National Marine Science Plan, White paper submission on Aspects of classifying, cataloguing, curating and systematics of marine biodiversity

An executive summary

Australia has the third largest Exclusive Economic Zone in the world, extending from the tropics to the sub-Antarctic, and from intertidal to deep-ocean habitats. Researching into identifying and understanding this large portion of the earth's marine biodiversity are 37 Australian professional marine scientists primarily in state museums and herbaria and some facilities of CSIRO. With this task essentially in its discovery phase no realistic estimates of the actual diversity of Australia's marine diversity is possible. It is thus difficult to measure loss in species and populations, or changes in range, through human usage, pollution, invasion and climate change. Identification of introduced species and their impact is difficult. In spite of this urgent need the number of permanent positions for marine taxonomists is declining, and the amount of specific ABRS Federal funding for taxonomy is being reduced in real terms. **Taxonomy is now considered a discipline in crisis (FASTS 2003).**

- Marine taxonomy underpins marine ecosystem health; conservation and marine protected areas; biosecurity; marine tourism; and marine resource management. Zoning plans for marine protected areas under our international obligations also require the identification of biota and their distribution. Early identification of introduced pest species can be vital for ecosystem health and the protection of fisheries resources.
- Clearly taxonomic science urgently needs support. The taxonomic workforce is aging rapidly and is not being replaced (ABRS). With much of our marine biota still undescribed (Ponder et al., 2002) our understanding of marine environments and their protection and use is

compromised. New methods in molecular analysis are providing a formidable addition to taxonomy, but a combination of both methodologies remains essential. Both also require voucher specimens on which a species is based to be retained, conserved in museums or herbaria.

- Over the next five years priorities should include increased research into the documentation of Australia's biodiversity (also obligated by Australia's being a signatory of the International Convention on Biodiversity). This will only be achieved if this research is included in a federal funding framework and not left primarily to the states. This includes reversing the decline in ABRS funding, and increasing support for inclusion of species in the national databases (ALA, AFD, APNI). In conjunction with the states a national Museum plan is needed to allocate new appointments across groups to minimise duplication of effort. Inventory of the diversity in MPAs and CMRs is needed, and the impact of climate change on their species, populations and shifting distributions monitored and understood.
- Priorities over 10-20 years include that all institutional collections be identified and incorporated into national data bases with keys, distribution maps and illustrations for better integration into industry needs and biodiversity health. Accurate means of identifying invasive species using traditional and emerging molecular technologies need developing.
- Realisation of these goals demands increased permanent taxonomic staff in existing organisations with appropriate infrastructure. In all exploratory cruises and expeditions taxonomy needs to be given a high priority in planning and outcomes. Involvement of the Federal

government is deemed essential given the magnitude and urgency of the tasks. To achieve this it is recommended that a Marine Taxonomic Facility (MTF) be developed similar to the successful Integrated Marine Observing System (IMOS).

b. Background

Australia has the third largest Exclusive Economic Zone (EEZ) in the world, which is home to a massively diverse fauna and flora (Costello et al., 2010). Our EEZ extends from the tropics to the subantarctic, and includes all types of habitat from from the intertidal to the deep oceans.

The work of documenting, identifying, describing and understanding marine biodiversity (known as taxonomy and systematics) is undertaken primarily in state museums, herbaria and facilities of CSIRO, which maintain biodiversity research collections. Taxonomy underpins all other biological sciences and at present approximately 37 (full time researchers- in addition there are retirees and some collection managers who undertake some taxonomy but this is not there primary role, plus some students) marine taxonomists are employed around the country.

Currently we cannot provide realistic estimates of the actual diversity of Australia's marine fauna and flora. This is due both to the extraordinary diversity of Australia's marine fauna, which is still essentially in discovery phase (Coleman et al., 1997; Poore et al., 2014), and to the small (and declining) group of professional taxonomists. For example, over 3000 species are recorded from Sydney Harbour and this is despite a comprehensive survey never having been undertaken. The actual number would be certainly more than double this figure.

At present, funding for taxonomists and maintenance of biodiversity collections is primarily a state responsibility. Federally, the Australian Biological Resources Study (ABRS) (through the Dept of Environment), provides grants for research on the taxonomy of the Australian biota or development of taxonomic tools. The program also aims to support projects that build Australian taxonomic capacity, providing funds to support and mentor students and postdoctoral fellows. ABRS funding, however, has been consistently declining in real terms for more than a decade. Further, the sphere of ARC (Australian Research Council) funding effectively excludes taxonomic research. Research funding is a major limiting factor.

Australian taxonomists are internationally respected and are in most cases, the global leaders in their fields. However, fewer than half of taxonomists who retired during the past two decades were replaced. Our national taxonomic capability continues to decline and the trend towards short term employment exacerbates the problem by preventing development and retention of a deep skills base.

c. Relevance

As an underpinning science, taxonomic research is used across a wide spectrum of disciplines, from bioregionalisation to marine conservation and biosecurity. It is critically important to manage and conserve our biodiversity in order to ensure we have healthy functioning marine habitats and that we can differentiate between those areas with high species diversity and/or endemicity which deserve priority conservation efforts, and those areas where we can sustainably harvest our marine resources. The first step in managing and conserving biodiversity is to be able to recognise and distinguish each species whenever it is encountered, which requires sound taxonomy. For many kinds of marine life, this is not yet possible. Most marine animals have larval stages that differ greatly from the adult and may live in completely different habitats. For example, many commercially important fish species and crustaceans have pelagic larval stages living over the continental shelf, juvenile stages that move to inshore seagrass beds and mangroves, and adults that migrate offshore or onto reefs. Thus, management of both wetlands and offshore areas is needed to ensure these fisheries are sustainable. Adults may be sedentary and firmly attached to rocky substrates yet their larval stages may spend weeks to months in the ocean. Management plans must account for all life stages. This means that the marine environment needs to be managed as a three dimensional habitat.

Well managed healthy marine environments are not only essential for their ecosystem services but are required for both commercial and recreational fishers as well as for recreational and tourist activities. The development of zoning plans for marine protected areas requires the identification of the biota and their distribution to ensure that a percentage of each of these communities is included within sanctuary zones. These communities must be characterised not just by physical surrogates such as depth and sediment type but by the range and uniqueness of the organisms living within them. Detailed taxonomic knowledge is necessary for these assessments.

Australia's unique marine biota is continually being threatened by the accidental introduction of non-native species (http://www.padil.gov.au/) which can severely modify marine communities. Accurate taxonomy is a critical component of effective biosecurity. For example the Pacific starfish introduced from Japan has wrought havoc in the Derwent River, Tasmania and has spread to SE Australia. This species when originally collected was not recognized and 20 years later, when it had reached plague densities, its true identity was discovered. This example illustrates the importance of accurately identifying species for biosecurity detection and subsequent response, such as eradication. The task of eradication is extremely difficult especially when a species becomes well established. The paucity of baseline studies in Australia's shallow coastal zones means that in most cases we do not know the impact of many introduced species. This is compounded by our incomplete knowledge of the native biota, so distinguishing between introduced and native species including as yet undescribed species is often challenging.

The international significance of Australia's marine biodiversity was recognised by the Census of Marine Life (CoML). Three different tropical locations were included in the C-Reefs project as a component of the CoML and while substantial funds were made available for field work and logistics, only limited funds were made available for working up the material and depositing it in museum collections. However these collections will continue to be worked up and increase our knowledge of Australia's biodiversity in these areas.

d. Science needs (*Taxonomy is in crisis)*

The National Taxonomy Forum in 2003 (FASTS, 2003) declared that *"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".*

Our understanding of marine environments is compromised by inadequate knowledge of the biota.

Until we have the ability to recognise and distinguish all species we encounter, the ability of scientists to understand and document marine environments will remain compromised, and for many common kinds of marine life, that remains a distant goal. Much of our biota remains undescribed (Ponder et al., 2002, and this is still true in 2014) and this was recently highlighted by a recent study of polychaetes and crustaceans present offshore in Western Australia (Poore et al. 2014) which found that only about 10% of the 805 species encountered were named; the remainder were undescribed or new to the Australian fauna, or both. Many more species from the same and similar studies remain unstudied. Our current knowledge of Australia's marine biodiversity varies according to the group as well as to habitat. Although the largest gaps in biodiversity knowledge are in Australia's deeper waters and the tropics, new species are still being frequently discovered even in areas thought well studied. For example, a recent month-long survey of Moreton Bay in Queensland – an area considered well-known and studied for over a century – revealed 53 new species, six new genera and even a new family of marine invertebrates. Similarly, fish species new to the Australian fauna are being found at a rate of about one per week, a rate that has been relatively constant for several decades. As fishes constitute about 75% of Australia's vertebrate species biodiversity, there is clearly a need for more taxonomic work: the era of discovery of Australian's fish fauna is far from over (Hoese et al., 2006). Higher rates of discovery occur amongst many of the other marine groups. For example, the Australian diversity of seaworms, small crustaceans and molluscs, which are the dominant groups in marine /estuarine sediments, has increased dramatically since the 1970s and new species are continually being discovered (Poore et al. 2014).

In addition to known diversity, new methods in molecular analysis have revealed previously hidden diversity. For example, the intertidal worm that encrusts every pier and reef in southern Australia with white coral-like growths comprises at least two cryptic species (Halt et al., 2009) and numerous similar studies suggest this phenomenon may be the rule rather than the exception even where we thought the biota was well-studied. The two most important commercial crabs in Australia, the Indo-Pacific Blue Swimmer Crab and Mud Crab, have both recently been shown to comprise at least four separate species each (Keenan et al., 1998; Lai et al., 2010). A recent study of what was thought to be only "several" species of wide-ranging sandy sponges (Irciniidae) from tropical Australasia turned out to contain 14 different species, each with different distribution patterns (Pöppe et al., 2010). All species that have been identified and databased by the Australian biological collections community in museums and herbaria are now accessible on the *Atlas of Living Australia* and on the ABRS Australian Faunal Directory (AFD) and Australian Plant Names Index (APNI), free online public enquiry databases that provides taxonomic and biological information on the Australian fauna and flora. A rough estimate of numbers can be obtained from the Chapman (2009) report which can be viewed at http://www.environment.gov.au/node/13875

New molecular technology has been widely touted as solving all taxonomic problems, but in reality it is a tool that is most useful when combined with morphological data that must be worked out and described by trained taxonomists (Leis, 2014).

Biodiversity collections are critical infrastructure for understanding biological phenomena
Retaining voucher specimens to "vouch for" biological phenomena allows hypotheses to be tested as new paradigms are developed. Resources must be invested in the preservation, maintenance and access to collections to ensure that they are available in perpetuity. Deposition of voucher specimens in relevant state or federal repositories should be a requirement of collecting permits with provision of resources to support collection agencies a routine component of collecting. Responsibility for these collections is predominantly within the realm of state and territory governments, as collections are part of the core-business of museums and herbaria, but represent Australia's biodiversity and must be adequately funded

d. Perspective

Within 5 years

- Acknowledgment that documenting Australia's marine biodiversity cannot be chiefly a state responsibility, requiring inclusion within a federal funding framework. As a signatory of the International Convention on Biodiversity, Australia has an international obligation to document its biodiversity. Our biota does not recognise political boundaries.

- The sole Federal funding agency supporting taxonomic research, ABRS, has had static or declining levels of funding from governments for decades. Yet ABRS plays vital roles in supporting taxonomy especially postdoctoral careers through a granting program and also enables taxonomists' input to AFD, APNI and the databases of ALA. Reversing the decline in real terms of support for ABRS is the single most significant funding lever available at federal level to redress decline of support for biodiversity knowledge. While we have made considerable inroads into databasing collections and biodiversity records, this is a large task given our extraordinary diversity.

- Most tenured marine taxonomists in Australia are employed in state natural history museums, but many have recently or will soon reach retirement age. Museums need a 5 or 10 year plan to strategically allocate new appointments across groups to minimise duplication of efforts. The Council of Heads of Australian Faunal Collections (CHAFC) and Council of Heads of Australasian Herbaria (CHAH) could be appropriate fora for these discussions.

- Develop a Virtual Marine Taxonomic Facility (MTF) similar to the Integrated Marine Observing System (IMOS), where researchers from other disciplines could more readily access and contribute to our taxonomic understanding. The MTF would be distributed facility which builds on existing collections based museums and herbaria and infrastructure such as ALA, AFD, APNI and the Australian Ocean Data Network (AODN) for ready dissemination of data on species attributes and geographic ranges. The MTF would promote integration and coordination of the national marine taxonomic effort to maximise resources and access to taxonomic knowledge and supports existing institutions.

- With climate change and Marine Protected Areas (MPAs) on the national agenda, the question of population genetics is going to be a key issue as well. We need a targeted approach to work with a good set of model species representing a range of taxon and life history traits to facilitate the development of MPAs and their adaptive management plans.

- We need to know the diversity of Commonwealth Marine Reserves (CMR) and MPA networks. What is the diversity of these areas? Establishing an inventory is critical given the CMRs are new and relatively unknown. For example are they representative of off-reserve diversity, are they well connected?

- **Within 10-20 years**

  - Ensure that all collections are identified, databased and incorporated into the ALA, AFD and APNI, where accurate maps of species distributions, plus links to keys, illustrations and other relevant data. This would create more streamlined pathways for taxonomic knowledge to be integrated into wider research or industry initiatives.

  - Most state museums and herbaria have associated networks of honorary and amateur naturalists who collectively make a vital contribution to Australia’s taxonomic skills. Many of these researchers have strong international reputations and their knowledge must be passed on to the next generation of taxonomists. A few such honorary researchers obtain support through the ABRS capacity-building grants for non-salaried researchers. Modest expansion of this high-value program could easily mobilise greatly increased published outputs of taxonomic works from this under-valued community who with minimal support can mentor the next generation.

  - Accurate means of identifying invasive species and distributions. To be effective, this should use traditional identification tools, citizen science networks, but also emerging molecular technologies.

1. Realisation

Employ research taxonomists. Major infrastructural components for biodiversity research are already in place in most in state museums, herbaria in the form of collections, facilities, laboratories and equipment. By far the MOST significant impediment to documenting Australian marine biodiversity is the loss of long term taxonomic research positions. This is not the result of inadequate training of new researchers (a common misapprehension), but the lack of career path for graduates – long term positions are needed. A similar misapprehension underpinned the approach of the US based National Science Foundation PEET (Partnerships for Enhancing Expertise in Taxonomy) program in the mid-1990s, specifically designed to train new taxonomists/systematists in recognition of the loss of taxonomic expertise (Agnarsson & Kuntner, 2007). Although PEET very successfully trained excellent taxonomists, it did little to improve national taxonomic capacity because it did not provide career path, i.e., jobs. This problem can only be addressed by museums, herbaria and other research institutions employing research taxonomists and treating taxonomic/systematic research as core business on an equal footing with other types of research already regularly undertaken at universities. To be most effective, these positions should be permanent. Temporary or contract positions are useful for training postdoctoral researchers, but have little prospect to make significant research inroads or to retain and develop skills because of their short term nature.

- Ensuring that taxonomists are involved from the early stages of planning biodiversity cruises and expeditions and providing adequate funds for all stages of collection acquisition and documentation. The MNF should ensure that representative collections made during voyages are deposited in the relevant collecting institution with adequate resources to support the incorporation of such collections and for this material to be sorted and identified to species, which will of course include the description of new species and range extensions.

- Increasing funding to ABRS. At present, ABRS is the most important source of Federal funding for taxonomic/systematics research. It is very important for research support but is unable to provide a long term career path. Museums should also be afforded the ability to directly compete for ARC funding; they are presently barred apart from acting as a secondary partner with a university.

List of contributing authors and affiliations

Pat Hutchings, Australian Museum (co-ordinator)

Shane Ahyong, Australian Museum,

Penny Berents, Australian Museum (retired),

Jeff Leis, Australian Museum (retired);

Jane Fromont, Western Australian Museum;

John Hooper, Queensland Museum

Andrew Hosie, Western Australian Museum

Lisa Kirkendale, Western Australian Museum,

Frank Talbot AM (retired but formerly Director of Australian Museum, Director Emeritus of Natural History Museum, Smithsonian Institute, Washington DC USA) prepared the Executive Summary,

Robin Wilson, Museum Victoria,

John Huisman, Western Australian Herbarium,

Pam Beesley, Australian Biological Resources Study

Neville Barrett, University of Tasmania

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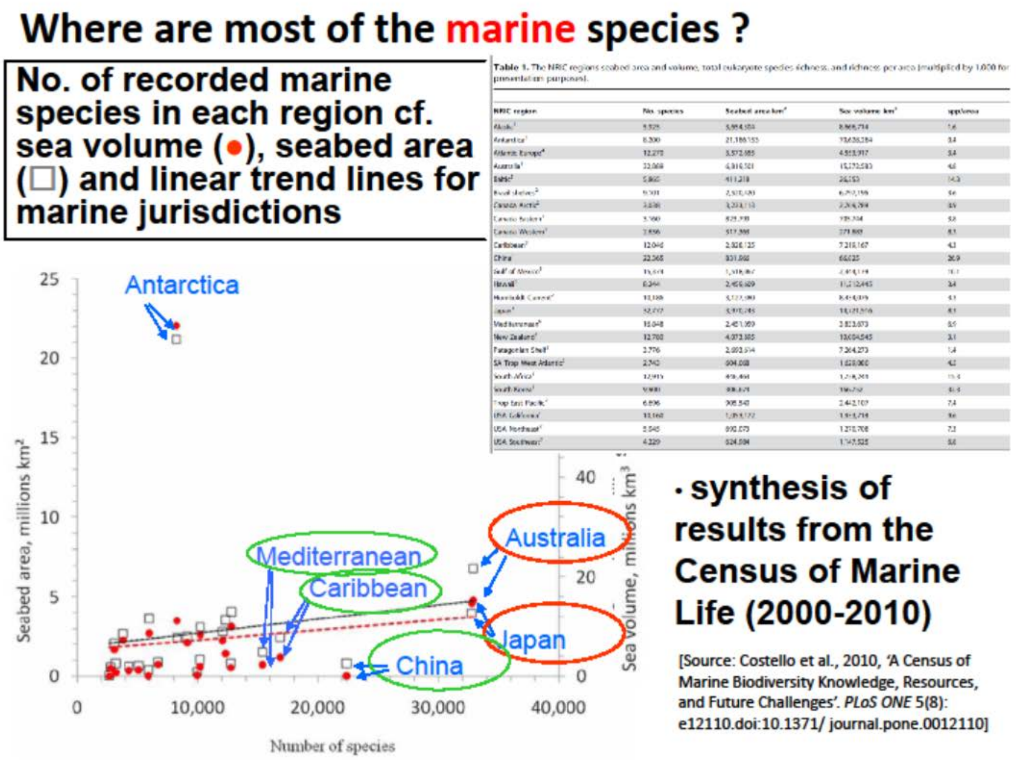
2. *Optional*: Attachments see map below



List of abbreviations

ABRS- Australian Biological Resources Study
AFD-Australian Faunal Directory
ALA-Atlas of Living Australia
AODN -Australian Ocean Data Network
APNI-Australian Plant Name Index
ARC-Australian Research Council
CHAFC- Council of Heads of Australian Faunal Collections
CHAH- Council of Heads of Australasian Herbaria
CMR- Commonwealth Marine Reserves
CoML -Census of Marine Life
EEZ-Exclusive Economic Zone
IMOS-Integrated Marine Observing System
MPAs -Marine Protected Areas
MTF- Virtual Marine Taxonomic Facility
PEET-Partnerships for Enhancing Expertise in Taxonomy