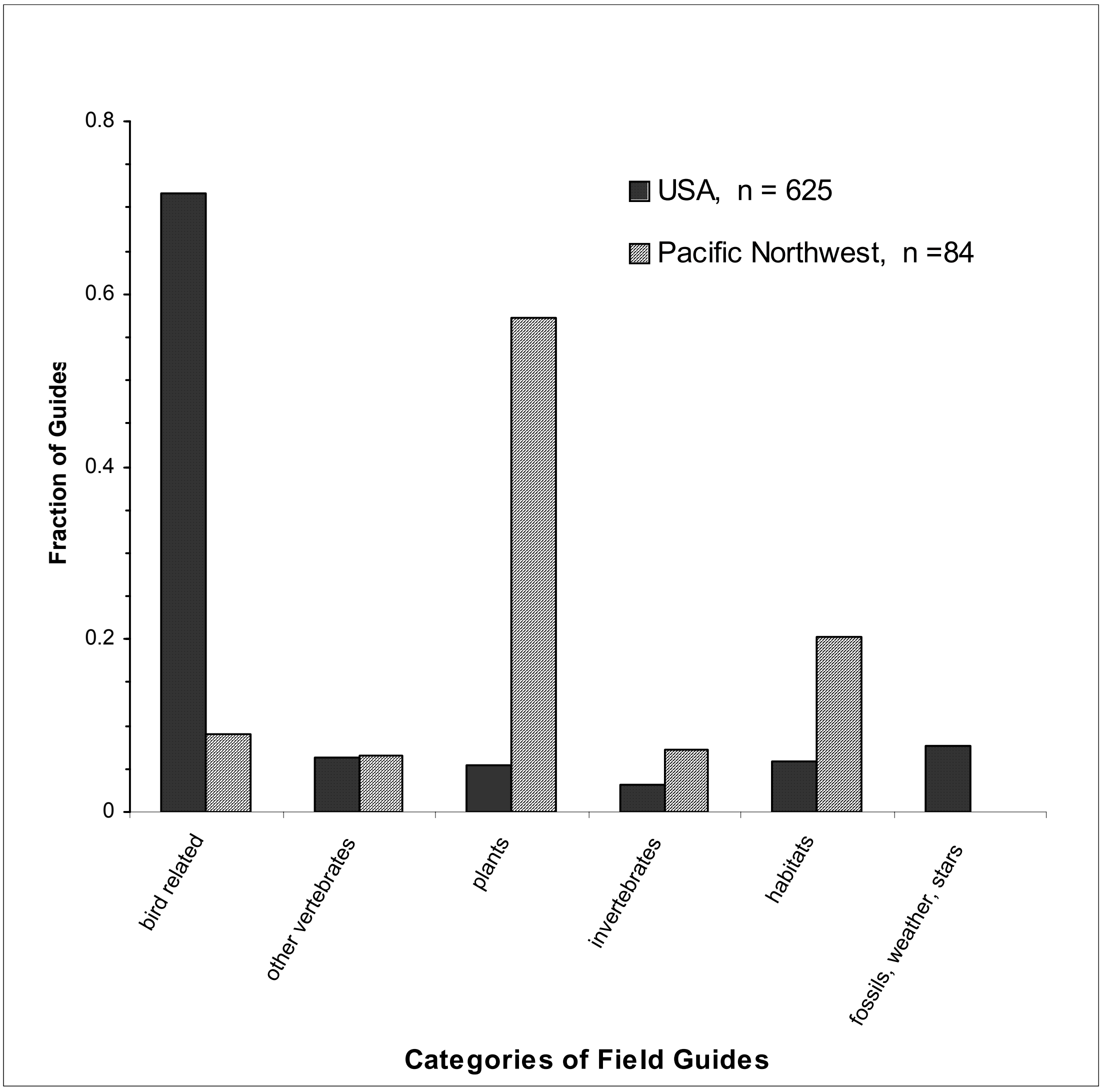

Figure 1. The fraction of field guides in six categories for the entire USA (data from Amazon.com) and for the Pacific Northwest (data from http://www.tardigrade.org/natives/fieldguides.html). Bird related guides accounted for more than 70% of those available for the entire USA at Amazon.com but plant related guides dominated (more than 55%) from a natural history seller located in the Pacific Northwest. These differences may reflect public interest, commercial decisions or biases of the seller. For further discussion see the text.

Appendix 1 –

Example of bad keys cited in TAXACOM: Biological Systematics and Biocollections Computerization Discussion List (http://www.keil.ukans.edu/mail_archives/taxacom/ or http://www.usobi.org/archives/taxacom.html

Dan Janzen wrote “From Standley's Trees and Shrubs of Mexico Quercus (80 plus species):

the opening couplet:
Acorns take one year to mature
Acorns take two years to mature

from Asclepiadaceae (huge number of species)

the opening couplet:

Pollen feels waxy to the touch
Pollen not waxy to the touch”

Robin Panza wrote “One of my "favorites" is from Munz--A California Flora and supplement.
In the "Umbelliferae", the couplet
Plants annual (if perennial, with celery odor and taste).
Plants perennial or biennial.

I know someone who wasn't sure if the plant was annual. It didn't smell like celery, so she tasted it. It was Conium (poison hemlock). She managed to make it home before she collapsed. She was hospitalized with paralysis for a couple of weeks, and continued to have nerve and muscle problems for weeks after. All she'd done was touch it to her tongue, spit it out and wash out her mouth (it's apparently quite vile-tasting).

Any couplet that can kill a beginner by its ambiguity gets my vote for worst.”

Barbara Ertter wrote “Let's not forget the apocryphal: "Differs in having a certain indefinable
grace that the other is lacking". E. L. Greene, perhaps?”

Neal Evenhuis wrote “From F.M. Hull's (1973) "Bee flies of the world”:

75. Large or small flies . . . .
-- Not such flies . . ..

Jef Veldkamp wrote

> -. Species mihi cognitae
> -. Species mihi ignotae
>
> R. Knuth. 1930. Oxalidaceae, in Engler & Prantl, Das Pflanzenreich 95: p. 57, 71, 77, 85, 132, etc. etc.

There also seems to be a Dutch field guide to birds, that starts off with

-. Bird sings its own name.
-. Bird does not sing its own name.

This works for birds singing in Dutch only, of course."