Marine Taxonomy in the New Millennium

Discussion Paper for the Oceans Policy Science Advisory Group

Prepared by the Australian Marine Sciences Association (AMSA)

Prelude

1) Taxonomy is the science that discovers and describes all living things. Taxonomists are the scientists that provide data on the identification, description and distribution of flora and fauna as well as the systematics of organisms (ie. the classification of species and other taxa).
2) In Australia there has been no comprehensive review of marine biodiversity; the rate of scale of loss of marine species is unknown; there is a critical lack of data and knowledge about marine biodiversity; and there is a critical lack of skills/resources to investigate and document it. Taxonomy is a science in decline and our taxonomists are almost becoming extinct!

Background – Australia's Mega-Unique Biodiversity

Undiscovered Treasure

Australia is considered to be one of the mega-diverse nations of the world, and as the only developed country in this group, bears considerable responsibility internationally for biodiversity conservation1. With some 6% of the Southern Hemisphere in the Australian Marine Jurisdiction (AMJ) we can also be expected to have a significant proportion of total global marine biodiversity under our care. About one sixth of the world's 1.5 million described species are marine, however it is estimated that marine life represents some two thirds of the world's biodiversity. For example, of the 32 or so invertebrate phyla, 31 occur in the oceans, 15 in freshwater habitats and 10 on land. It has also been suggested that the unexplored deep-sea (representing about 60% of Earth's surface) could hold tens of millions of undiscovered species2 and recent estimates suggest that deep-sea diversity is much higher than in any other marine habitat, perhaps rivalling tropical rainforests in total species numbers.

Significance of Biodiversity

Biodiversity refers to the variety of genomes (the genetic material specifying all characteristics and functions within an organism), species and ecosystems. It is the foundation for understanding and predicting how human and natural effects can change ocean ecosystems. An understanding of the diversity of genes responsible for individual species' adaptations and responses to their environment (intraspecific diversity) is a foundation for understanding almost all ecological and evolutionary processes3. Marine biological diversity is changing, dramatically in some cases, and the most recent changes are due to broad-scale human activities3. However, our ability to evaluate the scale and ultimate consequences to life in the sea of a plethora of anthropogenic effects is limited by our inadequate knowledge of marine biodiversity and the patterns and processes that control it3.

Adequate understanding of what creates and maintains diversity must be the scientific underpinning for policy decisions regarding pollutant and waste disposal, habitat alteration, fisheries management and the preservation of threatened species. Not knowing how many species are in a community severely limits our ability to predict the fate of that community under different kinds of anthropogenic stresses. Not knowing the identity of species in a community severely limits our ability to compare different systems and to understand the biology and ecology of such organisms by comparing them to their better-known relatives3. The inability at this time to provide such taxonomic and ecological information to policy makers may have important implications for the conservation of marine life4 and the sustainable use of marine resources.

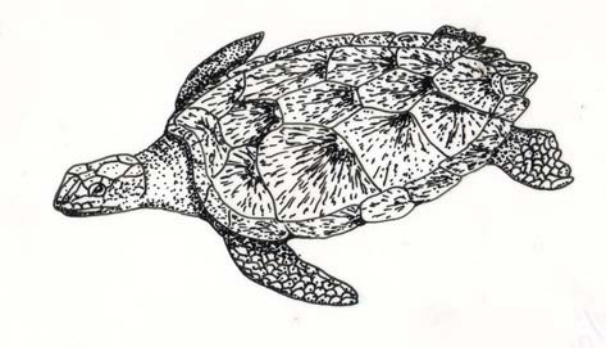
A Range of Records

Australia's long geographic isolation has led to high levels of endemicity within its flora and fauna, with high proportions of each group unique to our region. In addition, the AMJ is one of the largest in the world and encompasses the five major climate zones, from tropical to polar. These features, along with the variety of geomorphology around our 60,000+ km coastline, have resulted in a wide range of habitat types supporting a vast diversity of species, ecological communities and ecosystems. Examples of our marine habitats include:

- estuaries (>1000, only 50% considered to be pristine)
- rocky reefs (estimated to support 50% of our temperate fisheries)
- coral reefs (360 coral species in GBR; 300 species in Ningaloo, WA)
- mangrove systems (43 species, the highest in the world)
- seagrass systems (30 species, the highest in the world)
- beaches and dunes (50% of our coastline)

Antarctic coastline and islands

Australia's marine environment also spans a range of depth zones, which in themselves provide diverse habitats; for example: intertidal, continental shelf (0 – 200 m), continental slope (200 – 1000 m), deep-sea mounts, and abyssal plains (4000 – 6000 m). It is currently thought that marine biodiversity peaks on the continental slope. However, to date less than 2-5 % of Australia's marine jurisdiction has been explored, with most of this confined to the shallower continental shelf margins. Whole regions (tens of



thousands of square kilometres) have never been surveyed and sampling has rarely occurred deeper than 1500 m.

This discussion paper complements and draws upon a report on the Conservation of Marine Invertebrates5 prepared for the Department of the Environment and Heritage - a report that concurs with conclusions drawn in earlier Australian and international reports,6,7,8,9.

Australia's Taxonomic Base

Role of Taxonomists

Taxonomists need to balance their existing time and resources between four important roles:

- **discovering** new information
- **synthesising** existing information
- **publicising** the taxonomic component of biodiversity to wide audiences, and
- providing taxonomic services.

These roles can be categorised into three broad tasks:

- **research** - to identify and describe, categorise (systematics) and understand the biota, its evolutionary relationships, ecology and natural geographic distribution, and to assist with the **identification** of ecological 'keystone' species
- extension/outreach - make taxonomic information available to the public and prepare tools and guides to enable the public to make identifications (usually high order) of plants and animals
- **service** - provide identifications of biota for others' specific purposes.

Issues in which taxonomy is critical, for example identification of exotic species (eg. introduced marine pests) or threatened species, and the development of detailed inventories, fall on the shoulders of few individuals. Often ecologists and marine managers have to make do without taxonomic help in their investigations. From a scientific perspective, and often in practical terms, the conclusions drawn from research that is not supported by accurate and comprehensive taxonomy may be seriously compromised. More optimistically, Australia's marine taxonomists would be well placed, given the right mix of opportunity and support, to provide a useful role in delivering taxonomic training and services international, particularly into the Asia Pacific region. This may be particularly pertinent for regions and nations involved with features such as tropical biodiversity hot-spots, or undescribed Southern Ocean-Antarctic communities.

Silos of Skills

Australia's taxonomic experts are mainly employed in State museums and herbaria of which there are only a limited number (~15) around the country and in CSIRO. Individual taxonomists tend to specialise in a particular group of organisms and therefore can only provide limited coverage of the wide diversity of Australia's marine biota. While taxonomic problems are few in marine mammals or birds and slightly greater in fishes, they are overwhelming for the limited number of taxonomists involved with the 30+ phyla of invertebrates and algae occurring in the marine environment. It is also important to recognise that some 95% of Australia's marine biodiversity is represented by the invertebrate phyla, and the bulk of these have yet to be discovered or described.

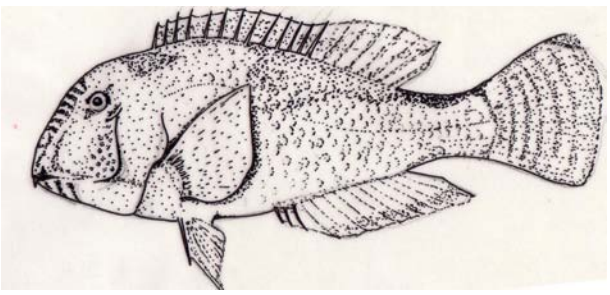
We are potentially in the position of losing functionally important marine invertebrate species, without ever knowing they existed.

New Technology

Another important issue related to skills and capability is that of the rapid growth in molecular-genetic techniques over the past decade. The application of molecular-genetic techniques for describing marine species is changing the recognition and description of the diversity of life in the oceans3. These new techniques now permit the discovery of many new organisms in the microbial realm (eg. picoplankton, protozoans, cyanobacteria, phototrophic bacteria – prochlorophytes, archaebacteria, viruses), as well as the identification of previously unrecognised multispecies complexes of multicellular organisms (eg. blue mussel, Mytilus edulis, corals). In particular, the discovery of such microbes has led to a greater understanding of their vital role in geochemical (eg. Carbon cycle) and productivity cycles in the world's oceans. However due to the decline in the more traditional systematic and taxonomic sciences, there are fragmentary and incomplete bridges between molecular and morphological systematics. Consequently, practical, straightforward species identification, ie. recognition on a morphological basis of taxa now regarded as genetically distinct, is compromised just when species-specific information is needed most for documenting biodiversity3. The linking of whole-of-species bioinformatics data to relevant molecular bioinformatics data is also important and a continued lack of integration may hamper natural product discovery (biodiscovery). Currently good models for bioinformatics data exist (eg. Australia's Virtual Herbarium, the Global Biodiversity Information Facility, and Ocean Biogeographic Information System). Building on these systems, including the incorporation of biomolecular data would benefit Australia's research capability and facilitate opportunities for biotechnology based development.

Limited Assistance

To date one measure that Australian taxonomists have used to deal with the large gaps in basic data is to involve taxonomists from other countries. As an example, a series of low-cost, field-based workshops (of 1 – 2 weeks) involving 10-15 Australian and overseas specialists has been run by the Museum of Western Australia and supported by AMSA over the past 16 years. These have resulted in 9 published volumes of taxonomic work and the identification of close to 300 new marine species from over 20 new genera and a variety of phyla. Such an intensive-collaborative approach enables a critical mass of



excellence, complements current strengths and provides excellent opportunities for exchange and training, while saving time and funds. International specialists are keen to be involved with new fauna but are often limited by funding opportunities. Students are another group whose research efforts contribute to addressing Australia's taxonomic impediment, however they are usually lost to taxonomy early in their careers, due to the lack of career structure and employment opportunities.

Strategic Breakdown

Although overseas taxonomists and our students provide a limited contribution to Australia's taxonomic research, adding to the numbers of species described and to understanding ecological relationships and biogeography, these groups make no contribution to Australia's requirement for the delivery of taxonomic services. Such services are often required to underpin research, management, planning, and industry development. An example of this is the need for the production of species' inventories when conducting environmental impact statements (EISs), a legislative requirement of most development activities at all levels of government. Another important example relates to the introduction of non-indigenous species (ie. marine pests) that can have significant impacts on the economy and ecology of coastal marine environments. Mitigation of NIS impacts is underpinned by their early detection, which allows management and eradication procedures to be implemented10. However, much of Australia's marine fauna awaits discovery and or description, contributing to the difficulty of correctly identifying whether taxa are native or introduced10. In cases such as these examples, where specialist knowledge is needed, there are only a limited number of Australian taxonomists available to undertake this type of service – and even then these specialists may have alternative priorities or commitments.

The recent diversion of some taxonomic research into molecular systematics has had the effect of adding new tools and new perspectives to taxonomic research. Molecular systematics is particularly useful in cases where the presence of widely spread morphospecies (ie. closely related and similar in appearance) makes traditional taxonomy difficult, and in helping elucidate biological aspects such as evolution, reproduction and distribution. While the growth of molecular systematics is an exciting and welcome trend, it has, unfortunately, often been at the expense of traditional, descriptive taxonomy.

Knowledge Gaps

Limited Timeframe

Unlike Europe and the USA, Australia does not have the legacy of hundreds of years of taxonomic research and accumulated knowledge. Gaps in knowledge exist for even the most well-studied of our macro-faunal taxa and are extreme for others such as marine invertebrates. This lack of knowledge results in a serious taxonomic impediment for Australia and the need to use inappropriate exemplars from outside the region when attempting to extrapolate ecological outcomes.

Patchy Status

Australia's taxonomic knowledge also varies considerably with habitat:

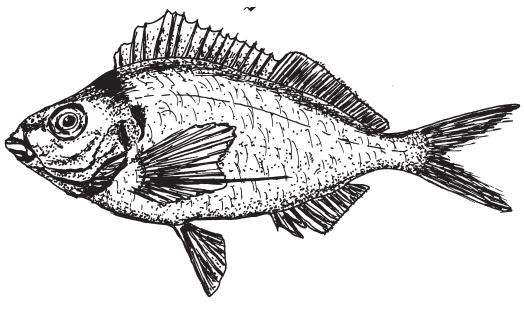
- that for intertidal and shallow water is most comprehensive while the deep-sea is virtually unknown (Note: the previous notion of a global deep-sea bottom that is uniformly featureless has been shattered by countless discoveries of unique, bizarre, and highly diverse deep-sea communities, such as those associated with hydrothermal vents, wood, seamounts, and whale skeletons3).
- coral reefs are relatively well studied compared with most other ecosystems, although only with regard to the most conspicuous taxa - hard corals and fish
- meiofauna (the minute organisms that inhabit sediments/substrates and have strong links with nutrient recycling and detritus based food-webs) in all habitats are poorly studied and described
- microbes - a group that has increasing importance in our understanding of marine productivity cycles and sedimentation processes, are virtually unknown

commensal and parasitic taxa are largely ignored (these may have important consequences for fisheries and mariculture).

In Australia, the state of taxonomic knowledge also varies with geographical location. For example it is strongest around major urban centres and marine research stations. Thus as a result of historical efforts and inputs, our current knowledge is focussed on the continent's south-eastern seaboard, where many museums are located, and on the Great Barrier Reef in north-east Queensland. However recent and surprising findings from a study of a range of different countries has highlighted the magnitude of the undescribed coastal zone. It found that even for familiar shallow marine habitats that are visible, accessible and well sampled – up to 99% of the organisms within a given taxon collected at a single site remain undescribed3. In fact, reliable estimates of undescribed species for any taxon are often nearly impossible to obtain, because it is the species descriptions that are published, not the lists of taxa for which there are no names3.

The Frontier Factor

Bio-prospecting or bio-discovery are rapidly expanding R&D activities in the Australian marine environment and support what government calls 'frontier technologies'. These endeavours involve the search for new compounds and chemicals for a range of purposes for the pharmaceutical and manufacturing industries. Currently more than half the world's drugs are derived from nature but none come from the sea, one of the most chemically and biologically



rich environments on Earth. When the Queensland Government proclaims the Biodiscovery Act (due late 2004), it will be the first Australian jurisdiction with a formal law for access and benefit sharing and this is expected to expedite the drug development process and open the way for attracting new investment. In addition, Australia's mariculture industry is rapidly expanding, while other traditional maritime industries are edging further and further offshore (eg. oil and gas exploration/extraction). All marine-based industries have a critical need for taxonomic services. There is also a growing call for related genetic and bio-molecular research and techniques. In particular this is an expanding area of taxonomy that urgently needs more support for both research and the training of skilled personnel.

Issues and Strategies

Funding

Taxonomic research and services are seriously under-funded in Australia. For example, in 1991, the US and Canada had 18,000 taxonomists while Australia had 45011. Over the past two decades, funding for taxonomic research has declined considerably, as has the number of taxonomists working in museums, herbaria and universities. For example, in 1991 the number of systematic experts in Australian universities was 64, down from 193 in 197411. There have been no surveys done since10. Consequently, there are usually significant difficulties for ecologists and marine planners, managers and industry in getting material identified reliably and in a timely fashion – particularly that of marine origin.

State and Territory governments currently provide little 'untied' (ie. stand-alone) funding for taxonomic research. Also, unfortunately, there seems to be a general perception that taxonomy is cheap and curiosity driven. On the contrary, taxonomic work is often labour intensive and time consuming. Employees of State/Territory institutions also have little access to untied Commonwealth funding. The funding that is available is usually part of issue- or development- or conservation-driven projects, rather than quest for new knowledge type projects.

It has been reported that for the recent Australian Research Council (ARC) round of Discovery grants (ie. for 2005 funding), no museums or herbaria were funded, despite biodiversity being a major theme of the granting process. This is one of the main sources of funding for taxonomic work in Australia.

Granting Awareness

The profile of taxonomy as a critical component of all marine biological/ecological research, planning, management, and industry development, needs to be raised. However, budget provisions for taxonomic services are rarely made in the granting of research and/or R&D funds. Even if taxonomic advice is sought, a budget for dealing with the sampled material is often not factored in. This critical shortfall needs to be addressed, as taxonomic research and services cost and need to be adequately factored into project proposals. In addition, taxonomists need to be involved early in the budgeting process for research and/or R&D projects, providing information on what is possible, what the likely costs are, and what returns and benefits the investment provides. There is a need for granting agencies to be made more aware of the critical role of taxonomy for certain project types and ensure adequate funding allowance for these services.

Threatened and Ageing Skill Base

Statistics compiled by the Australian Biological Resources Study (ABRS) show that the taxonomic expert base is diminishing and ageing in Australia11. A significantly large cohort of the currently employed taxonomists are approaching retirement. Replacement of these experts is uncertain, as universities have reduced appropriate courses at undergraduate level (although interest from students at postgraduate level remains high). The decline in Australia's taxonomic capabilities through retirement of aging specialists, lack of relevant curricula, and few opportunities for young scientists and early career researchers, is a major concern and could set back efforts to understand and manage our biodiversity well into the future. Unfortunately, specialist knowledge of this type is not acquired quickly, nor is the training and accumulated expertise needed to underpin it. We do not currently have statistics on the number of students undertaking taxonomic PhDs, nor of their retention rate in the workforce.

Access Barrier

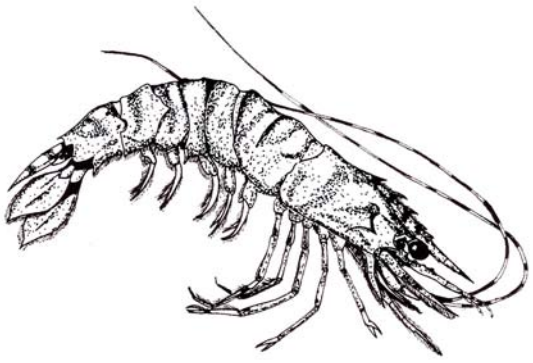
While there is, relatively speaking, considerable information about Australia's marine invertebrate fauna, much of this is only accessible to a few experts and it remains difficult for other users to access or obtain the information. Therefore, increasing public access to existing information is a key issue that needs to be addressed as a priority. The barrier to access relates to there being insufficient tools available to enable the transfer of taxonomic information to potential users. Such tools could be websites or publications that have taxonomic guides or keys. Notwithstanding the well regarded work of ABRS, currently, there are few taxonomic keys and guides available to identify Australia's marine invertebrates, and those that are available are restricted to only a few taxonomic groups. There are some programs available, such as the Global Biodiversity Information Facility (GBIF), that are globally based. Australian input to such initiatives is vital and should be supported. Australia's contribution to the global Census of Marine Life project is another good example. The Online Zoological Collections of Australian Museums, and the Virtual Herbarium are rare, but good local examples.

It seems that to date, the development and compilation of basic taxonomic data and tools, such as databases,

species descriptions, guide books and keys, etc., is not seen by many funding agencies as 'research' and is therefore often not funded. However this aspect of taxonomic endeavour is the critical 'extension' or 'outreach' component necessary to communicate and share knowledge with, and provide tools for, the various potential users (eg. policy-makers, managers, ecologists, consultants, industry). The argument needs to be made that these taxonomic tools assist to build resources on which many activities can be based, and that such tools can assist with the provision of foundation knowledge needed to underpin a variety of research initiatives. Good examples of how this type of information can be made available to a wider audience are the web-based product www.crustacea.net and the CD, Guide to Polychaetes12. While the work of ABRS in this respect is invaluable, they have not had the resources to date to provide a focus on Australia's marine fauna and flora, particularly marine invertebrates.

Reference Collections

Collections made as part of environmental and research surveys are an important part of Australia's historical archives that serve to document our natural heritage and enable change to be tracked. Museums, herbaria and CSIRO are the only institutions that have long-term commitments to holding collections in perpetuity13. However, these agencies, in particular the museums and CSIRO, are often struggling to maintain reasonable curatorial standards13. Some do not have the resources to database their collections in ways that allow information to be electronically available via the Internet for use by decision makers and the community at large. Some museums/collections charge for accessing their specimen databases to raise funds to maintain the collections and database. In this 'Information Age', taxonomic data and information should be available through dedicated websites or portals, or at a minimum be linked to other major websites/portals such as that currently proposed for Australia's Oceans by the National Oceans Office and the OBIS (Ocean Biogeographic Information System) site of the global project, Census of Marine Life (also the marine component of GBIF – Global Biodiversity Information Facility see http://www.iobis.org/Portal.html). It is understood that museums are actively databasing their collections, the level of which depends on resource availability. Some marine invertebrate information is available online through OZCAM (Online Zoological Collections) which is similar in concept to the 'virtual herbarium'. OZCAM involves all State/Territory museums and CSIRO divisions with collections.



While it is recognised that some progress is being made to overcome the difficulties associated with collections, the need for increased Commonwealth investment in supporting State/Territory museums and providing national guidance is becoming critical. As an example, a program is being developed to try to incorporate material into State museums that has been collected during Port surveys for detecting introduced marine pests. It is imperative that such material be maintained for posterity for future cross-checking, enabling colonising dates of marine introductions to be determined and assessments to be made of their impact on native fauna and flora. Incorrect identification of introduced species may lead to costly eradication programs down the track. There have been several instances of this with respect to delayed detection of terrestrial introductions through miss-identification, eg. the fire ant 13p.8. Also the Northern Pacific seastar was first noticed in 1986 but misidentified as a native seastar and dismissed as posing no threat. It was not until 6 years later in 1992 when visiting taxonomists examined the seastar and it was recognised as Asterias amurmensis introduced from the Northern hemisphere14 but by this stage it had made a major impact on the Derwent Estuary.

Blue Horizons

Australia is now at an important point in its development - implementing Australia's Oceans Policy (AOP) and Regional Marine Planning around Australia's coastline (RMP). Now is the time also for consideration of ABRS and other taxonomic agencies (eg. museums, universities, CSIRO) to be 'enabled' to give marine biodiversity and taxonomy the priority focus required to effectively underpin AOP and RMP. It is acknowledged that new information will continue to be obtained through individual research projects, targeted student scholarships, work experience and exchange schemes, workshops and surveys. However, our publicly funded taxonomic centres such as ABRS, CSIRO, State/Territory museums and herbaria - need targeted support to continue this essential work. They also need assistance in the training and development of modern methodologies such as molecular-genetic techniques. It is also important that the issues discussed in this paper are considered by the National Bioinformatics Strategy currently being developed by the Department of Industry, Toursim and Resources, and Biotechnology Australia. The Australian Marine Sciences Association, in assessing the status of marine taxonomy and marine biodiversity in Australia concedes that there is cause for serious concern and the need for consideration of the issue at a national level. Australia is not alone in this issue, these sentiments are being expressed at a global level –

"It is time to address the long-term consequences of the obvious contradiction between the decline in the study of systematics in the life sciences and the international cry for the study of biodiversity3."

AMSA believes that the following recommendations provide a starting point with which to engage in dialogue on this important and complex gap in Australia's marine science (if not general science) capability.

Recommendations

Policy-based

1. As a priority, increase funding and provide direction for ABRS (in conjunction with taxonomic centres) to allow it to continue to describe the marine biota of Australia.
2. Encourage and support ABRS (in conjunction with taxonomic centres) to enhance the development of interactive keys and guides and other taxonomic outreach products.
3. Recognise the value of accurate taxonomy in biodiversity, environmental impact and natural resource management studies by facilitating and promoting the involvement of taxonomists in such studies and ensure that the cost of their contribution is budgeted for in publicly funded projects (eg. in port surveys, bioregionalisation studies, environmental impact statements, fishery management assessments, etc.). Collection and lodgement of voucher specimens/collections from such projects also requires funding support and allocation, including the costs of curation.
4. Encourage Government-led direction of funding sources (such as the ARC, National Heritage Trust, or similar arrangements) to encourage support for biodiversity initiatives and the development of taxonomic capacity building tools, such as guides, keys and other communication products, to support a broad range of individuals and organisations to answer their questions about change, environmental health and biodiversity for marine habitats.
5. Facilitate organisations at Commonwealth and State/Territory government levels, such as DEH, DAFF, NOO, EPAs, and State/Territory Fisheries departments, that do not themselves employ taxonomists, to be aware of these recommendations and the need to give closer attention to the taxonomic concerns that underpin the management and conservation of Australia's marine biodiversity, and lead to improved understanding of marine ecosystems and their health.
6. Ensure that the costs of cataloguing, curating and transfer of specimens to museums and herbaria are built into the budgets of programs relying on identification of taxa within environmental samples.
7. Ensure that funding for the maintenance and databasing of collections in State/Territory museums, herbaria and CSIRO is maintained and adequate. Recognition that these collections represent national assets.

Training-based

8. Enlist the support of FASTS and the Australian Academy of Science to promote the inclusion of taxonomy in undergraduate curricula and the teaching of taxonomy by appropriately trained educators.
9. Support for DEST, ARC and ABRS to work with marine taxonomists to develop the following strategies to help address the issue of an ageing expert workforce and gaps in marine taxonomic groups:
   (a) employment opportunities for graduate students in taxonomy, including international exchange training opportunities
   (b) targeted PhD scholarships for students of taxonomy
   (c) mentoring programs to support early-career researchers to train with some of our expert (but ageing) taxonomists.

   Note: the timeframe for this issue is critical as Australia will have lost a significant proportion of our taxonomic expertise within 5 years; 10 years is considered too late. There already exist critical gaps with some taxonomic groups where the experts have retired or died.
10. Support increased research and training funding for the development of molecular genetic techniques in the taxonomy of marine organisms – including post-graduate training and developing incentives to partner with industry.

References

1. Australian State of the Environment Committee (2001) Australia State of the Environment 2001, Independent Report to the Commonwealth Minister for the Environment and Heritage, CSIRO Publishing on behalf of the Department of the Environment and Heritage, Canberra.
2. Pain, S. (1996) Mud glorious mud. New Scientist. No. 2054, Supplement 5-7.
3. Butman, C.A., and Carlton, J.T. (1995). Marine Biological Diversity: Some important issues, opportunities and critical research needs. U.S. National Report to IUGG, 1991-1994. Rev. Geophys. Vol. 33 Suppl. American Geophysical Union. http://www.agu.org/revgeophys/butman01/butman01.html
4. Norse, E.A. (Ed.) (1993) Global Marine Biological Diversity Strategy: Building Conservation into Decision Making. 383 pp., Center for Marine Conservation, Washington.
5. Ponder, W., Hutchings, P., and Chapman, R. (2002). Overview of the Conservation of Australia's marine invertebrates http://www.austmus.gov.au/invertebrates/pdf/marineoverview.pdf. A report for Environment Australia: Canberra. 588 pp.
6. Disney, H. (1998). Rescue plan needed for taxonomy. Nature 394: 120.
7. Gibbons, M.J. (1999). The taxonomic richness of South Africa's marine fauna: a crisis at hand. South African Journal of Science, 95: 8 - 12.
8. Hutchings, P.A. 1999. Taxonomy of estuarine invertebrates in Australia. Australian Journal of Ecology 24: 381-394.
9. Godfrey, H.C.J. (2002). Challenges for taxonomy. Nature 417: 17-19.
10. Neil, K. M., Hutchings, P. A. and Stafford, H. (in press) Port surveys for non-indigenous species - the benefits of taxonomic networks.
11. Visher, L. (Ed.) (1996) Taxonomy in Crisis? A report on a national workshop held in Canberra, 18 October 1995. Australian Biological Resources Study, ANCA.
12. Wilson, R., Hutchings, P.A., and Glasby, C.J. (2003) Polychaetes: An interactive Identification

Guide. CSIRO Publishing: Melbourne. (CD)

13. Day, M.F.C., et. al. (2004) The Biological Collections in CSIRO: a National Heritage? Historical Records of Australian Science. Vol 15 (1): 1-19.
14. Turner, E. (1998) Groping in the Dark, p. 4-12. In Goggin, C.L. (Ed.) Proceedings of a meeting on the biology and management of the introduced seastar Asterias amurensis in Australian waters. Hobart, Tasmania, 19th May 1998. CSIRO Marine Research, CRIMP Technical Report 15.