PROCEEDINGS OF THE
NATIONAL TAXONOMY FORUM

Australian Museum, Sydney
3–4 OCTOBER 2007
Note on Proceedings:

This document reflects the Australian taxonomic community’s unanimous concern regarding the urgent need for action and funding. It provides a record of the presentations by invited speakers and reflects the input of participants at the workshop sessions held at the National Taxonomy Forum at the Australian Museum, Sydney on 3–4 October 2007. The document covers the topics, debates and viewpoints raised and addressed by participants, but is not a verbatim transcript of the actual proceedings. It has been compiled and edited to incorporate additional submissions from taxonomists and user-groups unable to attend the forum in Sydney. It is intended for dissemination among the taxonomic community, user-groups and other interested parties to provide solutions and strategies for the future practice of taxonomy in Australia.

Compiled by Kathryn Hall
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Australia has a huge national jurisdiction, encompassing a continental land area of 700,000km² (approximately 50% larger than Europe), 70,000km of coastline, 8,600,000km² of continental marine territory and 16,100,000km² of oceanic seabed. The Australian jurisdiction includes 80 terrestrial and 60 marine bioregions; all five oceanic climatic zones, extending from the tropics to polar seas, the intertidal to the abyssal plains; and 16 sites that are World Heritage listed. It is therefore not surprising that Australia is one of only 17 nations that are classified as biologically mega-diverse, together containing >70% of all life on earth. It has been estimated that about 80% of Australia’s native species are found nowhere else in the world, but in over 200 years only about 172,000 species have been described from an estimated 580,000–680,000 species that actually live here (i.e. only 25–30% of the biota has been described to date).

Despite the concerted efforts of the small pool of Australian scientists engaged in the discovery and documentation of our biological diversity [taxonomists] and their international collaborators, our knowledge of the native biota has not escalated in proportion to the growing need for this knowledge. This knowledge is pivotal to effective conservation, management or sustainable use of the biota and the ecosystems they form. Despite repeated Commonwealth Government reviews that explicitly acknowledge the need for taxonomy, its underpinning of much of the other biological sciences, and the continued decline in our taxonomic capabilities, measured against the huge task still remaining to document the biota (the “taxonomic impediment”), little of substance has been done for over two decades.

What is at issue is the capacity of the Australian science sector to continue to provide a timely and effective research and identification service.
Taxonomy is clearly a discipline in crisis. A survey of Australian working taxonomists undertaken by the Australian Biological Resources Study (ABRS) during 2003 showed the taxonomic workforce is aging rapidly and is not being replaced. The survey found about half of Australia’s taxonomists are aged over 45 years, one third are over 60 and one third of the taxonomic workforce is voluntary. Moreover, four full-time positions are being lost each year, while only 1–1.5 are gained, resulting in a net loss of expertise at the level of 2.5–3 taxonomists annually. Even as the majority of Australia’s current capacity rests with taxonomists who are approaching retirement, students are not being recruited into the science and practice of taxonomy. Thus as the taxonomic workforce continues to age, the rate of loss of expertise is escalating dramatically. ABRS predicts that in just five years, Australia will face the real and tangible crisis of a chronic lack of taxonomic capacity.

Taxonomy, as a discipline and in practice, faces multiple crises, however. Not only does it face the crises of an aging workforce and of diminishing student participation rates, but also the crises of funding reduction and restrictions, and of invisibility. The aim of the National Taxonomy Forum, held at the Australian Museum in Sydney, was to highlight areas of key concern for Australian taxonomy now and into the future. The forum, which included working taxonomists (responsible for documenting plant, animal, prokaryote, protist and fungal diversity), policy makers, public interest and industry groups, and end users, also aimed to search for solutions and strategies.
I NATIONAL ACTION PLAN: TAXONOMY IN AUSTRALIA — THE WAY FORWARD

Key Recommendations
To achieve a comprehensive national response to revitalising taxonomy, governments and the taxonomic community of Australia need to respond to the national taxonomic crisis now, by:

- Identifying Australia’s taxonomic research and delivery priorities
- Undertaking effective succession-planning and building the public profile of taxonomy
- Developing new funding models

Strategies for Building Taxonomic Capacity

1.1 Identify Australia’s taxonomic research and delivery priorities

- Identify species groups that are important to biodiversity information users
- Identify species groups in which we are losing or have lost taxonomic expertise
- Prioritise identified species groups for research action
- Develop identification tools for Australia’s fauna and flora
- Improve service delivery of taxonomic information for users

1.2 Undertake effective succession-planning and public profile development

- Secondary school through to undergraduate: promote taxonomy/systematics, provide opportunities for internships in museums and herbaria
- University — postgraduate: encourage taxonomy/systematics research training through structured funding of honours stipends, Masters and PhDs, and provide postdoctoral fellowships and support for early career researchers

1.3 Develop new funding models

- Commission cost-benefit analysis to assess the contribution of taxonomy to the economy, development and wellbeing
- Promote joint appointments/research centres between universities, museums/herbaria
- Develop funding for field work, research infrastructure, maintaining existing and new collections and digitising and databasing existing material
- Develop larger, longer-term grants enabling major national studies of priority groups
- Seek industry partners to support national high-priority projects
2 WORKSHOP SESSIONS

2.1 Taxonomic priorities and research gaps

This workshop aimed to identify high-level priorities, both in terms of important taxonomic groups and groups that have lost (or are in danger of losing) taxonomic expertise in Australia. Ideas put forward at each of the sessions may be considered in directing national priorities over the next four years.

Key recommendations

- urgently stock-take Australia’s national taxonomic capacity
- cross-reference issue-based and taxon-based approaches to prioritise and develop a predictive matrix for all taxa
- prioritise research that specifically documents Australia’s unknown biota

Overview

The priorities and gaps workshop was held in four sessions, with a mix of taxonomic specialists and users of taxonomic services participating in each workgroup. On more than one occasion, participants expressed the opinion that identifying priorities in this forum was probably not possible. However, it was conceded that, given current funding shortages, it is very necessary to attempt to isolate groups that are of immediate concern due to losses of expertise or urgent and emerging needs.

Discussion

The responses received from forum participants during the workshop fell into two broad categories:

1. groups of organisms clustered by an underlying issue or imperative; and
2. specific taxa identified as needing urgent investigation.

These two groups reflect the different approaches of the participants to the task of assessing priorities.

The first approach, grouping based on perceived need, is an inward process: a problem is identified and methods to address it are sought. The second, taxon-based approach is more outward: studies of individual taxa may address numerous scientific, economic and social problems. There is considerable overlap between the issue-based and taxon-based approaches, and similar taxa were identified in each instance. Notably, the identification of Australia’s largely “unseen” microorganisms was recognised as an area for high priority taxonomic study. Soil-dwelling, marine and interstitial organisms were highlighted as important groups.

2.1.1 Issue-based approaches to assessing priority candidates for taxonomic research

Using the issue-based approach to identifying key areas for taxonomic research, taxonomy (and systematics) is perceived as a service discipline. That is, the main rationale for undertaking taxonomy is seen to be that it will enable, enhance or answer. Taxonomy can enable other biological studies by providing crucial data for ecological and evolutionary studies. It can enhance accuracy in biodiversity survey work and has extended benefit to government and industry in allowing informed decision-making for projects that may have environmental impact. Further, taxonomy can provide answers to government and industry stake-holders, especially in times of crisis or threat from peril, through the correct and reliable identification of agents of indigenous or exotic disease.

Workshop participants suggested various issues of economic, social and political concern to contemporary Australia, which can be categorised broadly into ten themes (Table 1). Each theme is discussed in detail below, including examples of taxa that address each topic.
**Table 1**
Criteria for justifying the selection of individual taxa for priority research

- Biodiversity
- Biosecurity
- Public Health
- Animal Health
- Agriculture and/or Aquaculture
- Environmental Protection and/or Conservation
- Areas where Australia has strong capacity/collections
- Areas where Australia has a gap in collections
- Biodiscovery or Biotechnology
- Other economic or cultural significance

**Criterion 1**
**Biodiversity**

Studies that aim to identify and document organisms in largely unexplored habitats or understudied taxonomic groups should be given priority under the criterion of Biodiversity.

The assessment of biodiversity (in this case referring only to the species and the ecosystems they form — genetic diversity is addressed elsewhere in this forum), is seen by both taxonomists and society as having intrinsic importance. However, a large volume of taxonomic work remains to be completed for Australia’s biota (see Case Study 3 and Case Study 6). There are mega-diverse taxonomic groups, such as the prokaryotes (bacteria and cyanobacteria — 99.9% are presumed unknown), and the Acari (mites), of which only 15% of the estimated fauna of 20,000 species is known. Similarly, diverse ecosystems were identified as key environments for future taxonomic surveys. One example of such ecosystems is marine systems, where the sediment fauna remain largely undocumented. Documenting and understanding the diversity of organisms has value in its own right and this stance is perceived as a non-negotiable moral and ethical imperative.

**Criterion 2**
**Biosecurity**

Taxonomic studies that research exotic and indigenous organisms, with a focus on those that have disease or invasive pest implications, should be given high priority.

Australia is an island continent home to unique and biodiverse ecosystems and many of Australia’s species are vulnerable to invasive species. Stringent quarantine measures are therefore needed to ensure their protection. In the case of marine pests, we first need to identify which species have been introduced, that is, to distinguish between introduced and undescribed native species. However, because of Australia’s geographic isolation, many of Australia’s agricultural activities remain well-protected from disease agents that cause devastating outbreaks in other countries (see Case Study 1). Further, it is possible that endemic plants and animals may become pests if exported to other nations (see Case Study 10).

**Criterion 3**
**Public Health**

Taxonomic research should be, in part, directed toward the study of groups that have the potential to become agents of disease and a menace to Public Health in Australia.

Climate change and the increasing ease of human travel have put Public Health firmly on the agenda for Australians. International travel is becoming cheaper and there are fewer restraints to the passage of people through international ports. The transit of people, plants and animals has implications for Public Health. Further, concerns about the potential effects of climate change, have led to speculation that devastating diseases such as malaria could easily become endemic to Australia. Workshop participants highlighted disease agents, such as parasitic nematodes and single-celled parasites, as significant taxa that should be flagged for priority study. Emerging diseases transmittable between humans and animals may come from domestic and introduced sources and Case Study 5 indicates the relevance of studying native parasite groups in addition to exotic taxa. It is crucial that Australia cultivates and maintains a capacity to deal with the taxonomic aspects of disease as it arises. The unpredictable nature of disease emergence means there may be a necessary degree of latency in that capacity, yet it remains vital none-the-less.
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Criterion 4
Animal Health
As with Public Health, Animal Health was revealed by workshop participants as an important criterion for the assessment of priority.
Increased ease of international travel and transportation and concerns about environmental alteration brought about by climate change also underscore the significance of Animal Health to the Australian community. The criterion of Animal Health has strong links with the economic criterion of Agriculture and/or Aquaculture.

Criterion 5
Agriculture and/or Aquaculture
The vulnerability of Australia’s agriculture and aquaculture industries to high economic losses or, worse, decimation, by pest species and disease agents justifies the prioritisation of such organisms for taxonomic research.
As highlighted in Case Study 4, taxonomic accuracy in the identification of pest species can enhance the efficacy of strategies for the eradication of plant pests. Further, as in Case Study 10, it is important that the Australian agricultural sector is able to distinguish among endemic, native species and exotic, noxious species of weed. Incorrect identification of species can have severe consequences and lead to the unnecessary embargo of commodity shipments. The agriculture and aquaculture industries also both require that Australia has the capacity to correctly identify disease agents. As indicated in Case Study 11, rapid and accurate diagnosis can increase survival outcomes for stock and minimise potential economic losses due to disease. Increased taxonomic accuracy in the identification of pests and diseases agents will ameliorate many of the current losses in industry from disease outbreaks and trade quarantine restrictions.

Criterion 6
Environmental Protection and/or Conservation
Taxonomic research that contributes to greater knowledge of Australia’s vulnerable and endangered natural heritage should be afforded priority under this criterion.
At times, there is conflict between the demands of industry and the need for environmental conservation. Workshop participants contended that taxonomy plays a key role in negotiating satisfactory outcomes. The interplay between industry and taxonomy is detailed in Case Study 7 and Case Study 8. In these examples, taxonomic research provided critical data, prior to the expansion of industry into ecologically sensitive environments, which will be used to establish frameworks for sustainable development. Taxonomy can also be crucial to the rehabilitation of degraded environments. For example, an increased taxonomic understanding of soil microorganisms may be able to assist in improving soil quality.

Criterion 7
Areas where Australia has strong capacity/ collections
Funding should be directed towards existing taxonomic workers who have demonstrated excellence and additional monies provided for the curation of associated collections of national significance.
Many participants highlighted the need for existing and future taxonomic funding to incorporate monies for the development and maintenance of collections, in particular those of national significance. In light of the increasing reliance on DNA-sequence data for taxonomic identification, the need for well-curated and staffed voucher specimen repositories is becoming ever more critical. Further, it is necessary that collections house physical specimen vouchers in addition to having the capacity to store whole genomic DNA extracts from specimens (Genome Banking facilities). The proper maintenance of biological material in perpetuity is required to support and enhance the work of Australia’s existing taxonomists (see Case Study 7). Collection development and maintenance is of particular importance where Australia holds recognised excellence in taxonomic research.

Criterion 8
Areas where Australia has a gap in collections
Taxonomic groups presently unable to be investigated because of critical shortages of expertise should be demarcated for the recruitment of skilled taxonomists to undertake priority studies.
The loss of taxonomic expertise due to the problems of an aging workforce and the lack of funding and employment opportunities has led to alarming weaknesses in Australia’s taxonomic capacity (see Case Study 2). Participants recognised that there have been significant losses of specialists in non-coral cnidarians (e.g. jellyfish), marine bivalves and gastropod molluscs, terrestrial...
gastropods (e.g. snails, slugs), bryozoans (moss animals), earthworms, flies, beetles, ants, fishes and most groups of parasites. Further, there is what was described as a "black hole" in Australia’s capacity to undertake research on certain taxa, such as the minor invertebrate phyla.

**Criterion 9**

**Biodiscovery or Biotechnology**

Taxonomic studies of groups, particularly marine organisms, of importance to bioprospecting or with other potential biotechnology economic benefit should be given priority under this criterion.

Biodiscovery (the use of native biological resources to identify bioactive compounds for commercial purposes, such as the production of pharmaceuticals and fine chemicals), relies completely on a diverse and healthy natural environment. Biodiscovery has escalated in Australia over the past two decades, particularly in the marine environment. Case Study 9 emphasises the importance of taxonomy in bioprospecting. Sponges and other marine organisms that form the sessile marine communities are important sources of bioactive compounds that may have application as therapies for human diseases. Taxonomy plays an essential role to correctly identify species containing or producing bioactive compounds, map their distributions, assess their prevalence, determine their uniqueness or commonality within the Australian biota, provide the ability to recollect additional samples for more in-depth screening and analysis, and culture populations in lieu of wild harvest. Further, closely related organisms may share biochemical traits and taxonomy and systematics can be used to identify chemical analogues or additional latent sources of compounds, via related organisms, with application in industry.

**Criterion 10**

**Other economic or cultural significance**

Taxonomic studies that may have extended impact into other biological disciplines, that may enhance the reputation of taxonomy or that have other unspecified economic benefits should be ranked as a priority.

Participants enumerated examples of taxa that were not able to be classified under the above criteria, but were deemed to be of high priority for research. For example, the identification of new or cryptic species of iconic and conspicuous Australian animals was seen as a priority for research (see Case Study 3). Such studies have resonance with the wider Australian community and provide persuasive evidence of the contemporary relevance of taxonomy in documenting the unique biota of Australia. Other groups of organisms may provide important insights into the natural history of Australian terrestrial environments (see Case Study 11), and taxonomic study of these groups was also viewed as a priority.

**2.1.2 Taxon-based approaches to assessing priority candidates for taxonomic research**

Some workshop participants were uncomfortable with providing socio-economic imperatives for the assessment of priority taxa. It was suggested, as under the Biodiversity criterion (Criterion 1) above, that all taxonomy was inherently significant. Some participants argued that the designation of priority taxa has the capacity to disenfranchise some specialists and to establish false and unfair impediments to taxonomic research. Using the taxon-based approach, it was recommended that priority be given to taxa that are currently understudied or for which Australia has a demonstrated capacity for excellence in research. These justifications are in accordance with the criteria of Areas where Australia has strong capacity/collections (Criterion 7) and Areas where Australia has a gap in collections (Criterion 8) detailed above. Table 2 presents a list of taxa identified by workshop participants as being taxonomic research priorities. Although all of the listed taxa are compatible with Criteria 1, 7 and 8, additional criteria may be applicable to individual taxonomic groups.

**Comparison**

Forum participants agreed there was a need to develop a matrix for prioritisation based on issues and taxa. It was recommended that ABRS develop such a matrix.
# Table 2
## List of taxa identified by forum participants as priorities for research in Australia

- **Prokaryota** (bacteria, cyanobacteria)
- **Protista** (unicellular eukaryotes)
  - Apicomplexa (parasitic protists)
  - Ciliata (protists with cilia)
  - Flagellata (protists with flagella)
  - Foraminifera (foraminiferans)
- **Fungi**
  - Basidiomycota (club fungi) particularly those forming lichens and ectomycorrhizae
  - Ascomycota (sac fungi) including Laboulbeniales (fungi parasitic on insects), and those forming lichens
- **Plantae**
  - Glaucocystophyta (freshwater unicellular algae)
  - Cyanidiophyta (blue-green eukaryotic algae)
  - Rhodophyta (red algae)
  - Heterokontophyta (brown algae)
  - Haptophyta (motile golden algae)
  - Cryptophyta (unicellular flagellate algae)
  - Dinophyta (dinoflagellates)
  - Euglenophyta (euglenids)
  - Chlorarachniophyta (green web-forming algae)
  - Chlorophyta (green algae)
  - Streptophyta
    - Charophycae (stoneworts, freshwater green algae)
  - Bryophyta (mosses, liverworts, hornworts)
  - Psilophyta (whisk ferns)
  - Lycopodiophyta (club mosses)
  - Equisetophyta (horsetails)
  - Polypodiophyta (true ferns)
  - Magnoliophyta (flowering plants), especially: Poaceae (grasses), Asteraceae (daisies), Convolvulaceae (bindweeds), *Acacia* and *Eucalyptus*
- **Animalia**
  - Porifera (sponges)
  - Cnidaria
    - Anthozoa (corals, anemones)
    - Scyphozoa (true jellyfishes)
  - Cubozoa (box jellyfishes)
  - Hydrozoa (hydroids)
  - Platyhelminthes
    - Turbellaria (free-living flatworms)
    - Digenea (flukes)
    - Monogenea (fish parasites)
    - Cestoda (tapeworms)
  - Rotifera (rotifers)
  - Nematoda (nematodes, roundworms)
  - Bryozoa (moss animals)
  - Mollusca
    - Gastropoda (snails, slugs, whelks)
    - Bivalvia (bivalves)
  - Arthropoda
    - Collembola (springtails)
    - Insecta, especially Isoptera (termites), Pthiraptera (lice), Hemiptera (bugs, including aphids, scales and psyllids), Diptera (flies, including fruit-flies), Lepidoptera (moths and butterflies), Coleoptera (beetles), Hymenoptera (wasps, bees and ants)
    - Arachnida (spiders, scorpions and allies), especially Acari (mites, ticks) and Mygalomorphae (tarantulas, funnel-webbed spiders)
    - Crustacea (crabs, shrimps, woodlice, ostracods), especially marine, groundwater, parasitic and terrestrial groups
  - Annelida
    - Polychaeta (bristle worms)
    - Clitellata (leeches and earthworms)
  - Echinodermata (starfish, sea urchins sea cucumbers)
  - Hemichordata (hemichordates, acorn worms)
  - Chordata
    - Actinopterygii (ray-finned fishes) especially the Teleostei (bony fishes)
    - Amphibia (frogs, toads)
    - Reptilia (reptiles)
    - Mammalia (mammals)
Summary
This workshop saw the construction of a list of taxonomic groups that are a priority for research, based on the need to document Australia’s remaining unknown biota. All groups were proposed because of significant gaps in taxonomic knowledge and because of their intrinsic biodiversity value. Discriminating among groups in this considerable catalogue, however, is difficult. Workshop participants suggested a series of socio-economic criteria that could be used to assist with ranking taxa for research. The criteria can be cross-referenced with taxonomic groups. However, the capacity for Australia to act, by focussing research efforts on identified high priority taxa, remains hampered by current taxonomic research capacity. Indeed, maintaining, nurturing and enhancing Australia’s existing taxonomic research community underscored all discussions of the designation of priority taxa. It is therefore critical, foremost, that Australia establishes a research capacity able to respond to current priority needs and to future changes in priority focus. To this end, it was strongly recommended that ABRS undertake a comprehensive stock-take of Australia’s current national taxonomic capability, incorporating a searchable database of all working taxonomists, their institutional affiliation, area of practice and expertise and specific client groups.

2.2 User needs
Conservation agencies and industries such as agriculture, fisheries and mining often expect taxonomic resources to be available to meet their demands. Such expectations could become increasingly difficult to meet over the next four years because of resource shortages. There is therefore an urgent need to identify user priorities and needs in terms of taxonomic services so that these can be planned for. Participants in this workshop were asked to identify priorities to inform future directions for institutions involved in taxonomic research.

Key recommendations:
- build user-tailored identification tools for Australian fauna and flora
- improve service delivery of taxonomic information
- seek industry partners to support national high priority projects

Overview
The workshop addressing the taxonomic needs of, and priorities for, user-groups was held in four sessions and both taxonomic specialists and representatives of user-groups attended each session. Participants were asked to identify user groups, to consider the needs of each group and to devise strategies that may address these needs. In this workshop, the role of taxonomy as an enabling discipline that provides a “product” in the form of biodiversity data, which can be applied in various contexts depending on the need of the “consumer” of taxonomic services, was highlighted.

Discussion “Products” and “Consumers”
The primary outcome from taxonomic research is the identification, circumscription and documentation of species. Commonly, these species are hitherto unknown. Through the completion of taxonomic studies, taxonomists generate data that can be applied to users beyond the discipline of taxonomy. These other uses can be considered “products” that can be marketed by the taxonomic community to users, or “consumers”. Table 3 lists the “Top 10” products from taxonomy and the consumers of these products, as identified by workshop participants.

Taxonomy offers a wide variety of products to an equally diverse array of potential consumers. The primary product of taxonomy, perhaps unsurprisingly, is the provision of specialist, accurate and considered taxonomic opinion in the form of identification services. Identification services are used chiefly by industry groups (e.g. in agriculture and fisheries), however, they can also be of interest to pathologists, the legal profession, other scientists and members of the wider community. The provision of professional identification services is closely linked to the development of reliable identification tools, such as keys, which can be used by interested user-groups to identify biological material “in-house”, without the need for the direct engagement of a taxonomist. Taxonomy also interacts with other biological and scientific disciplines through the supply of biodiversity data, biological data such as life history information and ecological observations, distribution data, DNA sequence data and phylogenetic information, and indeed the specimens themselves as in the case of biodiscovery. Biodiversity data is also used
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biosecurity, the identification and demarcation of protected areas based on biodiversity values, and issues commonly by government agencies to inform policy decisions, particularly with respect to relating to industry development in sensitive environments. Despite these product linkages, however, matching taxonomic product to the specific needs and priorities of user-groups remains a significant obstacle to the effective dissemination of taxonomic knowledge and outputs.

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<table>
<thead>
<tr>
<th>Products</th>
<th>Consumers</th>
</tr>
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<tbody>
<tr>
<td>Specialist identification services</td>
<td>Agriculture and Aquaculture industries</td>
</tr>
<tr>
<td>Identification tools</td>
<td>Mining industry</td>
</tr>
<tr>
<td>Distribution data</td>
<td>Forestry industry</td>
</tr>
<tr>
<td>Assessments of provenance</td>
<td>Government agencies</td>
</tr>
<tr>
<td>Taxonomic history advice (including synonymies)</td>
<td>Medical, veterinary, plant and forensic pathologists, diagnosticians, and legal profession</td>
</tr>
<tr>
<td>Biological information (life histories ecological data such as diet, habitat)</td>
<td>Medical, veterinary, plant and forensic pathologists, diagnosticians, and legal profession</td>
</tr>
<tr>
<td>DNA sequence data</td>
<td>Biologists (ecology, evolution, computational biology)</td>
</tr>
<tr>
<td>Biodiversity inventories</td>
<td>Other sciences (geology, mathematics)</td>
</tr>
<tr>
<td>Evolutionary histories and systematic data</td>
<td>Museums and public media</td>
</tr>
<tr>
<td>Philosophy, ethics and art</td>
<td>General community (including gardeners, hobbyists, amateur naturalists, artists)</td>
</tr>
</tbody>
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data is also used commonly by government agencies to inform policy decisions, particularly with respect to biosecurity, the identification and demarcation of protected areas based on biodiversity values, and issues relating to industry development in sensitive environments. Despite these product linkages, however, matching taxonomic product to the specific needs and priorities of user-groups remains a significant obstacle to the effective dissemination of taxonomic knowledge and outputs.

**Strategies to meet user-group needs**

Stemming directly from taxonomists’ primary task of describing and identifying biodiversity is the provision of identification services to interested user groups. Indeed, this work performed by taxonomists is invaluable to user-groups. The appended case studies indicate convincingly that without taxonomy, many agricultural and public health problems would continue to plague Australians. However, forum participants suggested identification services need to be provided in a format that is affordable, timely and readily comprehended by lay-users. In order to meet this objective, taxonomic information needs to be translated from the jargon-dense and description-rich format of scientific journal publications into formats that can be easily digested by user groups.

The taxonomists at the forum were able to suggest many mechanisms for the dissemination of taxonomic information to users. Chief among these was the development of identification tools. Taxonomists were clear and united that interactive keying tools, delivered by CD-ROMs, or intuitive web-based interfaces, are a rapid, cost-effective and efficient means of aiding users to identify biological material in-house, without the need for time-consuming and costly reference to specialists. The parallel continued publication of dichotomous keys and pictorial keys in books and field-guides was also seen as imperative. For some users, such as island communities or members of the wider community including gardeners and amateur naturalists, innovative book publications (e.g. weather-proof and pictorial guides) are the most appropriate means of delivery. Forum participants agreed that the appropriate technology should be used for each user group and identification tools should be tailored based on the specific needs of each group. It was also suggested that the provision of specialist taxonomic identification services could be formalised under user-pays agreement models.

**Summary**

Participants at this workshop identified the strong need for taxonomy to provide tailored solutions to interested user groups. Participants identified numerous products that can arise from fundamental taxonomic research and provided a number of innovative solutions aimed at presenting these products to consumers in user-friendly, attractive packages. Translating scientific taxonomic descriptions into formats that are functional and useful for industry, government and lay groups means taxonomists are then positioned to tailor their research in response to specific taxonomic requests from user groups. For example, an individual researcher may decide to preference the study of one taxon over another because they perceive a greater benefit to their known user group, such as agriculturalists or mining companies.

**2.3 Taxonomic impediments and resourcing**

The number of practicing taxonomists and systematists is dwindling and there are increasingly serious shortfalls in the number of graduate and undergraduate students able and inclined to take their place. This workshop canvassed participants for innovative solutions to resource issues such as the scarcity of employed taxonomists, the absence of career paths and the shortage of students.

**Key recommendations**

- commission cost/benefit analysis to assess the contribution of taxonomy to the Australian economy
- undertake effective succession-planning to safeguard Australia’s future taxonomic capacity through the establishment of stable career pathways
- re-invigorate teaching and course options for undergraduate and postgraduate students through cross-institutional interaction between universities and museums, herbaria, CSIRO
- form an independent, professional, advocacy body
- promote greater visibility of taxonomy in the scientific and lay communities
Overview
A professional facilitator moderated four workshop sessions attended by taxonomists and non-specialists aimed at finding solutions to the current impediments to taxonomic research. Participants were asked to put forward new strategies and changes that would enhance career prospects for taxonomists and increase the numbers of taxonomy students. The “PEST” approach was taken, whereby solutions to the problem of a decrease in working taxonomists in Australia were separated into four areas — Political, Economic, Social and Technological.

Discussion
Political approaches
These solutions involved influencing specific people, including politicians, to assist with improving career prospects for taxonomists. State and Commonwealth governments and universities emerged as the key bodies that need to be influenced in order to create stable career paths for taxonomists. Nearly all taxonomists work in these sectors and it is the sustained net loss of taxonomic researchers from these sectors that has contributed fundamentally to the absence of real career opportunities for taxonomists in Australia. Influencing these sectors to arrest and reverse the rate of loss of taxonomists is critical to ensuring future careers in taxonomy. Further, if governments and universities fail to recognise the significance of a strong and well-resourced taxonomic research capacity, the task of influencing the private sector to invest in taxonomic research becomes very difficult.

Private industry and individual philanthropic benefactors were also suggested as being able to contribute to the development of careers in taxonomy. Companies, from industries such as forestry or mining, make use of taxonomic information and perhaps they should be encouraged to employ taxonomists on staff or to endow research fellowships within universities. However, some workshop participants felt the user-pays concept of taxonomists working for private corporations or private benefactors could deny the concept of Australia’s biodiversity as a common natural asset. There are considerations such as autonomy of research agendas, ownership of intellectual property, sovereignty over biological and genetic assets, objectivity in the presentation and analysis of results. Situations may arise in which taxonomists working for companies specialising in bioprospecting, for example, may be bound, by confidentiality agreements and patents, not to release taxonomic information to the wider scientific community. This is, however, not generally true of the Australian experience in biodiscovery, whereby there have been a significant number of new and published taxa derived from biodiscovery collaborations (e.g. tripling the known fauna of Australian sponges over two decades). Usually, the only commercial propriety involves protecting any specific association between a particular biotechnological characteristic of a species for the duration of the contractual collaboration.

As outlined by the keynote speakers, and strongly reinforced by workshop participants, governments and universities are not recognising the importance of taxonomy because of the emergence of directed research priorities and research performance indicators. This lack of recognition has created the current disastrous career landscape for taxonomists. Workshop participants agreed that, as a matter of priority, state and Commonwealth governments and universities need to be lobbied. It was suggested that a taxonomy advocacy group be established to do this.

Economic approaches
Cataloguing biodiversity is often viewed by governments and society as having immediate social and ethical, rather than economic consequences. However, cataloguing biodiversity has significant economic outcomes for the nation in terms of agriculture, forestry, fisheries and, more indirectly, biosecurity.

Workshop participants and Forum participants more generally identified an urgent need to undertake a cost-benefit analysis of the economic benefits of taxonomy, particularly in terms of savings to industry in terms of rapid pests, weeds and disease identification. The recent outbreak of horse flu highlights the national need to rapidly identify and respond to serious outbreaks. Other recent examples include the identification and attempted control of fire ants in Queensland, which has so far cost over $141 million dollars (as at 2006). There is, however, difficulty in relating these examples to any economic cost-benefit analysis of the value of taxonomy. There are two essential issues:
a. Generally, taxonomy is an indirect contributor to biosecurity, providing species descriptions and identification tools. It is difficult to cost this service contribution to biosecurity and therefore Australian industry.

b. In specified instances where an unknown species has been intercepted or identified in the country, it is possible to cost the role of taxonomy and the saving to industry, but there is no adequate way of applying this cost as an annual benefit to the Australian economy.

Taxonomy has also been identified as a significant element for Australia’s seafood and fishing industry. Correct identification of commercial species and bycatch is of major economic concern, both in terms of fisheries management and also meeting customer expectations for a consistent product on the plate. In the case of the fishing industry, reliable and consistent identification is worth $30 million dollars per annum to the industry, based on industry estimates.

The role of taxonomy in extraction industries and development was also flagged in workshops. Conservation planning in these industries is a significant cost, and rapid, accurate identification of species is essential. Again, costing this benefit is difficult, however, it was identified that the mining industry is funding molecular systematic work on stygofauna in Western Australia because it was recognised that there was a need to react proactively to groundwater conservation issues. Similarly the identification by taxonomists of a possible rare species as a common native heath allowed the Meander Dam and significant state investment to proceed. These savings are not possible without taxonomy.

Workshop participants suggested there was a need to commission a study of the contribution of taxonomy to the Australian economy, assessing cost-benefit ratios and methods for accrual accounting of the benefits flowing from taxonomic research. These findings can then be used by researchers and policy makers to argue for the need for investment in taxonomy. The case studies provided in Appendix I identify a range of examples where taxonomy has provided significant economic or conservation benefit.

Social approaches

Workshop attendees, taxonomists in particular, agreed that taxonomy is largely invisible, and when it is visible, it is not viewed in a positive light. Members of the general community do not even know what taxonomy is. Taxonomists reported instances of public misconceptions: is a taxonomist someone who stuffs dead animals? Others reported that among their scientist colleagues, taxonomists are commonly disregarded and dismissed. Their work is considered unimportant, boring, old-fashioned and pointless. Enhancing public visibility and overcoming such negative stereotypes was agreed to be a problem that taxonomists must urgently address.

The modern practice of taxonomy integrates field-based collection work, laboratory-based microscopy using traditional microscopes and modern electron microscopes, DNA-based and biochemical studies and statistical analysis. It is a truly interdisciplinary science, and taxonomists are scientists adept in numerous and varied cutting-edge techniques. However, this has not been conveyed to the general community, or indeed, scientific colleagues. Workshop participants were unanimous in their view that this multi-faceted, contemporary and vital image is one that needs to be communicated to the public. Strategies for doing this included open days and exhibitions in museums and herbaria where the public is invited into the work spaces of taxonomists. The example provided in the Keynote Address by Dr Thiele (Appendix I), and also presented in Case Study 3, of public “launches” of newly discovered species takes taxonomy out of the scientific literature and to the people. Such launches engender feelings of ownership of Australia’s natural heritage among the community.

It was also suggested that taxonomists could participate in science programs in secondary schools, demonstrating their work and educating children about biodiversity. They could engage in public lectures and increase their interaction with the media through documentaries, docu-dramas like Border Security and profile pieces. Cultivation of the media, however, requires mutuality. Taxonomists need to understand that if they are boring or their work seems overly complex, the media will not engage with them. Taxonomists must lead by example and not allow themselves to be the stereotypes they are currently perceived to be. As one participant said, “self-respect breeds respect”. Taxonomists must believe in their worth as highly skilled and multi-dimensional research professionals, and must convince the community of it too.
Technical approaches

Workshop participants proposed many innovative changes that can be made in the education sector, chiefly at tertiary and professional levels, to increase the numbers of working taxonomists and enhance recruitment rates of students. Strategies proposed include: programs to revitalise university education at undergraduate and postgraduate levels for taxonomy students; programs for end users of taxonomy, such as industry, through vocational training; developing larger and longer-term funding options similar to the National Science Foundation grants discussed by Professor Cassis in his Keynote Address (Appendix I); and on-going professional development for working taxonomists to encourage skill acquisition over entire career spans (see Table 4). It was also suggested that networks of core infrastructure (such as electron microscopy and DNA-analysis facilities, libraries, and collections and database resources) be established through long-term co-operative agreements between universities, museums, herbaria and other research organisations. The infrastructure networks would enable cost-sharing and also increase access to important resources for workers in regional areas, where there is currently limited infrastructure. These networks could be formalised as designated “Taxonomic Research Hubs” (possibly TRubs), or similar, which could be administered like other existing co-operative research models, such as Co-operative Research Centres (CRCs) and Centres of Excellence (CoEs).

Table 4
Practical strategies for overcoming taxonomic research impediments, with particular reference to skills shortages, low student numbers and the absence of career paths

- fresh approaches to under-graduate teaching aimed at student recruitment:
  - incorporating specialist teaching in lectures, practical classes and tutorials led by museum- and herbarium-based taxonomists, including tertiary sector funded cross-appointments at universities
  - innovative courses in phylogeny and systematics (such as being offered at UNE)
  - summer sessions with short research project components in museums and herbaria (internships)
- fresh approaches to post-graduate teaching aimed at student recruitment and retention:
  - expansion of BSc Honours programs into MSc programs by coursework and practice aimed at developing professional taxonomists with appropriate skills to make graduates work-ready (see Appendix III, for example)
- Vocational Education and Training (VET) courses to provide workshop-style training for workers from industry
- development of programs of on-going professional education for taxonomists to ensure awareness and competence levels in newly emerging technologies, with particular reference to advances in information technology
- infrastructure sharing through the establishment of co-operative resource networks to enhance the capacity of regional workers to participate in taxonomic research
- formation of a peak advocacy body to enhance the reputation, credibility and professionalism of taxonomy
- formation of a professional body acting like the Royal College of Surgeons
In parallel to the suggested changes in education and resource sharing, participants proposed that it is now necessary for taxonomists to establish a peak body representing Australian taxonomy. This body could lobby on behalf of the Australian taxonomic community. Some participants further proposed the establishment of a professional bar, similar to the Royal College of Surgeons or CPA, which could have a role in recognising or accrediting taxonomists. Workshop participants maintained the establishment of an independent body would greatly enhance the reputation of taxonomy as a profession and provide much-needed recognition and credibility for taxonomic research.

**Summary**

Baseline information on the identity and distribution of Australia’s plants and animals, provided by taxonomists, is vital to Australia’s agriculture, forestry and fisheries industries, and, more indirectly, to biosecurity. In this vein, forum participants recommended cost/benefit analysis to assess the contribution of taxonomy to the Australian economy and industry. This analysis would be useful to a peak body in lobbying state and federal governments and universities to invest more heavily in taxonomic research, a task participants identified as key to the future of taxonomy in Australia. Workshop participants also concluded that enhancing the visibility of taxonomy and taxonomists in the community would be an important first step in recruiting and retaining taxonomists. Further, participants asserted that an increased public profile for taxonomy would have flow-on effects and make it easier for the taxonomic community to gather support for other, more targeted approaches to increasing the taxonomic workforce.

**2.4 Barcoding**

Several institutions around the country are currently proposing to establish an Australian node of the Barcode of Life.

*Presentation by Dr Les Christidis, Chair of the Australia Barcode of Life Steering Committee*


**Overview**

This workshop consisted of a short presentation plus a question and answer session. DNA Barcoding, through the International Barcode of Life Project (iBOL), aims to collect, collate and integrate genetic data from all eukaryotic life-forms within a searchable database. This reference collection, based at the University of Guelph, Canada, plans to initially gather data from 500,000 species. iBOL is a truly collaborative, multi-national approach to DNA-based taxonomy, running with a budget estimate of $150 million. However, among the taxonomic community, reception of the initiative has been mixed. Some taxonomists have received the concept enthusiastically, while others contend the program has the capacity to undermine and make obsolete traditional morphology-based alpha-taxonomy studies.

**Discussion**

The sessions on DNA barcoding elicited a large number of comments and questions, both positive and negative, from the audience. Approximately 40 participants (half of all participants) raised issues associated with iBOL, affirming that the emerging field of DNA-barcoding is a rich area for taxonomic debate.

Forum participants were united in their general acknowledgment of DNA sequence data as a valuable source of evidence for taxonomic hypotheses. Many taxonomists suggested that DNA-barcoding is a process already occurring in a fragmented fashion among the research community. Support and enthusiasm for the iBOL centred on the multi-national collaborative approach to the centralisation of barcoding. Through the establishment of demonstrable data quality standards, iBOL has the ability to introduce rigour and means of authentication currently lacking in the GenBank/EMBL repository of DNA sequence data. Forum participants welcomed these safeguards, but cautioned there is also a strong need for formalised accreditation of the workers and laboratories undertaking the sequencing.

The focus of iBOL on the cataloguing of DNA sequence data from existing known taxa was received with both praise and criticism. By
developing a searchable database for described taxa, iBOL will enable the accurate identification of specimens through the sequencing of one small, easily amplified genetic locus. It is anticipated that, in the future, this capacity will enable rapid identification of specimens by non-specialists, extending the reach of taxonomy into the wider scientific community. For example, ecological studies may overcome many of the current stumbling blocks of taxonomic inaccuracy. Detractors contend this identification role will diminish the need for morphological taxonomists. The strong emphasis within iBOL on vouchering, however, ensures that there is still a critical need for specialist morphologists (and institutions with a mandate to store vouchers, currently the state museums) within the barcoding program. Further, although a DNA barcoding approach may provide genetic support for the detection of new species, formal morphological description of newly discovered taxa is still mandatory under International Codes of Nomenclature. Proponents of barcoding suggest that by isolating new genotypes, the project may even lead to an increased need for traditional alpha-taxonomic studies.

Participation with iBOL requires co-ordination. Haphazard and uncooperative attempts to enter into DNA-barcoding will detract from the aims of the program. Forum participants agreed that more communication via the Australian Barcode Network was needed to establish consensus among the Australian research community about the ground-rules for Australia’s participation in iBOL. In particular, concerns about the retention of sovereign rights over the genetic resources of Australia (and other nations) must be able to be preserved. Meetings of the Australian Barcode Network are planned and aim to resolve the issues surrounding engagement with iBOL in a manner that is both cooperative and collegial and maintains the autonomy and integrity of Australian research.

Given the scale and scope of iBOL, many forum participants suggested that DNA barcoding could be viewed as an opportunity to leverage funding. DNA sequencing remains a more costly research technique than microscopy, and it was suggested that these costs be addressed in applications for research monies. Further, the critical importance of reference collections to DNA barcoding, and indeed all taxonomy, is an additional cost that needs to be acknowledged in funding considerations. Barcoding, as a fresh and captivating new technological approach, therefore has the capacity to attract and inject vital funds into taxonomy.

Summary

Overwhelmingly, iBOL was received as a positive initiative, with the potential to expand the discipline of taxonomy and its applications. Further, the cachet of molecular biology in garnering funding is a distinction of iBOL taxonomists cannot afford to underestimate. DNA barcoding is not intended as a substitute for traditional morphology-based alpha-taxonomic studies. Rather, it is seen as a valuable tool for rapid assessments of identification within an integrated arsenal of methods currently used for taxonomy. This enhancement, not replacement, capacity and the focus on the identification of existing known taxa are roles that require greater promotion in order to overcome negative preconceptions of iBOL.

2.5 Atlas of Living Australia

The Atlas of Living Australia is an attempt to make current electronic biodiversity information publicly available via a single portal on the Internet.

Presentation by Dr Kevin Thiele and Cameron Slatyer, members of the Atlas of Living Australia Management Committee

Overview

This workshop consisted of a short presentation plus a question and answer session. The Atlas of Living Australia (ALA) is conceived as a one-stop web-based portal for information on Australian biota, with the capacity to interact with domestic and international biodiversity information and databases. It is an ambitious, but undeniably crucial and powerful, centralised and scientifically verifiable tool for disseminating and collating information about Australian biodiversity.

Discussion

During the two sessions introducing the ALA, approximately thirty questions and comments were received from the forum participants. The ALA project was perceived by participants to have potentially wide appeal and utility. The mission set by the ALA, to provide free and universal access
to Australian biodiversity data from an authoritative and credible source, was seen as a valuable and laudable ideal. Concern was raised, however, that stakeholders and clients have not yet been clearly enunciated. Further, forum participants raised concerns about how the ALA would interact with other, pre-existing databases of biological data, some of which are already available online. Some explanation on whether the ALA would replace or make redundant other databasing systems was sought. Additionally, participants raised the absence of a clear taxonomic focus, querying which groups would be included in the first roll-out of the ALA.

Summary
In the main, the Atlas project has been received with enthusiasm as a potentially powerful harvester and provider of taxonomic data for the Australian biota. However, there have been significant delays with the development of the ALA, and it is acknowledged that the project needs strategic development and momentum. Forum participants noted the need to create a unified and clear vision and develop an action-plan to see that the project reaches completion. Communicating the utility and broad scope of the ALA will do much to enhance the project’s momentum. The continued involvement of interested user groups in discussions of the development of the ALA will bring focus and impetus and establish support for this valuable project.

(Postscript: Donald Hobern has since taken up the position of ALA Director and substantial advances have been made.)
3 PLENARY SESSION

The final session of the forum commenced with presentations from each of the professional facilitators summarising the outcomes of the workshop sessions. These fed into a more general discussion of issues raised during the forum. Cameron Slatyer (ABRS) agreed to post the slides from the keynote addresses on the ABRS website. ABRS and FASTS agreed that a summary of discussions would be written and circulated among forum participants and other interested parties. It is anticipated that taxonomists and end-users will have additional concerns and suggestions to raise, and the publication of the Forum Proceedings will be a useful platform for future debate and consultation. Bradley Smith (FASTS) proposed that a formal document be prepared to deliver cogent strategies aimed at the development of taxonomy in Australia for adoption at state and federal levels. The content and design of the strategy document will emerge from the forum discussions and on-going consultation with the taxonomy and user communities. Forum participants agreed to provide a range of case studies demonstrating the importance of taxonomy.

Forum participants reached consensus during the Plenary Session on the formation of an advocacy group for taxonomy. A title for the group was suggested: the “Australian Species Taskforce” (subsequently agreed as “Taxonomy Australasia”, or TaxA, during the first meeting of this group). The group was conceived initially to comprise representatives from the following organisations:

- Council of Heads of Australian Herbaria (CHAH)
- Council of Heads of Australian Fauna Collections (CHAFC)
- Council of Heads of Australian Botanic Gardens (CHABG)
- Society of Australian Systematic Biologists (SASB)
- Australian Systematic Botany Society (ASBS)
- universities

Additional representation could be offered to:

- National Farmers’ Federation
- Australian Fisheries Management Authority
- Seafood Services Australia
- Minerals Council of Australia
- other interested user-groups

Positions on the committee as independent observers would be offered to:

- ABRS
- other, as yet undecided, independent parties

Long-term, the committee will aim to establish an independent chair and spokesperson, but Brett Summerell (Botanic Gardens Trust, Sydney) agreed to convene and chair the first meeting of the group. The aim of the advocacy group would be to represent the consensus interests of the taxonomic community and user-groups. One opportunity for the advocacy group to pursue would be to send a delegation to “Science Meets Parliament”, due to be held in Canberra in March, 2008. It was suggested that the group establish an internet-based communication forum (e.g., mailing lists and/or websites announcing and reporting on the activities of the group). Support for the group was enthusiastic, and participants were unanimous in their view that passionate advocacy was urgently needed and should capitalise on the momentum achieved through the forum discussions.
APPENDICES
APPENDIX I: KEYNOTE ADDRESSES

Microsoft Office PowerPoint presentations from the Forum’s keynote addresses are available for download from the ABRS website:
Abstract

It cannot be assumed that the significance of taxonomy is self-evident. Taxonomy needs to build a clear case for political and funding support, including identification of end users, gaining third party endorsement and identification of value propositions.


Synopsis

Taxonomy is a small field, a niche discipline but important to all biological sciences. It enables other disciplines and should inform decision-making by governments on issues of biosecurity and environmental sustainability. However, while the importance of taxonomy may be self-evident to taxonomists, they need to build a compelling case for why taxonomy needs additional funding. Identifying why, and to whom, taxonomy is important is the first step.

The case for taxonomy has already been made in part, through the PMSEIC Biodiscovery report (2005) and the State of Environment Report (2006). As a result there have been some recent investments, such as the CERF Taxonomy Hub, and NCRIS ALA grant.

There has been major structural changes in Australian R&D over the past decade or more. Between 1996/7 and 2004/5 (the most recently published ABS data) there has been an increase of 42% in aggregate Australian research expenditure in real terms (ie taking account of inflation). This increase has been distributed unevenly among sectors and among disciplines. Business R&D increased by 60%, University R&D by 44% but Commonwealth and State Government R&D was barely static. In 1982 over 50% of Commonwealth expenditure on R&D was for its own agencies like CSIRO but now that share is less than 24% as Government investment has shifted to business and university R&D.

Between 1995 and 2004 expenditure on all broad fields of research increased but unevenly. Medical research increased by 82% and humanities, arts and social sciences (HASS) by 50%. Natural sciences increased by the smallest amount of 13%, although that was uneven with biology increasing by more than 20% but mathematics, physics and chemistry by less than 10%. As a share of GDP, public expenditure (universities and government) on science, engineering and IT/Computing all declined while Medical and HASS both increased.
Governments throughout the developed world are becoming more aggressive about setting priorities and demanding greater economic impacts from publicly-funded R&D in a globally competitive knowledge economy. Various governments are also demanding universities become more transparent and rigorous in their claims about quality (eg British RAE). Developing a RQF has already had a significant effect, with universities being more hard-nosed about what constitutes research activity and what outputs and impacts are required.

Morphological taxonomy, with its emphasis on large monographs and generally low citations, may struggle in an RQF environment. In the four years before the RQF was announced, taxonomy research declined in real terms and as a share of biological research. Between 2000 and 2004, aggregate government and university expenditures in microbial, animal and plants systematics, taxonomy and phylogeny decreased in real terms from $34m to $29m (in 2004/2005 prices) while biology increased from $672m to $756m (2004/2005 prices).

There are no codes for taxonomy in the Australian Bureau of Statistics (ABS) socio-economic data and if there are no codes then you are invisible. These needs to be addressed in the current review of ABS research classification.

Under existing university funding structures, which fund student load in broad disciplinary areas rather than the institutional profile or strategic mission, niche areas like taxonomy are becoming unsustainable. There are many areas like taxonomy where Australia may only need, say, 30 or 40 graduates per annum, but they are needed.

There are interventions that could be made to ensure viability of niche areas including weightings (like regional universities receive) or guaranteed minimum EFTSU (funded places). But such interventions do not address the attractiveness, or otherwise, of taxonomy to students. Perhaps the problem is subjects like taxonomy, which are inherently detailed, take a long time of study to reach a competence threshold that enables intellectual enjoyment. Perhaps taxonomists need to look carefully at current methods of teaching and presentation and search new ways of engaging students. Critically, career pathways need to be better articulated and not just into public sector employment.

Although taxonomy is a relatively small discipline, the research it undertakes is fundamentally important to other biological sciences. Taxonomy must be sustained, not just because it is an enabling discipline, but also because taxonomical knowledge and skills are a form of insurance to ensure Australia has some preparedness capability to meet future risks in, say, biosecurity.

Although the problem of funding is critical and dictated in part by government policies and structural issues in, for example, universities, taxonomy as a discipline must remain committed to its unique role. Finding a sustainable path is the challenge facing taxonomists. Surmounting this challenge will require pragmatism and realism, but also enthusiasm and passion.
Australia’s taxonomic impediment: a global perspective and industrializing the taxonomic method

Abstract
The taxonomic impediment is primarily an issue for organisms of the Southern Hemisphere. Australia, where the classificatory framework, adequacy of existing collections, and magnitude of the descriptive effort are issues that require attention, is a case in point. Capacity to address these perceived shortfalls is tacitly thought to be insufficient in Australia and heading in the wrong direction. Global perspectives, such as the US National Science Foundation program’s Planetary Biodiversity Inventory, are designed to bring together international teams, with an emphasis on cybertaxonomy and postgraduate training. This is one approach to expediting the taxonomic effort, and it serves as a model for discussion of an alternative for and/or an enhancement of existing solutions.

Presentation available from:

Synopsis
Taxonomy in Australia suffers from two perennial issues. Firstly, Australia’s taxonomic research capacity is declining, chiefly because most taxonomists are reaching retirement age and there are few up-coming taxonomists to replace them. Secondly, Australia’s flora and fauna are still unknown. At most, only 25% is documented. These problems are not, however, Australia’s alone. Of the approximately 10 million species on Earth, only 20% has been described.

The National Science Foundation (NSF) in the USA has commenced an ambitious program to catalogue global biodiversity and urgently catalogue some of the remaining undocumented 80%. The Planetary Biodiversity Inventory (PBI) aims to establish international research teams to document the biodiversity of problematic taxonomic groups. PBI projects focus on cosmopolitan and monophyletic taxa and must adopt an approach that capitalises on recent advances in information technology and incorporates training plans. Based on the success of a recent NSF PBI project on the taxonomy of the insect family Miridae (Hemiptera), the PBI model should be widely adopted for Australian research.

Under the PBI model, the project aimed to formally describe over 1500 species of Miridae. In its first two years, the project has succeeded in publishing the description of almost 700 species. The main mechanisms for the success of the project have been the cultural shift engendered in the research team and the division of labour among many hands. Typically, work on the Miridae project proceeds by teamwork, rather than the traditional independent descriptive work undertaken by individual taxonomists for other taxa. For instance, one worker may pin and prepare specimens, another...
may complete morphometric measurements, still another the taxonomic illustrations and another the description of terminal genitalia. Data is then compiled into one multi-authored taxonomic description. This division of labour has increased the speed with which descriptions can be prepared and has diminished feelings of territoriality over research. This cultural shift has created an inclusive collegiality. The incorporation of information technology into the Miridae project has also resulted in time benefits. Accurate and enhanced databasing and record keeping by extra workers has freed valuable time that is now more profitably diverted to microscopy and collecting efforts. However, future research could be hampered by the inability to maintain staffing levels and IT resources after the expiration of current funding allocations.

The Miridae project is a remarkable example of successful practice in taxonomy. On the strength of this positive experience from the Miridae PBI project, similar models should be widely adopted in Australia. The founding of taxon-based research clusters would do much to develop the field of taxonomy through the establishment of a critical mass of researchers in Australia. A critical mass has the ability to develop momentum for research. Further, taxon-based research clusters would enhance and promote opportunities for early career researchers and develop sustainable career paths. Currently, museums and herbaria are under strain and the adoption of cross-institutional partnerships through the research clusters would do much to alleviate this strain. The PBI model provides an inspirational example of how modern technology and the assemblage of efficient, well-resourced teams can interact to achieve significant advances in alleviating the crisis in the documentation of global biodiversity.
Abstract

Universities make an important contribution to systematic research, training and collections. However, there is a need to reverse the past decline in the number of academic staff positions in a university environment where attracting significant research funding and having high citations are success measures.

Presentation available from:

Synopsis

Taxonomy and systematics are widely perceived to be anachronistic. However, taxonomy and systematics are important disciplines that underpin the management of natural resources. The interplay between taxonomy and systematics, and biosecurity, biodiversity, conservation and resource management issues, makes these biological sciences vitally relevant to contemporary society. Sadly, despite the critical need for working taxonomists, the workforce is dogged by numerous problems. A lack of career opportunities, lack of funding and lack of secure tenure are major impediments to young scientists wanting to undertake systematics research. Universities, the traditional employers of systematists, are increasingly not recruiting taxonomists and systematists. Universities are no longer willing even to support existing staff levels in systematics research.

Domestically and internationally, universities are placing reduced emphasis on systematics research. In the UK, there was a 50% decline in the appointment rate for systematists across the leading twenty universities between 1976 and 1991. Although there is some indication that in the USA and UK systematics research is enjoying a renaissance, there is no corresponding revival to be observed in Australia. In Australia, universities are concerned with attracting funds and meeting the performance indicators prescribed by the Research Quality Framework (RFQ). The RQF has meant that new appointments within universities are driven by impact factors and historical funding success rates. Taxonomy does not attract funds or students, is not high impact, and under the RQF, fails to impress.

The future for taxonomy and systematics in the current funding and academic climate is not bright. Funding for research presently comes from a number of sources:
- ARC Discovery
- ARC Linkage
- ABRS
- CERF
Furthermore, fully-funded fellowship programs spanning entire careers should be developed. As a minimum, fellowships should aim to support researchers for ten to fifteen years. Fellowship programs on this scale would create security of tenure for researchers, an unprecedented achievement for non-academic research appointments in Australian universities. By undertaking massive and constructive changes in the university sector, significant inroads can be made in slowing and reversing the downturn in systematics and taxonomy research in Australia. Changes should be made as a matter of urgency, to ensure future capacity for this important biological research in Australia.

Other small domestic grants and student awards
International alliances, e.g. NSF (USA)

Of these sources, only ABRS and CERF funding are targeted chiefly at taxonomy and systematics research. Unfortunately, these agencies are not well-resourced compared with other bodies. The total 2007 ABRS grant budget of $2.4 million is in stark contrast to the $2 million each ARC Centre of Excellence receives per annum. Of particular concern is that the ARC does not fund taxonomic research. The focus of traditional funding agencies on Government-defined research priorities is to the detriment of taxonomy and systematics, and more broadly, actively dissuades the free pursuit of research excellence.

Remedial action within universities should be multi-faceted. Changes need to be made to student levels and recruitment rates, staffing levels, opportunities for funding and potential career pathways. An innovative MSc program has been proposed at the University of Melbourne (see Appendix III). The program is aimed at increasing student participation rates and producing graduates within generic skills in systematics that meet employer expectations. In addition, the introduction of cross-appointments between universities and museums or herbaria through memoranda of understanding would do much to enhance career opportunities for researchers. It would have extended benefit to students through the demonstration of career paths and the ready access to specialist knowledge.
DNA barcoding, a combination of morphological and molecular methods of species study, has the potential to revolutionise the study of taxonomy. Through increased access to funding and increased speed and accuracy of species identification and biodiversity assessment, DNA barcoding will be a very powerful new tool. It will be one that will make our current taxonomic collections and expertise valuable and useable in new ways, and one the Australian taxonomic community should embrace.


Molecular genetics (phylogenetics) and taxonomy is enjoying success and an increased public profile, in contrast to more traditional, morphological approaches to taxonomy. Molecular techniques have been of immense benefit to taxonomy and evolutionary biology. The use of molecular methods is able to provide taxonomists with robust, independent estimates of phylogeny. Further, these methods allow for the estimation of divergence dates through molecular clocks. Molecular methods have also penetrated population studies and have enabled researchers to better understand species concepts and the processes of hybridisation.

Rather than making morphological taxonomy redundant, however, molecular genetics has greatly enriched the study of evolutionary biology. Using molecular methods, morphologists are now able to investigate patterns of morphological trait and adaptive evolution. The robust phylogenies inferred from molecular data have enabled researchers to assert more confidently hypotheses of vicariance and co-evolution. Despite historical disunity between morphologists and molecular systematists, molecular methods will not make morphology obsolete. Molecular methods are an additional tool in the research kit for taxonomists. A synergetic approach, using complementary molecular and morphological methods, will allow taxonomic researchers to address, with greater levels of confidence, fundamental questions in systematics and evolution.

DNA barcoding is a relatively recent innovation within molecular taxonomy. Barcoding is a method using DNA markers to provide rapid and accurate estimates of species identity and diversity. It is just another tool, a very powerful one if used appropriately, and not a means of ostracising morphologists from taxonomic research. Potential uses of barcoding include the development of genetic distance-based measures of species identity and the analysis of species diversity from environments historically difficult.
to assess, such as the biodiversity within sediment cores and of stygofauna. Barcoding, as an exciting new technique, could capture the attention of funding bodies, as projects incorporating barcoding programs will benefit industries such as mining, where rapid assessments of biodiversity are needed to ensure environmental sustainability. DNA barcoding projects will amass vast databases, and this resource can also be used to track future changes in species distributions from the present day. The functionality of any DNA barcoding endeavour, however, depends crucially on the rigorous maintenance of reference collections. Here, morphologists will play a vital role. They may even be in increased demand in coming years to establish and curate such collections.

In order that Australian taxonomists are ready to face the challenge of undertaking research in the new barcoding age, taxonomists should begin preparations as a community. Primarily, taxonomists need to organise groups that are ready to liaise with international barcoding projects (e.g. iBOL). Additionally, barcoding should be budgeted for in existing and newly proposed taxonomic research programs. Repositories of Australian genetic material (DNA banks) should be established and these banks integrated with specimen data and existing morphological collections. By undertaking these steps and developing common modes of best practice, Australian taxonomists will be well positioned to capitalise on the looming DNA barcoding revolution.
Abstract
A high proportion of undescribed known taxa in Western Australia is of conservation significance. Although undescribed taxa can be listed under state legislation, the lack of knowledge of these taxa and poor taxonomic resolution limits conservation policy and planning. Since 2006, a team of three early career researchers at the Western Australian Herbarium has been working successfully towards high-throughput taxonomic resolution of a range of undescribed species occurring in areas of high mining prospectivity.


Synopsis
In 2006, a Western Australian government initiative was created that aimed to address critical conservation issues among Western Australian biota. The “Saving Our Species” (SOS) program was devised as a short-term funding scheme, with each project running a maximum duration of two years, and was provided with $15 million to achieve its targets. The Western Australian Herbarium (WAH) was awarded a grant under the SOS program in 2006. Thirteen months into the project, the progress and outcomes of the WAH project were detailed and assessed.

There are a large number of Western Australian flora species yet to be formally described (~1,700), many of which are of conservation significance (~500). These taxa represent 13% of Western Australia’s flora. Many of the undescribed species are listed as Declared Rare or Priority Flora under state legislation, and are often known only by their collection locality names. It is of immense concern that a large proportion of these plants is known to occur in regions of high mining prospectivity. Formal description of these plants is vital to the correct identification of Western Australia’s flora and essential for effective and rational conservation policy and planning. Under the SOS project, essentially an alpha-taxonomy project, the WAH aimed to catalogue and identify this unknown flora.

Three early career researchers (ECRs) were appointed to the SOS project to undertake the taxonomic studies. The ECRs formed a taxonomic “SWAT team”, which aimed to move in quickly, sort through the copious material stored in the herbarium and highlight priorities for immediate description while focussing on the areas of high mining prospectivity. They established collaborative research links with approximately seventy plant taxonomists throughout Australia. Through this network, the ECRs facilitated the completion of taxonomic manuscripts and monographs that had already commenced and initiated new works on the description of additional...
material. To date, the ECRs have amassed a total of 45 publications and put into print 95 new species, 78 of which are conservation taxa. This work represents a vast undertaking and a mammoth taxonomic achievement in thirteen short months. By employing three dedicated taxonomists on the focused, discrete and daunting task of sorting a massive taxonomic backlog, the SOS project and the young ECRs have made a spectacular contribution to the understanding and knowledge of Western Australia’s unique and at-risk flora.

Although the SOS project is barely half completed, remarkable strengths and positive outcomes can already be seen from this intensive and collaborative approach to alpha-taxonomy. The on-going utility of the taxonomic network is an enhancement to the capacity of the ECRs to continue to publish robust and enduring descriptive works. Further, the “baptism of fire” through which the ECRs have emerged has prepared them as astute and highly competent taxonomic professionals. The ECRs have garnered a wealth and breadth of taxonomic experience in an amazingly brief period and are now well-able to handle any future taxonomic research.

The production of high-quality alpha-taxonomic research outputs by the ECRs has been enormously well-received by the Western Australian government and public alike. This project has taken alpha-taxonomy out of the back rooms of the herbarium straight to the hearts of the people. There is a broad appeal for the discovery of new things among the public, and politicians too enjoy the feel-good factor of news of these unearthings. The SOS project has therefore been successful in not only achieving a high rate of descriptive taxonomy and enhancing the careers of taxonomists, but in making alpha-taxonomy visible, palatable and appealing to funders and the public.

Although the SOS project at the WAH is enjoying remarkable success, a few factors have emerged that stand as caveats to future taxonomic endeavours. It is clear that the enthusiastic reception for this project and its results has come primarily from the sharp alpha-taxonomic focus. That is, taxonomic revisions and higher-level systematic treatises do not have the appeal of new discoveries. Although these treatments are a vital component of modern taxonomy, they lack the funding punch of “look — one hundred new species!” So, while higher-level research will continue to comprise an important part of any taxonomic study, for the purposes of marketing taxonomy to funding bodies and industry, these works are of little utility.

Industry and governments, especially with respect to the burgeoning mining activity being undertaken in Western Australia, need to know about species. They need to know what are they, where they are and what their vulnerability is, not their phylogenetic interrelationships. Opening the doors to additional funding and capitalising on industry opportunities means understanding this need and responding to these questions. Alpha-taxonomy, perhaps sometimes unkindly seen as lacking the razzamatazz of other molecular systematic research, has a golden marketing opportunity in the shape of such voyages of discovery. Keys to the success of future taxonomic research lie in realising this potential and harnessing it under well-organised and focused teams committed to quality output.
Abstract
Taxonomy in Australia is faced with few students, few opportunities to learn in universities, and very few jobs. The broader community does not understand the need for it, and/or thinks enough is already known. Agreement is needed between taxonomists on the priorities and a broader-based training approach and career structure with taxonomy as a part, not an end in itself. Coordination and communication between educators, funders, problem owners and problem solvers, about how to achieve this, is also needed.

Presentation available from:

Synopsis
Taxonomists’ work is not visible and taxonomists are not valued. An examination of the popular press reveals the media does not, in the main, cover taxonomy. Only when it meets technology does it become newsworthy. Moreover, the community perceives taxonomy as old-fashioned, out-dated and unnecessary.

The historical taxon-focus of taxonomic research is anachronistic in the face of current funding climates, both state and federal, which favour targeted, results-oriented research programs. Currently, Australia faces numerous environmental and socioeconomic problems, such as crop pest control, biosecurity concerns, invasive marine organisms and land degradation. Taxonomy has an important role to play in meeting and addressing these challenges. In many instances, informed and reliable taxonomic opinion will be critical to overcoming these problems. Taxonomists must therefore revamp their traditional approach, abandoning subjective taxon-based research foci and, instead, launching whole-heartedly into problem-based taxonomic research.

In Australia, current approaches to research and funding applications by taxonomists are predominantly taxon-based. Taxonomists pursue avenues of research based on objectives external to problems, then attempt to “retro-fit” their research to emerging environmental or agricultural problems. Ultimately, this reactionary approach is unlikely to yield tailored, appropriate or timely results for critical and urgent issues requiring taxonomic input. A new paradigm for research is needed, wherein taxonomists form part of focused teams that initially identify key areas for research then tailor research programs to address the needs of the community. Under this model of applied taxonomy, funding will flow more easily. Further, taxonomy will enjoy greater visibility and receive the much-needed respect for the valuable contribution it makes to biological research.
Parallel to the adoption of applied taxonomic research strategies, the taxonomic community must better develop existing infrastructure and modes of working. Databases and inventories of the biosphere must continue to be developed. It is important for taxonomists to continue to develop and use existing technologies and bioinformatics research tools, as this will keep taxonomy contemporary and help the discipline escape the negative perceptions of it as an antiquated pseudo-science. In addition, structured postgraduate training and the evolution of meaningful and sustainable career paths will do much to ameliorate the problems of low student numbers. The applied taxonomy model can make a key contribution here, as increased opportunities for employment will come with increased funding.

Current taxon-based approaches to research are not serving the taxonomic community. They are diminishing the reputation of the discipline and impeding taxonomy’s ability to obtain funding in a results-based climate. Furthermore, although taxonomy, taxonomists and the services they provide are fundamental to Australia’s biological research capacity, current approaches to research are not serving the user community. Lag-times in the solving of biological problems have economic and social consequences. Crucial to the continuance of important taxonomic research is a total reconfiguration of negative perceptions of the discipline. Taxonomists must unite behind the model of applied taxonomic research strategies. Marketing the function of and contributions made by taxonomists, through the adoption of a problem-based approach to taxonomy, can and will bring about positive outcomes for taxonomic research in Australia.

**Discussion**

The reconceptualisation of taxonomy as a service-industry focused on achieving solutions for pressing commercial and social problems was received with a mixture of enthusiasm and scepticism by forum participants. Some argued it was only through the academic freedom to pursue taxon-based research that some problems are and will continue to be identified; that it is only from a position of knowledge that some problems are ever isolated. However, Mr Howarth argued that an applied approach to taxonomy is the only one that will secure funds from modern funding structures. This argument was in contrast to the presentations from earlier speakers, such as Mr Smith and Professor Ladiges, who argued that, rather than altering the approach of taxonomists, it is funding agencies that must change approach. They argued funding must extend beyond the narrow prescriptive boundaries of popularly and arbitrarily defined research priorities and support excellence in pure, discovery-focused research.

The disparity in the philosophical approaches to funding allocation reflects a fundamental schism within the scientific community. There are those who believe that science exists to serve the community, that scientists must address community problems and emerge, triumphant, with definitive answers. Others, contrastingly, contend that science is, as the word itself suggests, the pursuit of knowledge. They contend that having this knowledge be harnessed to the benefit of the community is a bonus, but that fundamentally, science exists for the purpose of knowledge building. Current funding models favour a utilitarian view of science, and it is this reality that Mr Howarth urged taxonomists to accept, understand and work within. To use an evolutionary biology example, taxonomists must adapt to the current conditions, lest they become extinct. This view is pragmatic and perfunctory, with funding constraints dictating the path for taxonomy as an applied, problem-based discipline.
APPENDIX II:
CASE STUDIES IN TAXONOMY
Bee mites of the genus *Varroa* are major pests and cause disease in Western honeybees. They do not occur in Australia, and are a major biosecurity threat to Australia’s beekeeping and pollination industries. Following evidence that called into question the taxonomy of species within the genus, Denis Anderson (CSIRO Entomology) and colleagues clarified the taxonomic status of these mites on their primary host, the Eastern honeybee, in the Oriental region.

One species of mite (*V. jacobsoni*) was found to be restricted to one strain of the honeybee in southern mainland Asia, Malaysia, and the Indonesian archipelago. A new species of mite (*V. destructor*), which had previously been mistaken for another species, was restricted to a different strain of honeybee in northern mainland Asia. Detailed microscopic examination revealed diagnostic morphological differences between the two mite species and molecular markers were developed for differentiating genetic types (genotypes) within and between each species. Only two genotypes of one species were found to have switched host to the Western honeybee, causing millions of dollars of damage each year worldwide. All other genotypes of *Varroa* mites were found to be harmless to Western honeybees, because they lacked the ability to reproduce on honeybee brood.

This clarification allowed Australian quarantine officials to better target biosecurity and incursion management strategies, and allowed researchers to search for mechanisms that make bee populations susceptible to attack by the two genotypes of the destructor mite. An independent economic assessment showed that Australia has benefited from this work to the tune of $66.4 million in Net Present Value (NPV) terms, with a benefit cost ratio of 17:1 and an Internal Rate of Return (IRR) of 27% (ACIAR Impact Assessment Series Report No. 46, July 2007).
For twenty years, the organism *Neoparamoeba pemaquidensis* was widely believed to be the cause of Amoebic Gill Disease (AGD). Management of this disease is estimated to be worth 10–20% of total production costs in the salmon industry, centred in Tasmania. Two decades after the first disease outbreak, however, the parasite causing the disease has now been definitively identified as a completely new species, *Neoparamoeba perurans*, by Dr Iva Dykova from the Academy of Sciences of the Czech Republic.

Incorrect identification of parasites can lead to difficulties in developing control and treatment methods, as well as incorrect assessment of risk factors, particularly with regard to other host species, especially native fish species. However, there is little expertise in the taxonomy of aquatic amoebae in Australia and most of the taxonomic work currently being done in Tasmania is in collaboration with Dr Dykova. Dr Dykova is the only world authority on this subject, however, she is getting close to retirement and there is currently nobody with the skills, knowledge and expertise who may be able to replace her. The loss of her expert and discerning taxonomic opinion will be a significant loss to parasite taxonomy. Perhaps more alarmingly, her retirement will be a significant loss to the aquaculture industry, which is totally reliant on accurate and rapid methods of organism diagnosis for risk assessment and the management of disease.

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Prof. Ian Beveridge  
(University of Melbourne)
The Age of Discovery is not yet over in Australia. Several new vertebrate species have been unearthed in two separate current research projects at the Western Australian (WA) Museum. A new species of venomous taipan has been collected from the central ranges near the WA-SA-NT border and four previously unknown species of frogs have been found in the Kimberley.

The new species of taipan was not recognised initially during the field expedition in the central ranges. Dr Mark Hutchinson (SA Museum) caught several brown snakes during the month-long trip, which involved the traditional owners, the Ngaanyatjarra people, and was funded through the federal Department of the Environment, Water, Heritage and the Arts. However, he did not believe any were new species. Back in the laboratory at Perth, however, Brad Maryan (WA Museum reptile collection manager) noticed an odd combination of features in one of the snake specimens, suggesting it to be a new species. Steve Donnellan (SA Museum) extracted DNA from the snake and found that it is a hitherto unknown and primitive member of the taipans, the most venomous snakes in the world. The specimen, nicknamed “Scully” by the WA-SA Museum teams, is the first taipan to be described in over 125 years.
New species of frogs have also been discovered as a result of Alcoa Frog Watch, a research partnership between the WA Museum and Alcoa of Australia. The program fosters public involvement through frog awareness and conservation campaigns and also funds active research aimed at documenting the wild Kimberley region’s frog fauna. The project is currently in its second of three years, and has led to the discovery of four new species of frogs. The first frog discovered, found near “The Grotto” outside of Wyndham, is known as the Chattering Rock Frog (Litoria staccatoi). It was noticed initially by its distinctive call, which is similar to Morse Code and involves a complex series of beeps and trills. Three more frog species were discovered in 2007, and it is hoped even more new species will be discovered in the next year.

Announcements of the new snake and frog species were made at the WA Museum, and specimens of the new snake and Chattering Rock frog were displayed in the museum’s Discovery Centre. Live frogs were displayed for public viewing and radio stations broadcast the unusual and distinctive call of the frog.

**Literature**


Doughty, P., Anstis, M., & Price, L. MS. A new species of *Crinia* from the high rainfall zone of the northwest Kimberley, Western Australia.

Blackberries infest valuable agricultural land as well as otherwise pristine natural habitats. Their ready dispersal and aggressive growth means they can spread quickly and easily into areas remote from existing infestations. Farmers and environmental managers have long utilised traditional manual and herbicide control in addition to novel approaches such as goats. Such control has limited effect, however. Herbicide potency varies among sites, killing out some plant species but not others.

Agricultural research organisations have invested much in trying to improve control methods, including biological control, for blackberry. Investigations by CSIRO in Montpellier, France, have identified promising rust strains and a series has been released in a monitored program across southern Australia (see www.ento.csiro.au/weeds/blackberry/project.html). Integral to the launch of the rust fungal strains has been the recognition in only the past decade or so that the traditional taxonomic concept of Australia’s weedy blackberry species has been woefully inadequate.

Addressing the inadequacy
After attending a blackberry workshop in Victoria in 1997, retired plant systematist Dr David Symon, of the State Herbarium of South Australia, realised there was more to blackberry than appeared in the contemporary literature. He initiated an extensive self-funded collecting program with weeds experts across southern Australia. Resulting collections were sent to two specialists in Germany and England for identification, and at the same time were used by Dr Kathy Evans of the Weeds CRC at the Waite Institute for molecular studies and Dr Molly Whalen of Flinders University for morphological analysis. This collaborative effort involving herbarium, university and weeds research centre specialists resulted in the publication of a new view of Australian weedy blackberry. The extensive basic morphological work that expanded the number of species to nineteen from previous estimates of three or four was largely unfunded.

Translating the new view of blackberry into improved control methods that meet environmental best practice
The Natural Heritage Trust Weeds of National Significance fund supported employment of a plant systematist in the State Herbarium of South Australia to produce an interactive key on CD (see www.cbit.uq.edu.au/software/blackberry/) as a means of disseminating the new knowledge about blackberry in Australia. This CD enables users to identify over twenty blackberry species now recognised as weeds and to distinguish them from native Australian species. Many environmental and agricultural land managers have now undertaken training sessions using the tool. With the release of newly developed rust strains throughout southern Australia, blackberry specimens are being collected as part of the project so that knowledge of which rust strains are effective on which blackberry species can be compiled.
The plant systematists who have produced the new view of Australian blackberry have indicated repeatedly that the classification is not final. Yet there persists the traditional tendency among weed authorities and users to believe the written word is the final one. More collections of blackberry are still needed, not only to confirm identifications, which are difficult because of the very close relationships among the species, but also to map these species and to find out whether there are others that remain unaccounted. There is also a need to document the properties of the species (e.g. how the blackberry grows and its flower colour, but also whether it is resistant to particular strains of rust or to particular herbicides). Without this knowledge, control will never be maximally effective.

The investment in blackberry taxonomy has been small and has depended on voluntary effort within the State Herbarium of South Australia. With the leaps and bounds made in the taxonomy, it should now be possible to make a real impact on blackberry. That impact would be enhanced greatly by providing the much-needed specialists in herbaria with continued resources to improve and collate the knowledge of blackberry species in Australia.

**Literature**


Several years ago, a paper appeared in *The Lancet* reporting the first case of infection with the parasite *Trichinella pseudospiralis* in humans, in a woman from Tasmania. Identification was based on the fact that the parasite occurred within the muscle cell, a phenomenon known at the time to occur only in the genus *Trichinella*. *Trichinella* is a major disease-causing agent of humans in other parts of the world and is often acquired from eating pork or, in recent years, horse meat.

The identification of the infection in the Tasmanian woman was confirmed using a DNA-based “molecular probe”. Subsequently, a second case arose, again in Tasmania. The man received a steroid treatment but his condition deteriorated. Morphological examination of the parasite revealed that it was not *T. pseudospiralis*, but a completely new genus and species, *Haycocknema perplexum*. The infection was presumed an accidental infection in the human cases with a reservoir, still unknown, in wildlife.

In this case, molecular tools were not sufficiently specific and led to a dangerous course of treatment for patients. A simple morphological examination was required to determine that a totally new organism was involved in this human disease. Although DNA tools can be useful adjuncts to other methods in taxonomy, this case study highlights the dangers of relying totally on a molecular approach. DNA sequences can only be cross-referenced within databases and databases do not yet contain all species. Further, not all species have yet been identified. Without morphological studies, they will remain unknown.

**Literature**

In 1998, the first major global coral bleaching event occurred, with 16% of the world’s coral reefs bleaching in that year. Two studies reported bleaching in sponges. The report of bleaching of *Chondrilla australiensis* in temperate Western Australia prompted a PhD project to determine whether a light-requiring microbe must be symbiotic with the sponge, and be responsible for its 1998 bleaching event. The study showed that, instead of one species of *Chondrilla* (*C. australiensis*), occurring in temperate Australian waters as was previously thought, two additional species also occurred. These two new species of sponges, which are currently being described, would never have been discovered without the symbiont project.

The study also named and described a new species of cyanobacterium, *Synechococcus spongiarum*. This species has since been found in eighteen sponge species from Australia, the Caribbean, the Mediterranean coast, the Red Sea and Zanzibar. However, it has never been found free-living in the water column. A second cyanobacterium was also discovered in the sponges.

Aside from detecting four new species, the study was remarkable in finding transmission of the symbionts not only within the eggs of the sponge but also in sperm. A cyanobacterial symbiont that is never found in the water column but is found in many sponge species throughout the world, suggests the symbiosis is very ancient and perhaps predates the formation of the Tethys Sea.

**Literature**


The Dampier Archipelago in north-western Australia is of great significance in terms of natural heritage and industrial usage. In 1988, Woodside Energy Ltd and the WA Museum formed an innovative partnership to investigate and document the marine biodiversity of the Dampier Archipelago through the development of the Woodside Collection. The objective of the partnership was to gather data on the diversity, distribution and abundance of biota in the Dampier Archipelago and the nearby continental coastline and to make the findings broadly available to the community.

The partnership spanned two stages (1998–2004 and 2005–2007) and has resulted in four expeditions, an international workshop, data collection, research and reporting, website creation, educational resource development and vocational training. The partnership has provided unique information on the biodiversity of the Dampier Archipelago, which facilitates sound environmental management, to help maintain and conserve the marine resources of the region for future generations. It also assists in the development of strategies to minimise the environmental impact of hydrocarbon exploration and production activities.

Four major scientific reports on the findings have been published. The Woodside Collection, containing more than 4,500 marine species, including 268 new species, is the first major collection of the North Eastern Indian Ocean biota. It has been identified by Australian and international taxonomic experts, and forms a unique, perpetual reference to the biodiversity of the region. The Woodside Collection is now readily available and accessible to a world-wide audience through the interactive, educational Woodside Collection Website. Information is also widely available through other media: two permanent exhibitions; an educational video; a major television documentary; radio and TV interviews; popular magazine and newspaper articles; and talks and lectures.

The partnership demonstrates the value of effective co-operation between industry, government and the community. Eighty-five scientists from twenty-five countries, nineteen international museums and forty-two universities, sixteen Australian Government agencies, nineteen industry and private partners, film and documentary makers and local communities and stakeholders, have cooperated with staff from Woodside’s environmental team and the nine WA Museum scientists. Additionally, training opportunities have been provided, leading to career advancement, for seventeen young people in both stages of the project. The achievements of Stage 1 of the partnership were recognised in 2001 through the WA Golden Gecko Award for Environmental Excellence and, in 2003, the prestigious City of Sydney Open Award category for the Australian Business Arts Partnership Awards. More recently, the WA Museum and Woodside Energy were announced as joint State winners in the 2007 Prime Minister’s Awards for Excellence in Community Business Partnerships (Large Business category).
8 Subterranean organisms: the importance of taxonomy for mining developments

The Pilbara region contains some of the best iron deposits in Australia and has helped to shape the modern Australian economy. The development of these deposits into iron-ore mines has created thousands of jobs and provided enormous economic wealth to the region.

Routine searches for subterranean organisms in a mesa system located within a paleo-drainage system near Pannawonica have uncovered a wide variety of troglobitic (airbreathing subterranean) organisms within each mesa. Research conducted at the WA Museum and the University of WA has found that each mesa in the valley possesses a unique biota, with several species restricted to individual mesas. Taxonomic research on a variety of these organisms, thus far including spiders, pseudoscorpions and schizomids, has allowed for the characterisation of each species, with subsequent formal descriptions in the taxonomic literature.

Approval for development of the Mesa A mine has been sought from the WA government by the mining company. However, misgivings from various government agencies regarding the long-term survival of the troglofauna if the mine were to proceed, have delayed approval of the application. The case is currently being considered by the Environmental Protection Agency.

Literature


A new genus and species of subterranean schizomid from Mesa B mine
Invertebrate animals living firmly attached to the seabed (sessile invertebrates), including soft corals and gorgonians (cnidarians), lace corals (bryozoans), sea squirts (ascidians) and sponges (Porifera) are the most productive sources of new chemical compounds with potential therapeutic benefits. However, we know very little about their diversity, distribution and their biology. These faunas are expensive to collect, living firmly attached to the seabed in shallow waters to the abyssal zone, and the expertise to document them is grossly inadequate. Yet this fauna remains of great commercial interest. The sponges in particular have been found to be the most productive sources of new compounds and also new species.

Over the past fifteen years, the Queensland Museum’s (QM) Biodiversity Program and Natural Products Discovery (NPD) of Griffith University’s Eskitis Institute have formed a unique and highly productive partnership, collecting over 12,000 specimens of about 5,000 species of marine invertebrates and algae. This effort has been funded predominantly by the drive to discover bioactive compounds (“biodiscovery” or “bioprospecting”). The partnership has made significant discoveries including the isolation of over 1,500 new bioactive compounds, most with novel bioactivity and a number in pre-clinical trials, and the discovery of new genera and thousands of new species in tropical and subtropical Australia.

Of the more than 3,000 sponge species discovered, about 70% are new to science — a three-fold increase on previous estimates of sponge diversity in Australia and worldwide (5,000 and 15,000 respectively). Mapping these species distributions, identifying areas of high species richness and/or endemism, and determining species-turnover points has provided
invaluable data for marine conservation planning and management, including the Great Barrier Reef (GBR) Representative Areas Program and the GBR Seabed Biodiversity Project. This material has also been used for genetic analysis, helping track the patterns of genetic connectivity in the sea, and other data has been used to develop and refine marine biogeographic models. Without the NPD–QM partnership, the exploration of many of the habitats, particularly those remote ones in the Coral Sea, and the discovery of the species living in them would not have been possible.

The collaboration between the QM and NPD has also provided other material benefits, such as funding the employment of up to four full-time parataxonomic positions at the QM each year, providing opportunities for substantial training in taxonomy, curation and marine collection skills, purchasing microscopes and other equipment and building the museum collections substantially by funding all field work. Additionally, there is potential flow of royalty benefits from the commercialisation of new pharmaceutical discoveries back to the owner of the genetic resources (the states and Commonwealth). The project has also substantially increased our knowledge of the tropical and subtropical sessile invertebrate fauna.

**Literature**


Australia has three species of a group of root parasites called “broomrapes”. Outside their natural habitats, broomrapes can be noxious weeds. Two of the Australian species have economic impact as a threat to crops and to Australia’s free trade in agricultural and horticultural products. The third species is a major contrast. All the evidence points to it having been on the Australian continent prior to European colonisation and it now being under threat, ironically, by land clearance for agriculture and horticulture.

Belonging to the genus *Orobanche*, broomrapes are fully parasitic. They rely on their host plants completely for survival. Molecular studies have confirmed they are closely related to a large group of semi-parasitic plants, traditionally placed in the foxglove family Scrophulariaceae. These have chlorophyll to convert carbon dioxide in the air to carbohydrates and also simple root connections to draw water and nutrients from the host plant. Australia’s three species of broomrape are not closely related to each other, however. They each belong with individual species widespread in Eurasia or across the Northern Hemisphere.

In matters of commerce and quarantine, we need to know much more than we do now about the weeds that inhibit free trade. Millions of dollars are at stake. For example, in the late 1990s, a shipment of Rhodes grass from south-east Queensland was turned back from Hawaii because of a single seed. Broomrapes are entirely absent from south-east Queensland. The identification of the seed as *Orobanche* was not definitive, but the mere chance that the seed could be from a broomrape was sufficient for the American botanist to advise rejection of the shipment. Had there been the ability to identify the seed definitely, the shipment might have been accepted and the returns to Australian agriculture realised.

One of Australia’s broomrapes, *O. ramosa* ssp. *mutelii*, is on the proclaimed noxious weeds lists in the mainland states (see www.weeds.org.au/noxious.htm). Farmers in the South Australian Mallee region have been quarantined for more than a decade because of the discovery of this branched broomrape, identified by the local State Herbarium in 1992. There is still a lack of knowledge of the age and origin of this infestation, which was found to cover an area of 70 km². However, in order to protect Australian agriculture and Australia’s free trade in agricultural product, this weed has been subjected to an intensive multi-million-dollar eradication program that, after more than a decade, has all the hallmarks of being successful.

While broomrapes, as a group (*Orobanche* spp.), are proclaimed in Australia, just as they are in other countries, the relatively benign agricultural weed *O. minor* and the native *O. cernua* var. *australiana* are specifically excluded from Australian noxious weeds lists. *O. minor* is widespread across southern Australia and attaches to both native and introduced (naturalised or garden)
plants (e.g. of the daisy family). Authorities have to be vigilant that one of the many closely related similar-looking species of the Northern Hemisphere does not appear. Agricultural authorities and taxonomists spent much time in the 1990s investigating whether an infestation in northern Tasmania was part of the long-standing regional occurrence of *O. minor*. Plants included unusually large ones that could have been from the complex of closely related species in Europe. DNA analysis determined it was *O. minor*.

The native Australian broomrape, *O. cernua* var. *australiana*, has a contrasting story. Many populations within its wide range across arid, mallee and coastal regions of southern Australia have been lost through land clearance for agriculture. Populations are characteristically small and confined to very small areas. The species was subject to bad press following the branched broomrape discovery, even being espoused as a major threat to Australian agriculture. Yet it is known to attach only to a narrow range of native species (of the daisy family) and has shown no propensity in 150 years to attach to naturalised species, even when they are within a few metres. In contrast, Northern Hemisphere *O. cernua* is on the proclaimed weeds list of countries in which it has become naturalised. Further proof that *O. cernua* has different properties across its global range, and in the first instance that var. *australiana* is genetically distinct, would help remove threats to its existence.

Taxonomic knowledge has, to date, highlighted the close relationship of *Orobancha* species in Australia with economically problematic species in the Northern Hemisphere. Taxonomists do not just delimit species; they also document the variation that occurs within species. Northern Hemisphere workers have used molecular (DNA) studies that show that the species are genetically variable across their range. While huge resources have been spent on management and, in the case of branched broomrape, eradication of invasive Australian broomrapes, there has been almost nothing spent on clarifying the relationships, the number of introductions to Australia (there may be more than one for a species) and the timing and place of origin of these. Decisions on management are being made without full taxonomic knowledge. Worryingly, the Australian species of broomrape, which are similar in appearance to invasive Northern Hemisphere species, may be easily misidentified and put further at risk by well-intentioned control programs.
Of all creatures that inhabit the earth, few are as poorly studied or as unloved as millipedes. Most people know only of the Portuguese Millipede that occurs in plague proportions in parts of southern Australia, and are blissfully unaware of the hugely diverse millipede fauna now known to occur throughout Australia.

One of the more attractive millipedes is the roly-poly or pill millipede, so named for its ability to roll into a tight ball to avoid danger. Within Australia, they occur within the eastern forests, with a single species found in the wet forests of south-western Australia. Recent collecting by Melinda Moir in the Esperance region of Western Australia has uncovered a new species that was found to belong to one of the eastern Australian genera (*Epicyliosoma*), rather than the endemic Western Australian genus (*Cynotelopus*). This remarkable new species has been described to fully document the wide distributional range of the genus, and to highlight the presence of relictual, short-range endemic invertebrates in the semi-arid south-west of Australia.

**Literature Cited**

APPENDIX III: PROPOSAL FOR A POSSIBLE MASTER OF SCIENCE — AUSTRALIAN BIODIVERSITY PROGRAM

Prof. Pauline Ladiges, University of Melbourne
1 The ABRS Forum identified taxonomic training as a high priority.

I propose that consideration be given to promoting Masters-level training, which could lead to a professional/technical level career or to a research-based PhD. Current undergraduate degrees do not provide sufficient taxonomic training (and are patchy across Australian institutions). A coordinated Masters level training could be marketed as:

- Enhancing the taxonomic skill base for research and applied studies of Australian biodiversity
- Providing the skills base to support:
  - biosecurity
  - conservation
  - natural resource management
  - global change management etc
- Building on Australia’s current expertise in universities, museum and herbaria
- A new model for training
  - multidisciplinary
  - authoritative
  - consistent within Australia

2 MODEL for discussion

A Master of Science could be offered at a number of universities (nodes). Participating universities would need to agree to a general structure, but that structure should be flexible. Students would enrol in their host university, but the total program and subject offerings would be marketed to them.

Students should be encouraged to move across these nodes for specialist subjects given by particular experts. Thus, subject units need to be offered as intense units (1 or 2 weeks, with follow-up assessment etc). Small bursaries could be offered to cover travel costs (students with part-time work may have to juggle times and work). Some units may be held at appropriate field sites (e.g. marine courses at coastal or field-based labs that students travel to currently).

Universities would have to provide credit to their students for units taken elsewhere, and resource transfer would have to be arranged (smoothly).

CP5 places as well as full-fee places should be included. The issue of how this program would relate to the 4th year Honours program of some universities needs discussion (but year 1 could be equivalent to 4th year Honours if an “exit” point were required).

ABRS and professional societies could help badge the program, providing endorsement or “accreditation”.

There is a need to review similar existing MSc programs in the UK and USA.

3 Possible structure of the MSc

- 200 points over 2 years (possible to do in 18 months)
- prescribe minimum 75 points courses work (6 x 12.5 point units)
- prescribe minimum 25/50 points research project for requirement to proceed to PhD with Scholarship (or industry placement if not)
- some units may be offered in more than one university, especially where there are already offerings in environmental courses; other specialist courses would not. The key is to use experts (including stakeholders) where they are situated and be efficient with the workloads and have sufficient student numbers

Generic units could include (ideas, list not exhaustive):

- Molecular tools for evolution and taxonomy
- Microscopy skills for biological science
- Phylogenetic systematics and biogeography
- Risk analysis
- Conservation Biology/Policy
- Communication & intellectual property
- Biosecurity
APPENDIX IV: LIST OF FORUM PARTICIPANTS
<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
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## Appendix IV: List of Forum Participants

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