THE CONTRIBUTION OF FLORISTIC AND MONOGRAPHIC STUDIES TO A COMPREHENSIVE WORLD UMBELLIFER DATA SET

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Recent trends in compilation of world consensus family classifications from existing floristic and monographic data, and demands for alpha-taxonomic and other traditional phenetic data for analysis with phylogenetic reconstructions derived from DNA sequences are discussed. Obstacles hindering the production of a meaningful, comprehensive data set for *Apiaceae* include: (1) the lack of comparable non-molecular phenetic data; (2) incomplete coverage of family accounts in recent Floras, particularly in the southern hemisphere; (3) large, artificial genera awaiting monographic treatment; and (4) the lack of database systems that handle differences in taxonomic opinion (alternative classifications). The use of electronic communication, particularly the Internet, can help to accelerate progress in these areas through promoting collaboration and information exchange. The contribution of the *Apiales Resource Centre* website (especially the umbellifer areas: www.umbellifers.com) is highlighted.

Keywords. *Apiaceae*, *Apiales*, consensus classification, Internet website, *Umbelliferae*.

Introduction

Recent years have seen international bodies applying increasing pressure on the taxonomic community at the national and international level to produce consensus classifications with stable names. There is undoubtedly a need for lists of preferred names for use in international legislation, global biodiversity studies, and other such far-reaching initiatives. However, some caution should be exercised when preparing and using these lists as a good understanding of the reliability and accuracy of the underlying data is essential. Projects such as *Species Plantarum* (Orchard, 1999) and *Species 2000* (Bisby & Smith, 1996) have been established to meet this requirement, and they themselves draw on the combined knowledge of the taxonomic community to provide reliable data. The *World Umbellifer Database* (Watson, 1998a) is involved in providing such information for the *Apiaceae* (*Umbelliferae*) as a Global Species Database for *Species 2000*. As the name suggests, the scope of the *World Umbellifer Database* is worldwide; however, work to date has actively concentrated on the Eurasian members, particularly China, India and the Himalayas. Nevertheless it has proved useful in assessing the feasibility of producing a reliable, complete data set for the *Apiaceae* across the whole of its distribution, and the results are discussed below. At this point it is worth noting that Hiroe's *Umbelliferae of World* (Hiroe, 1979) is not in fact a world family monograph, but rather an agglomeration of his

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past monographic floristic works on Asian *Apioideae*, plus other miscellaneous data gathered during study visits to the University of California, Berkeley. This large volume contains a great deal of valuable information, but it is incomplete (less than half the currently 'accepted' genera are included) and there are many misprints, so it should be used with care.

Heywood (1971) stated that 'it is difficult to obtain a realistic idea of the state of knowledge of any large plant family from the normal handbooks'. He was referring to published Floras, monographs and revisions, and, indeed, when working on a large geographic scale there are four main obstacles that need to be overcome in order to arrive at an accurate understanding of a plant group:

- Lack of detail in descriptions
- Incomplete coverage in Floras
- Uneven taxonomic coverage
- Differences in taxonomic opinion

Lack of Detail in Descriptions

Monographic treatments usually aspire to include a full morphological description and illustration for all known features of the taxa they cover. Floristic treatments are rarely able to match this level of detail, and in many cases can only provide concise, diagnostic descriptions to facilitate identification, e.g. Tutin (1968) in *Flora Europaea*. Larger Floras provide fuller descriptions (e.g. *Flora of Turkey*, Davis, 1972, and *Flora Iranica*, Hedge *et al.*, 1987), but they will always be limiting for detailed comparisons. For example, these 'big Floras' may tell you the number and general distribution of vittae, but few other anatomical details of the fruit are given. Phylogenetic reconstructions based on DNA sequences are shedding light on past evolutionary relationships, but now we are finding that our ability to analyse these results with more traditional alpha-taxonomic and other phenetic information is hampered by the paucity of comparable data. Only a few literature sources consider longitudinal sections of fruits, compare origins of sepals and ovules, give accurate shapes for the petals, stylopodia etc. Obviously recording at this level of detail for all taxa will be a mammoth effort, particularly as much of it will have to be collected afresh. Producing a widely available and internationally agreed list of characters and character states (a 'character proforma') will be vital for the organization of these data, and steps towards this have already been taken for the Australian species (M. Henwood, pers. comm.). Electronic communication will no doubt play its part in co-ordinating this effort and disseminating the results, however, these data sets will be of little use without critical first-hand examination of the plants. It is vitally important that areas of traditional taxonomic research (such as anatomy, micro-morphology, cytology, palynology etc.) resurge as a priority for research, as without these basic data little real progress can be made in areas that are totally dependent on it (e.g. molecular phylogenies, conservation strategies, suprageneric classifications).

Coverage in Floras

Floras are perhaps the best reference source that can be used to compile broad surveys, but great care must be taken when equating data associated with names in these, and other publications. Taxonomic concepts will differ to varying extents, even when the names they use are the same (the most obvious cases later being referred to as '*sensu* taxa'). Although monographs and revisions usually cover complete geographic ranges of the taxonomic groups in question (usually genera), this kind of detailed information is available only for a small fraction of the family. In this instance they are perhaps most useful in resolving conflicts in taxonomy between floristic accounts. During the first international *Umbelliferae* symposium at Reading in 1970, Heywood (1971) and Mathias (1971) discussed the status of floristic knowledge in the Old and New World respectively. In some regions there has since been great activity, but for others the situation is virtually the same. Figure 1 illustrates a current estimate of the coverage of *Apiaceae* accounts in major regional floristic works post c.1940.

Coverage in the northern hemisphere is now very good (almost complete), however, treatments for the southern hemisphere are still rather patchy (particularly South America, Sub-Saharan Africa and Australia). At the first umbellifer symposium, Heywood (1971) posed the question 'how well do we know the Old World umbellifers?'. He came to the conclusion that, in fact, this was a lot less than one might imagine. Since then most of the major floristic gaps have been filled by publications such as *Flora Iranica* (Hedge *et al.*, 1987), *Flora of Turkey* (Davis, 1972) and *Flora Reipublicae Popularis Sinicae* (Shan & Sheh, 1979, 1985, 1992). So, although new taxa continue to be discovered and there are still problems with species

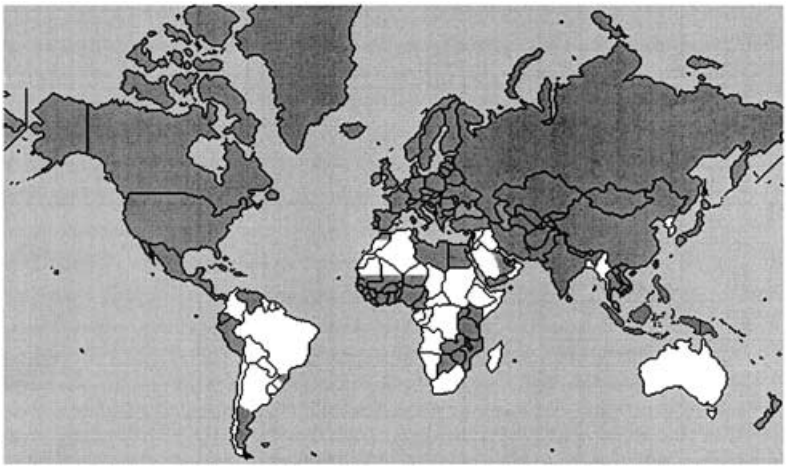

FIG. 1. Coverage of umbellifer accounts in recent (post-1940) Floras (full details available on the *Umbellifer Resource Centre* website (http://www.rbge.org.uk/data/URC/floras/worldlist.htm).

relationships and generic delimitation, our understanding of Old World species is now much more complete.

Mathias (1971) addressed the situation in the New World, stressing that problems are even greater than those encountered in the northern hemisphere of the Old World, as they are compounded by paucity of collections and complexity in synonymy. When faced with the influx of new materials from the New World early European botanists usually resorted to forcing the newly described species into existing European genera. It was not until the end of the nineteenth century that North American taxa began to be recognized in distinct genera of their own. Mathias points out that the result of this situation is well illustrated by the reduction of 1900 names to just 509 accepted names in the most recent complete account of *Apiaceae* in North America (Mathias & Constance, 1944–5). These figures indicate a great complexity of umbellifer names in North America, with 73% falling into synonymy. Using the *World Umbellifer Database* these figures can now be compared with the situation in the eastern parts of the northern hemisphere. Of the 5115 checked taxon names in the database for Eurasia, 2872 (56%) are considered synonyms. This percentage is far less than seen in North America, and reinforces Mathias's earlier observations that complexity in synonymy is greater in the New World compared with the Old World. It is less straightforward to derive similar estimates for the worldwide situation with any degree of accuracy. There are about 16,000 published names in the *World Umbellifer Database*, and according to Pimenov & Leonov (1993) about 3600 species and 400 genera in the family. These figures put a crude global estimate of taxon name synonymy for *Apiaceae* at 75%, a figure comparable with the estimate of three or four synonyms per accepted species name for all seed plants (Stace, 1989: 190). This figure for the whole *Apiaceae* is higher than seen in any of the broad-based regional floristic treatments, and indicates that complexities in synonymy will be greater in the southern hemisphere than so far seen in the North.

Uneven Taxonomic Coverage

Figure 1 illustrates that South America, Sub-Saharan Africa and Australia are the largest geographic areas most in need of modern floristic treatments. These areas are important as they are well represented at the generic level, and have a significant proportion of endemic genera: South America has 45 genera (18 of which are endemic); Sub-Saharan Africa has 69 genera (38 endemics); Madagascar has 16 genera (6 endemics); and Australia has 36 genera (11 endemics). Burtt (1991) adds that the Southern African component is important beyond its size, as there are several woody genera that have obvious phylogenetic interest.

Traditionally the *Apiaceae* has been divided into three unequal subfamilies (Table 1). The majority of species are placed in the *Apioideae* and are primarily northern hemisphere. As discussed above, these areas are relatively well known and covered by modern floristic treatments. However, the *Hydrocotyloideae* and *Saniculoideae* are predominantly southern hemisphere groups, and thus

TABLE 1. Statistics on the three subfamilies of the *Apiaceae* (data from Pimenov & Leonov, 1993)

Hydrocotyloideae Link
42 genera, 469–490 spp.
Primarily southern hemisphere (90% found in South America)
Saniculoideae Burnett
9 genera, 304–325 spp.
Predominantly southern hemisphere (South America, Sub-Saharan Africa, Australia)
Apioideae Drude
404 genera, 2827–2935 spp.
Primarily northern hemisphere (cosmopolitan in temperate areas)

comparatively poorly known. Phylogenetic studies are revealing the important position of these subfamilies in resolving basal relationships (see Downie *et al.*, 2001; Lowry *et al.*, 2001; Plunkett, 2001), but the lack of basic taxonomic data will hinder future expansion of these projects (see earlier comments). Fortunately active research is in progress, at least in some of these regions (e.g. Winter & Van Wyk, 1996; Allison & Van Wyk, 1997; Van den Borre & Henwood, 1998; Hart & Henwood, 1999; Schubert & Van Wyk, 1999; Van Wyk *et al.*, 1999), and work is underway for the family account for *Flora of Australia* (for current information see http://www.rbge.org.uk/data/URC/floras/australia.htm).

Patchy coverage in floristic treatments is one factor contributing to the uneven spread of knowledge across the family; problems with large genera is another. The difficulties posed by large, heterogeneous genera are not restricted to the *Apiaceae*, but it is becoming increasingly problematic for this family. Traditional reliance on fruit characters to delimit genera (and suprageneric taxa), coupled with widely acknowledged convergence, parallel evolution, and uniformity of visual characters, has resulted in several unwieldy genera (Table 2) and numerous small mono- and

TABLE 2. Large genera with more than 50 species in the three *Apiaceae* subfamilies (data from Pimenov & Leonov, 1993)

Hydrocotyloideae		*Apioideae*	
Hydrocotyle L.	(120–130 spp.)	*Bupleurum* L.	(180–190 spp.)
Azorella Lam.	(65–75 spp.)	*Ferula* L.	(170 spp.)
Saniculoideae		*Pimpinella* L.	(c.150 spp.)
Eryngium L.	(230–250 spp.)	*Angelica* L.	(110 spp.)
		Seseli L.	(100–120 spp.)
		Peucedanum L. *s.l.*	(100–120 spp.)
		Lomatium Raf.	(74 spp.)
		Heracleum L.	(65 spp.)
		Arracacia Bancroft	(55 spp.)
		Ligusticum L.	(40–50 spp.)

ditypic genera (Heywood, 1971; Spalik *et al.*, 2001). This has long been regarded as unsatisfactory, but as yet it has not been possible to resolve these issues.

In recent years molecular evidence has added fuel to the fire, confirming long felt dissatisfaction with some genera (e.g. *Peucedanum*, Downie *et al.*, 2000), and in some cases upset what have traditionally been considered natural groups, for example *Hydrocotyle* (Downie & Watson, unpubl. data), *Ferula* and *Angelica* (Downie *et al.*, 2000). Monographic study of these genera is indeed daunting, not only because of the species numbers involved, but also for the wide geographic spread. Some authors have nibbled away at parts of these large genera, delimiting new segregate genera for the species in their area of interest, for example *Demavendia* Pimenov, *Johreniopsis* Pimenov and *Leutea* Pimenov are segregates of *Peucedanum* proposed in *Flora Iranica* (Hedge *et al.*, 1987). The editors of *Flora Iranica* justly comment that 'Many botanists will rightly criticize the recognition of segregate genera in a Flora in the belief that the very real problems of *Peucedanum* taxonomy can only be solved by a worldwide ... assessment of the situation' (Hedge *et al.*, 1987: 442). In practice students working at the global level are forced to adopt a more conservative approach and maintain the *status quo*, unsatisfactory as it may be, until such time as a complete generic revision is available. Mathias also pointed this out at the 1970 symposium (Mathias, 1971), but we have been unable to make significant progress over the last thirty years. Instead there has been a flurry of activity in Flora writing.

Now we have reached a point where attention needs to shift to monographic work on large genera and genera from poorly known areas. As one might expect, many of the genera listed in Table 2 are long-standing Linnaean genera that have become artificial creations of taxonomists through the sequential addition of species for want of a better place. Undertaking monographic revision of such large genera is probably beyond the scope of any one individual, and collaboration is needed. International and transnational interdisciplinary collaboration was successfully achieved as a direct outcome of the 1970 Reading Symposium. A group of researchers studied the distinctive tribe *Caucalideae* Spreng. using many different techniques on the same plant material (several papers given at the 2nd International Umbellifer Symposium at Perpignan in 1977 present work resulting from that collaboration, see Cauwet-Marc & Carbonnier, 1982). A similar arrangement could be made for tackling large genera, as individual participants could take individual (or related groups of) characters and produce a comparable data set of uniform quality across the whole geographic and taxonomic range of the genus. Establishing collaborative enterprises is not easy, and Heywood (1978) pointed out some of the difficulties during the Perpignan Symposium. Poor communication was a major contributor to the problems. Today communication can be greatly facilitated by electronic means (e-mail, ftp, Internet, intranets etc.), and rapid exchange of data and ideas on a worldwide scale is becoming increasingly easy. The exponential spread of Internet access, particularly in developing countries, means that it is now easier and cheaper to communicate via computers than has so far been possible by other means (even if this is restricted to a local Internet café with basic modem connection). It was with this in mind that

the *Apiales Resource Centre* was established as an Internet website (Watson & Pullan, 1998). Mathias (1971) lamented the poor progress with these seemingly intractable genera. It is hoped that the recent advances in taxonomic methods and communication will provide the means to solve them in the near future.

Differences in Taxonomic Opinion

When a new classification is published that diverges from a previously accepted one, a period of digestion usually follows during which the biological community assimilates the ideas, and either supports or rejects them. As everyone is entitled to their own opinion there is no formal process by which a new classification can be endorsed or rejected, and instead people use the classification that suits them. Quite often, in well-worked groups, a consensus is soon reached and there is general agreement on the favoured classification system. In other cases, perhaps where there are fewer experts, opinions can remain divided and no general agreement reached until additional evidence is found to support one of the competing classifications. For groups where there is only one taxonomic expert any potential problems are less obvious as there will be no dissenting voices, and an uninformed user would unwittingly follow one person's opinion. This opinion cannot be endorsed or rejected until some external assessment is available.

The use of computerized databases as working tools for taxonomists is ever increasing. However, there is currently no fully mature database system that adequately handles multiple classifications that result from differences in opinion as discussed above. This is generally not seen as a problem as most databases on single taxonomic groups are managed by one, or maybe a few, people and as such are intended only to represent one classification (one 'view'). As the scope of data sets is expanded to encompass a wider area, and the user base increased by remote access (e.g. via the Internet), then the limitations of these consensus classification databases will become critical. Pullan *et al.* (2000) discuss these issues in greater detail, and put forward the *Prometheus* taxonomic model and prototype system for storing multiple classifications in a database system. As others explore these ideas, further models will be published and hopefully complete working systems will soon be available that allow us to accurately store classificational and nomenclatural data. Glossing over alternative classifications gives a false impression of the state of knowledge, and may ultimately do more harm than good. One would probably wish to offer a 'preferred view' for general usage, but people should be aware of the alternative viewpoints, and be able to access and interpret relevant information irrespective of which names they were originally linked to.

The Apiales Resource Centre

Background

The *Apiales Resource Centre* (Watson & Pullan, 1998) is a multipage Internet website designed to enable a broad spectrum of people to gain access to a wide variety of

information on the families *Apiaceae* and *Araliaceae* (Fig. 2). Royal Botanic Garden Edinburgh is the administrative centre and provides the backbone of the website, but several other bodies (Virginia Commonwealth University, USA; University of Illinois at Urbana-Champaign, USA; The University of Reading, UK and Horticulture Research International, UK) are involved in the development, storage and maintenance of their particular areas. Users can explore the information available by browsing through menus (e.g. Fig. 3), and following the hypertext links.

Static information pages

In common with many websites, the site includes semi-static information pages giving details of events, ongoing projects and general umbellifer data, as well as useful links to other related sites (e.g. details of the Apiales Symposium at the 16th International Botanical Congress are available, as is an account of the higher level classification of the family). Project pages are particularly useful as people can read about ongoing or newly completed work, information that is otherwise difficult to find. Floristic treatments in preparation offer a good example of where these pages are very useful. Floras often take many years/decades to appear in print, particularly when they cover large or botanically rich areas. Meticulous preparation of family accounts for large groups is time consuming (e.g. Mathias & Constance, 1944–5), and sometimes publication of finished accounts can be held up by other elements of the Flora

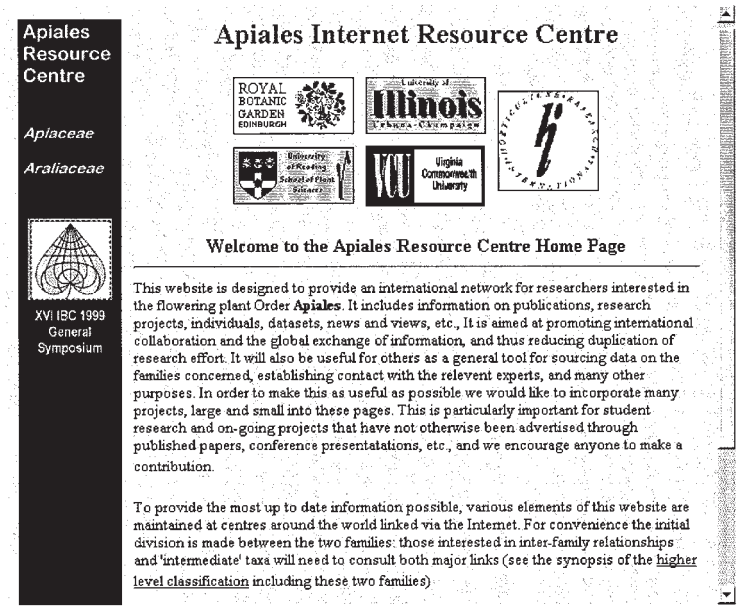

FIG. 2. Screenshot of the *Apiales Resource Centre* website homepage (http://www.rbge.org.uk/data/URC/arc.htm).

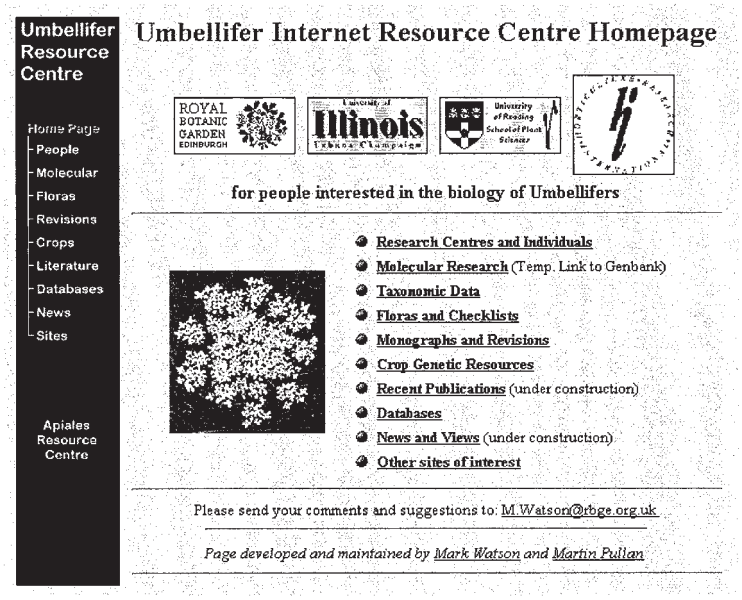

FIG. 3. Screenshot of the *Umbellifer Resource Centre* website homepage (http://www.rbge.org.uk/data/URC/urc.htm).

volume (e.g. Watson, 1999a, was actually completed in 1994). Flora project pages provide background information on umbellifers for the Flora area, scheduling dates, contact information, and a bibliography of publications resulting from the work. Similar pages cover monographic studies and major umbellifer databases. Discrete subject areas such as molecular research and crop genetic resources are developed and maintained by partner institutes, but the whole website can be accessed through a common interface.

World Network of Umbellifer Researchers

Networking, or personal collaboration, is an essential element of good science. Forming collaborative links is not always easy as often it is not a simple matter to find out who is working on what and where. Such information can be gleaned from publications, conference abstracts, or the personal knowledge of experts, but these are often disparate sources, and often refer only to completed studies that are already published. One of the main reasons for setting up the website was to provide a solution to this problem, enabling new collaborations to be established and reducing the instances of duplicated research.

The *World Network of Umbellifer Researchers* search page (Fig. 4) accesses a database of researchers, returning a list of relevant people in response to a variety of query methods. The world map is touch sensitive and researchers based at a location can be found by clicking on a dot. Alternatively, data can be entered into

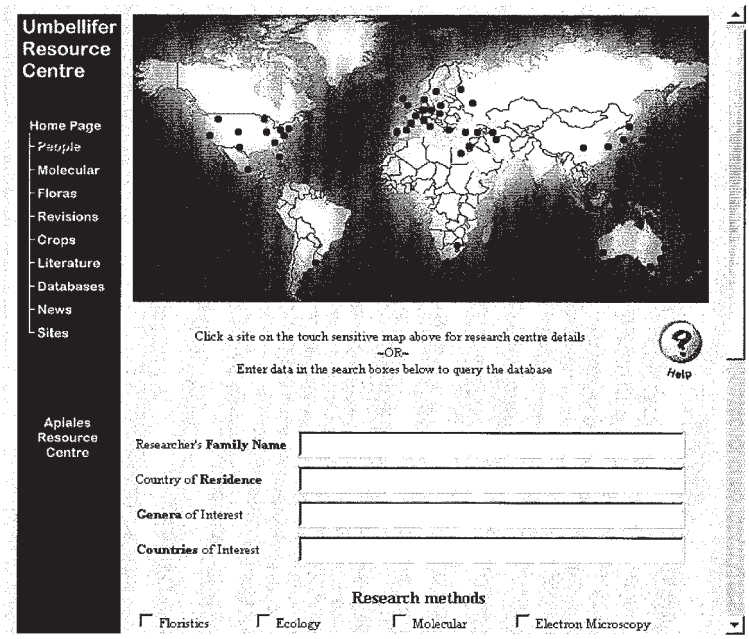

FIG. 4. Screenshot of the searchable data set of umbellifer researchers on the *Umbellifer Resource Centre* website (http://www.rbge.org.uk/data/URC/centres.htm).

one or more of the search fields and/or research methods can be selected by using the check-boxes. Users can find the current contact details of someone they already know about, or find the people interested in a particular subject or familiar with a specific technique. These queries return a short list of names, and each name can be followed to see the full personal page of that researcher. In all cases contact details are provided (postal address, telephone, fax, e-mail etc.) with areas of interest and a personal profile. Information is provided by the researcher and incorporated into the underlying database. Researchers not represented in the database, or those wishing to change their details, can send these in using the web entry form or any other method (e-mail, fax, post etc.). As these web pages are generated on demand, only the database need be updated. Currently there are over 140 people in the researchers' database.

Searchable taxonomic data

Access to the Internet is accelerating rapidly as more and more countries come online and connection speeds improve. With this growth people are beginning to integrate the Internet into their daily work, utilizing it to access the basic data needed for their research. Within plant systematics there are already numerous sites giving access to data of widespread general usage (e.g. *International Code of Botanical Nomenclature (Tokyo Code)*, International Association for Plant Taxonomy, 1997;

International Plant Names Index, Cross, 1999; *Index Herbariorum*, Holmgren & Holmgren, 1999), and others that are directed to a more specific audience (e.g. *E Himalayan Gazetteer of Plant Collecting Localities*, Watson, 1998b). The *Internet Directory for Botany* (www.botany.net) provides an excellent index to botanical information available on the Internet. Currently there are two major searchable data sets accessible through the umbellifer website which are specifically for students of *Apiaceae*. The first is accessed through the '*Taxonomic Data*' link in the main menu (Fig. 3), and provides full nomenclature, and some classification data, for all 16,000 taxon names included in the *World Umbellifer Database* (Watson, 1999b). When names have been verified against the original literature, full bibliographic citation is given as well as type data and supplementary notes. The second is an online version of the umbellifer account for the *Flora of Bhutan* (Watson, 1999c, accessed via the Bhutan page under 'Floras and Checklists'). Again the database is used to provide information to generate these pages when required, so, unlike the printed version, full voucher specimen lists and complete nomenclature details and synonymy are available for those who wish to see them. Recent developments have seen the incorporation of interactive distribution maps (showing the individual specimens that are represented by the dots), specimen lists, and images of plant portraits, herbarium specimens and line drawings.

The Internet is clearly a very powerful tool for communicating both within the botanical community and with the public at large. It enables us to exchange data and ideas rapidly, gives opportunities to disseminate information that would be slow or impractical to produce in print, and offers global access to fundamental data resources. The isolation felt by those working in countries where Internet access is not practical (either technically or financially) may be significant in the short term, but must surely diminish as the relevant technology and communication links become cheaper. Indeed, heads of government are openly supporting Internet access for all as a short-term requirement. It will not be long before individuals working in any institute will have access to some of the wealth of information that only those with access to large libraries and herbaria have so far had the luxury of using on a daily basis. Of course the Internet can never replace herbarium material where you can examine specimens to find new characters, or check old ones, but online images and supplementary data can answer many less detailed inquiries. Speakers at a recent *Taxonomic Databases Working Group* meeting focusing on digitizing botanical collections (Frankfurt, November 2000) estimated that when online specimen images are made available to researchers, the size of the subsequent physical loans of specimens was reduced by 70%.

Summary

So in answer to the question 'Do we currently know enough about the family as a whole to produce a meaningful, comprehensive data set for umbellifers of the world?' I would say that we do not, for the following reasons:

1. *Lack of comparable non-molecular data.* In the current ascendancy of phylogenetic studies based on DNA sequences, traditional taxonomic data are still critically important. There is a pressing need for the collection of fresh non-molecular data for combined analyses and interpretation of groupings.
2. *Incomplete floristic coverage*. There are many areas of the world, particularly in the southern hemisphere, that still have not been critically studied floristically.
3. *Large artificial genera.* Several large, widespread genera are known to be heterogeneous, and some have been subdivided within parts of their distribution. Difficult as they are, monographic treatments of these genera across the whole geographic range are essential.
4. *Lack of database systems that can handle differences in taxonomic opinion (multiple classifications).* It is not realistic, or advisable, to force a consensus classification from the rich diversity of taxonomic knowledge and opinions that exist (this is why the title of this paper refers to a 'comprehensive ... data set' and not a 'consensus classification'). We must acknowledge that there will always be alternative viewpoints on classification, and we must strive to store and present our data in a way that reflects this and does not merely gloss over areas of taxonomic flux.

The use of electronic communication, particularly the Internet, will undoubtedly accelerate the progress of initiatives addressing these points, but commitment and human resources first need to be in place. After comparing the umbellifers of India with surrounding areas, Mukherjee & Constance (1993) gave the following well-considered caveat: 'All these numbers [of genera and species], it should be emphasized, are to be taken *cum grano salis* because many generic boundaries are debatable, a number of described taxa are of questionable status, and correlation with Floras of surrounding areas very imperfect'. This, I would say, applies equally well to the current situation in many parts of the world, but I hope that we can make significant improvements in the near future.

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References

Allison, I. & Van Wyk, B.-E. (1997). A revision of the genus *Anginon* (*Apiaceae*). *Nord. J. Bot.* 17: 561–577.

Bisby, F. A. & Smith, P. M. (1996). *Species 2000: indexing the world's known species*. UNEP/GEF. (See also http://www.sp2000.org)

Burtt, B. L. (1991). *Umbelliferae* of Southern Africa: an introduction and annotated check-list. *Edinb. J. Bot.* 48: 133–282.

Cauwet-Marc, A.-M. & Carbonnier, J. (eds) (1982). *Les Ombellifères: contributions pluridisciplinaires à la systématique: actes du 2ème Symposium International*

sur les Ombellifères, Centre Universitaire de Perpignan, 18–21 Mai 1977. St Louis, MO: Missouri Botanical Garden.

Cross, N. (1999). *International Plant Names Index Homepage*. http://www.ipni.org.

Davis, P. H. (ed.) (1972). *Umbelliferae*. In: *Flora of Turkey*, Vol. 4, pp. 265–538. Edinburgh: Edinburgh University Press.

Downie, S. R., Katz-Downie, D. S. & Watson, M. F. (2000). A phylogeny of the flowering plant family *Apiaceae* based on chloroplast DNA rpl16 and rpoC1 intron sequences: towards a suprageneric classification of subfamily *Apioideae*. *Amer. J. Bot.* 87: 273–292.

Downie, S. R., Plunkett, G. M., Watson, M. F. *et al.* (2001). Tribes and clades within *Apiaceae* subfamily *Apioideae*: the contribution of molecular data. *Edinb. J. Bot.* 58 (2): 301–330.

Hart, J. M. & Henwood, M. J. (1999). *Brachyscias* (*Apiaceae*), a new genus from south-west Western Australia. *Austral. Syst. Bot.* 11: 175–179.

Hedge, I. C., Lamond, J. M. & Rechinger, K. H. (1987). *Umbelliferae*. In: *Flora Iranica* 162, p. 555, tabs. 499. Graz: Akademische Druck-u. Verlagsanstalt.

Heywood, V. H. (1971). Systematic Survey of Old World *Umbelliferae*. In: Heywood, V. H. (ed.) *The Biology and Chemistry of the Umbelliferae*, pp. 31–41. London: Academic Press.

Heywood, V. H. (1978). History and aims of Symposium. In: Cauwet-Marc, A.-M. & Carbonnier, J. (eds) (1982). *Les Ombellifères: contributions pluridisciplinaires à la systématique: actes du 2ème Symposium International sur les Ombellifères, Centre Universitaire de Perpignan, 18–21 Mai 1977*, pp. 1–4. St Louis, MO: Missouri Botanical Garden.

Hiroe, M. (1979). *Umbelliferae of World*. Tokyo: Ariake Book Company.

Holmgren, P. K. & Holmgren, N. H. (1999). *Index Herbariorum*. http://www.nybg.org/bsci/ih.

International Association for Plant Taxonomy (1997). *International Code of Botanical Nomenclature (Tokyo Code)*. http://www.bgbm.fu-berlin.de/iapt/nomenclature/code/tokyo-e.

Lowry II, P. P., Plunkett, G. M. & Oskolski, A. A. (2001). Early lineages in *Apiales*: insights from morphology, wood anatomy and molecular data. *Edinb. J. Bot.* 58 (2): 207–220.

Mathias, M. E. (1971). Systematic Survey of New World *Umbelliferae*. In: Heywood, V. H. (ed.) *The Biology and Chemistry of the Umbelliferae*, pp. 13–29. London: Academic Press.

Mathias, M. E. & Constance, L. (1944–5). *Umbelliferae*. In: Anonymous, *North American Flora*, Vol. 28B, pp. 43–295. New York: New York Botanical Garden.

Mukherjee, P. K. & Constance, L. (1993). *Umbelliferae (Apiaceae) of India.* New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd.

Orchard, A. E. (1999) *Species Plantarum: Flora of the world. Introduction to the series*. Canberra: Australian Biological Resources Study. (See also http://iopi.csu.edu.au/iopi/iopispp1.html)

Pimenov, M. G. & Leonov, M. V. (1993). *The Genera of the Umbelliferae: a nomenclator.* Kew: Royal Botanic Gardens, Kew.

Plunkett, G. M. (2001). Relationship of the order *Apiales* to subclass *Asteridae*: a re-evaluation of morphological characters based on insights from molecular data. *Edinb. J. Bot.* 58 (2): 183–200.

Pullan, M. R., Watson, M. F., Kennedy, J. B., Raguenaud, C. & Hyam, R. (2000) The Prometheus Taxonomic Model: a practical approach to representing multiple taxonomies. *Taxon* 49: 55–75. (See also http://www.prometheusdb.org)

SCHUBERT, M. T. R. & VAN WYK, B.-E. (1999). Three new species of *Centella* series *Montanae* (*Apiaceae*). *Nord. J. Bot.* 19: 427–434.
SHAN REN-HWA & SHEH MENG-LAN (eds) (1979). *Umbelliferae* part 1. *Flora Reipublicae Popularis Sinicae*, Vol. 55 (1). Beijing: Academia Sinica.
SHAN REN-HWA & SHEH MENG-LAN (eds) (1985). *Umbelliferae* part 2. *Flora Reipublicae Popularis Sinicae*, Vol. 55 (2). Beijing: Academia Sinica.
SHAN REN-HWA & SHEH MENG-LAN (eds) (1992). *Umbelliferae* part 3. *Flora Reipublicae Popularis Sinicae*, Vol. 55 (3). Beijing: Academia Sinica.
SPALIK, K., WOJEWÓDZKA, A. & DOWNIE, S. R. (2001). Delimitation of genera in *Apiaceae* with examples from *Scandiceae* subtribe *Scandicinae*. *Edinb. J. Bot.* 58 (2): 331–346.
STACE, C. A. (1989). *Plant Taxonomy and Biosystematics*, 2nd edition. London: Edward Arnold.
TUTIN, T. G. (ed.) (1968). *Umbelliferae*. In: TUTIN, T. G., HEYWOOD, V. H., BURGES, N. A. *et al.* (eds) *Flora Europaea*, Vol. 2, pp. 315–375. Cambridge: Cambridge University Press.
VAN DEN BORRE, A. & HENWOOD, M. J. (1998) A revision of the genus *Diplaspis* (*Mulinae–Hydrocotyloideae–Apiaceae*). *Austral. Syst. Bot.* 11: 1–12.
VAN WYK, B.-E., TILNEY, P. M. & WINTER, P. J. D. (1999). Four new genera of woody *Apiaceae* of Madagascar. *Taxon* 48: 737–745.
WATSON, M. F. (1998a). *The World Umbellifer Database*. http://www.rbge.org.uk/data/URC/dbases/wud.htm
WATSON, M. F. (1998b). *Gazetteer of East Himalayan Plant Collecting Localities*. http://www.rbge.org.uk/sikkim/sikgaz.htm
WATSON, M. F. (1999a). *Umbelliferae*. In: GRIERSON, A. J. C. & LONG, D. G. *Flora of Bhutan*, Vol. 2, Part 2, pp. 434–504. Edinburgh: Royal Botanic Garden Edinburgh.
WATSON, M. F. (1999b). *Taxonomic Data for the Umbelliferae*. http://www.rbge.org.uk/data/URC/Nomenclature
WATSON, M. F. (1999c). *Flora of Bhutan Umbelliferae Online*. http://www.rbge.org.uk/data/URC/bhutanumbels
WATSON, M. F. & PULLAN, M. R. (1998). *The Apiales Resource Centre*. http://www.rbge.org.uk/data/URC/arc.htm
WINTER, P. J. D. & VAN WYK, B.-E. (1996). A revision of the genus *Heteromorpha* (*Apiaceae*). *Kew Bull.* 51: 225–261.

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