CHAPTER SEVEN

Taxonomy is a foundation of marine science, and it is in trouble

Pat Hutchings[a,b,*], **Claire E. Rowe**[a], **Maria Byrne**[c], and **Rachel Przeslawski**[d]

[a]Australian Museum Research Institute, Australian Museum, Sydney, NSW, Australia
[b]Marine Ecology Group, School of Natural Sciences, Wallumattagal Campus, Macquarie University, North Ryde, NSW, Australia
[c]Marine Invertebrate Futures Group, School of Life and Environmental Sciences, The University of Sydney, Camperdown, Sydney, NSW, Australia
[d]Research Connect Blue, Bungendore, NSW, Australia
*Corresponding author. e-mail address: Pat.Hutchings@Australian.Museum

Contents

1. Introduction 198
2. Case studies 199
   2.1 *Acanthaster* crown-of-thorns sea stars 199
   2.2 Names of the bêche-de-mer species (Echinodermata: Holothuroidea) 201
   2.3 Teatfish names, taxonomy and CITES listings 202
   2.4 Invasive species *Cassiopea* spp. 204
3. Challenges 205
4. Moving forward 207
References 209
Further reading 212

Abstract

This volume of Advances highlights not only the importance of marine benthic diversity in several regions of the world but also the impediments to describing this fauna. Taxonomy is the science of classifying organisms and is the bedrock of marine biodiversity research and conservation, yet it faces significant decline in Australia. Thus, it is critical that the scientific community understand why taxonomy is so important. This paper underscores the foundational role of taxonomy in marine ecology, using case studies that highlight its critical relevance to species management, conservation policy, and international trade regulation. Despite extensive research and funding, unresolved taxonomies continue to affect our management of ecologically and economically important taxa, including crown-of-thorns seastar (*Acanthaster* spp.), exploited sea cucumbers (Holothuroidea), and invasive *Cassiopea* jellyfish. These ambiguities hamper accurate species identification, hinder effective conservation strategies, and complicate regulatory listings under frameworks such as

Advances in Marine Biology, Volume 101
ISSN 0065-2881, https://doi.org/10.1016/bs.amb.2025.08.003
Copyright © 2025 Elsevier Ltd. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

CITES and the IUCN Red List. Key challenges include dwindling taxonomic expertise, reduced funding, lack of university training, and limited career pathways, all of which contribute to Australia's inability to adequately explore and manage its vast marine jurisdiction. The paper advocates for immediate systemic reforms through a series of 11 recommendations related to revitalizing taxonomic education, fostering museum-university partnerships, supporting early career researchers, and investing in infrastructure to enable species discovery. Taxonomic rigor is also essential to validate modern tools like eDNA, metagenomics, and image-based analysis. Without it, efforts to safeguard biodiversity and to foster a sustainable blue economy risk failure.

1. Introduction

Taxonomy allows us to discover, describe, and classify all organisms and is a dynamic discipline fundamental to all aspects of biology and ecology. Working in the life sciences without a good understanding of taxonomy is like trying to follow a recipe without knowing many of the ingredients. There are many undescribed species, particularly among the invertebrates and especially in deep waters (<300 m depth). Under the UN Convention of the Law of the Sea, many nations have a legal obligation to manage their extensive marine territories and resources, which is difficult to do when so much of its fauna is undescribed. For instance, in Australia it is estimated that only 32 % of the marine fauna is described (Decadal Plan Working Group, 2018). A recent report prepared for the Australian Academy of Sciences as to the need to document biodiversity and the cost of failing to do this (Deloitte Access Economics, 2021) could range from $Aust 465 million to $Aust 660 million in avoiding costs of biosecurity events.

The marine area for which Australia is responsible is over 10 million km^2, ranging from the tropics to the Australian Antarctic Territory (Bond and Jamieson, 2022) but most of Australia's marine jurisdiction remains to be explored; as of August 2024, only about one-third of Australia's continental shelf has been mapped at a resolution high enough to inform marine science and management (Geoscience Australia, 2024).

This volume of *Advances in Marine Biology* highlights the importance of marine benthic diversity, as well as the impediments to describing this fauna. The aim of this paper is to consolidate this information and convey the importance of taxonomy, as highlighted previously (2025, this volume). We build on the position statement on taxonomy from the Australian Marine Sciences Association (AMSA, 2021). First, we use case

studies to further illustrate the importance of taxonomy, then we highlight key challenges in the current state of taxonomy, and finally we present recommendations to address these challenges. The taxa in need of taxonomic revision used here as case studies are ecologically and economically important in tropical marine regions with one group in a perilous state of conservation.

2. Case studies

2.1 *Acanthaster* crown-of-thorns sea stars

Coral eating sea stars in the genus *Acanthaster* are large (>40 cm diameter), multi-armed (14–23 arms) species named crown-of-thorns (COTS) for their cover of sharp penetrating toxic spines. These sea stars are common throughout coral reefs of the Indo-Pacific and Red Sea where they are significant predators of coral (Deaker and Byrne, 2022). They can inflict considerable damage to coral reefs when their populations boom. The basal/sister species is *Acanthaster brevispinus* which, as the name suggests, has short spines while also sharp do not produce toxin. This species tends to occur in deeper water including on soft sediment and has a broad diet of invertebrates including coral (Keesing et al., 2023; but see Sommer et al., 2025). Despite the striking differences in the colour of COTS across Indo-Pacific regions and over a thousand papers published, these widely distributed sea stars were all incorrectly considered to be a single species, *Acanthaster planci* (Linnaeus, 1758) (Fig. 1A). Not surprisingly, considering its vast Indo-Pacific distribution, this name is now known to include a

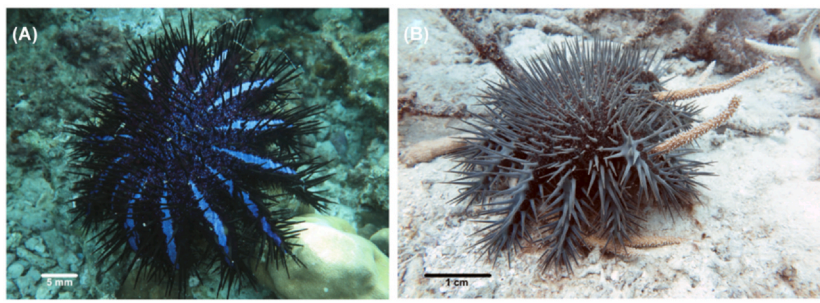

Fig. 1 (A) The bright blue *Acanthaster planci* from Phuket, Thailand. (B) *Acanthaster cf solaris* from One Tree Reef, Great Barrier Reef, Australia. Photographs courtesy Mike Kingsford.

complex of species divided between the Red Sea and the Indian and Pacific Oceans (Haszprunar and Spies, 2014; Worheide et al., 2022). In addition to the well characterised *Acanthaster brevispinus*, genetic studies have indicated there are at least four and maybe five COTS species, two in the Indian Ocean (*Acanthaster planci*, *Acanthaster mauritiensis*) one in the Red Sea (*Acanthaster benziei*) and one in the Pacific Ocean (Haszprunar and Spies, 2014; Haszprunar et al., 2017). These clades are supported by molecular phylogeny (Uthicke et al., 2024). The fifth species from the eastern Pacific, called *Acanthaster ellisii*, while having distinct features, clades with the Pacific species and so at this stage is not supported as a separate species.

The original *Acanthaster planci* was described by Linnaeus from Goa, India hence this is the name for the northern Indian Ocean species which is a very vibrant bright blue colour (Fig. 1A). The southern Indian Ocean species is *Acanthaster mauritiensis*. The widely occurring COTS species in the Pacific, including from Japan, Guam and the Great Barrier Reef (GBR) lacks a type specimen and a reliable type locality (Haszprunar and Spies, 2014). As a definitive designation and a reliable type locality is lacking, a neotype needs to be designated, but it is not clear from where?

The Pacific COTS is temporally or informally called *Acanthaster* cf *solaris* (Fig. 1B) (Haszprunar et al., 2017). This name originates from specimens assumed to have been collected in the Philippines (as *Asterias solaris*) while another name *Acanthaster echinites* with origins from near Jakarta, Indonesia (as *Asterias echinites*) is also available (Haszprunar and Spies, 2014; Haszprunar et al., 2017). Due to the poor descriptions and absence of type material it is not clear which of these names, "*solaris*" or "*echinites*" should be used for the Pacific Ocean COTS. This conundrum will be difficult to resolve.

A specimen of *Acanthaster* from near Jakarta is needed to determine if *Asterias echinites* is a junior synonym of *Acanthaster planci* or is a senior synonym of *Acanthaster solaris*. While this dilemma remains to be solved ecologists are using *Acanthaster* cf. *solaris* for the Pacific species, but this cannot be considered valid under the International Code of Zoological Nomenclature. Thus, the most studied sea star in the world virtually lacks a name.

Recent reviews of *Acanthaster* species show that COTS species from different regions in the Indo-Pacific differ in their diet, ecology and their impacts on local reefs (Burn et al., 2020; Foo et al., 2024; Uthicke et al., 2024). To some extent study region will help inform what species was being investigated. Unfortunately, *Acanthaster* species boundaries overlap,

especially in the coral triangle. Ironically the species for which we appear know the least on its biology and ecology is *Acanthaster planci* from the northern Indian Ocean.

Thus, despite its massive ecological and economic importance, the plethora of papers published and the vast financial investment in research and management of COTS, we still do not know the species identity of *Acanthaster* on the GBR and elsewhere in the Pacific Ocean!.

2.2 Names of the bêche-de-mer species (Echinodermata: Holothuroidea)

Tropical sea cucumbers are harvested globally for the high value bêche-de-mer product (dried body wall) largely for the Chinese luxury sea food market (Wolfe and Byrne, 2022) and are one of the oldest trade commodities in Pacific (Conand and Byrne, 1993). Bêche-de-mer is of great socioeconomic importance as a major source of income for many fishing communities. As slow-moving and easily harvested animals, many of the 80 + species of commercial sea cucumbers are over-harvested to the point that some of the highest value species are now locally extinct (Purcell et al., 2014). For instance, extinctions at the scale of lagoon systems and regions have occurred for the sandfish, *Holothuria* (*Metriatyla*) *scabra*, in Palau, Papua New Guinea and Solomon Islands and in the early harvest of this species in the Torres Strait, Australia (e.g. Warrier Reef complex). In Fiji, fishing has decimated stocks of the black teatfish such that none were found in surveys in three-quarters of island groups in 2009 (Pakoa et al., 2013) and 2014–2015 (Lalavanua et al., 2017). Bêche-de-mer sea cucumbers fetch very high prices and are being poached and trafficked. High price leads to rarity leading to local extinction or reproductive failure due to low spawner density.

Conservation and management of bêche-de-mer resources have been hampered by the uncertain taxonomy of many species in the trade (Uthicke et al., 2004, 2010; Byrne et al., 2022). The names under which sea cucumbers are fished include a plethora of common names such as green fish, blackfish, curryfish, dragonfish, lollyfish and teatfish. These names are used by managers, but many of these fishery names include several species and the names used differ across regions. The identity of important species in trade continues to be a problem including species in the genera *Stichopus* (e.g., *Stichopus monotuberculatus* dragonfish species complex) and *Holothuria* e.g., subgenus *Microthele* teatfish complex (Fig. 2) (Uthicke et al., 2004; Byrne et al., 2010). Many sea cucumbers are difficult

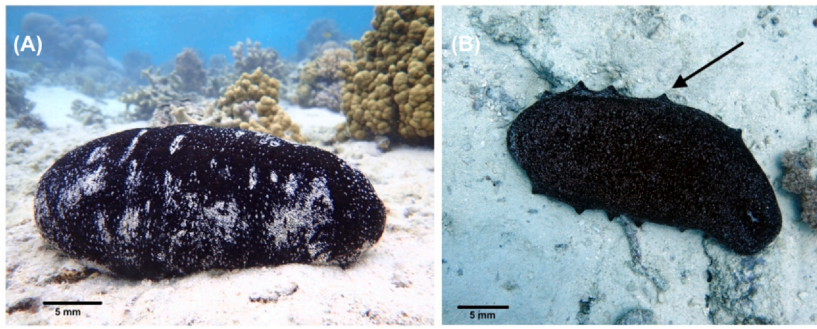

Fig. 2 Black teatfish (*Holothuria whitmaei*) photographed in the lagoon at One Tree Reef, Great Barrier Reef. B Teatfish are among the highest value species in the bêche-de-mer trade and are readily recognised by the teat-like extensions along their lateral margins indicated by arrow. Photographs Maria Byrne.

to identify based on morphology. Importantly, much of the dried product in the market is not possible to identify to species. Uncertain identity is an important problem to resolve because a fully characterised and vouchered taxonomy is required for conservation measures such as the listing of species on the International Union for the Conservation of Nature (IUCN) and on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Unresolved taxonomy has impeded the conservation and management of bêche-de-mer sea cucumbers. The listings of sixteen species as threatened on the IUCN and, more recently, of nine species on CITES, were made possible by careful taxonomic work over decades especially for the teatfish group. The detective work to determine the taxonomy of the teatfish species and the campaign that led to their CITES listings in 2019 (Di Simone et al., 2020) is an interesting case study.

2.3 Teatfish names, taxonomy and CITES listings

Teatfish are among the highest value species in the bêche-de-mer trade due to their thick body wall and flavour (Fig. 2A). They are readily recognised by the teat-like extensions along their lateral margins (Fig. 2B). In the early days of the trade, the species called the black teatfish encompassed several varieties with a range of colours from totally black, to black with large white spots, black and white mottled forms and some that are mostly white (Purcell et al., 2012, 2017). It was clear that the black teatfish was a species complex, as also indicated by their differing reproductive biology and ecology (Conand, 1981). In New Caledonia scientists recognised that

sympatric all-black and the mottled black-and white forms were distinct species. The all-black species commonly occur in shallow water in reef top and shallow lagoon habitats and the mottled black-and-white species were mostly found at greater depths (Conand, 1989).

Cherbonnier (1980) attributed the black form as *Holothuria* (*Microthele*) *nobilis* and described a new species, *H.* (*M.*) *fuscogilva*, for the mottled form harvested as the white teatfish. This left the black teatfish as *H.* (*M.*) *nobilis*, described by Selenka (1867), with a distribution from East Africa to Hawaii. However, the black teatfish in Africa has large ventro-lateral white spots while the Pacific variety was totally black. Rowe and Gates (1995) pointed out that Seleka's material contained two colour forms and molecular phylogeny confirmed the presence of two species (Uthicke et al., 2004). Seleka's original description illustrated the black and white specimen and the specimen in the Museum of Comparative Zoology (MCZ 819) is also black and white. Thus, Rowe and Gates (1995) designated the black and white specimen from the Indian Ocean to be the lectotype of *H. nobilis*. Thus, the taxonomy of the totally black species from the Eastern Indian Ocean and Pacific Ocean, needed to be clarified. described a completely black specimen from Samoa as *Holothuria* (*M.*) *whitmaei* and Rowe and Gates (1995) noted that the holotypes of *H. whitmaei* (BMNH, 1875.10.2.6) are completely black. This name was therefore used for the all-black teatfish. Across the Indo-Pacific there are two species harvested under the name black teatfish *H.* (*M.*) *whitmaei* and *H.* (*M.*) *nobilis*.

After 17 years of discussions and Conference of the Parties meetings, the three teatfish that were on the IUCN list, *Holothuria* (*Microthele*) *whitmaei*, *H.* (*M*) *nobilis* and *H.* (*M*) *fuscogilva*, were approved and listed under CITES Appendix II in 2019, effective from August 2020 (FAO, 2019; Di Simone et al., 2020). Importantly, unlike many commercial sea cucumbers, teatfish are readily recognised in the seafood trade due to their distinct "teats" (Fig. 2B). Due to the CITES listing, the Scientific Authorities of producing countries are now required to show a Non-Detriment Finding to continue to export of teatfish, as a Wildlife Trade Operation.

The taxonomic clarification of teatfish in the trade is far from complete. The white teatfish appears to be a species complex (Uthicke et al., 2004). The taxonomy of the pale coloured, beige-blotched teatfish known as "Pentard" in the north eastern Indian Ocean harvested as *H. fuscogilva* is unknown with great concern for its conservation (Purcell et al., 2017). While there has been a large effort to improve awareness and identity of harvested bêche-de-mer sea cucumbers in recent decades, many taxonomic challenges remain contributing

to the difficulty of managing these resources. There is an urgent need to resolve taxonomic uncertainty for species exploited for global trade and for research to address major gaps in knowledge of species' population parameters. Such work is needed to underpin future sustainable management, and conservation plans to help preserve diversity and avoid extinctions. Taxonomic clarification is essential to ensure that global protection efforts are effective to be able to differentiate species at-risk.

2.4 Invasive species *Cassiopea* spp.

Cassiopea spp. are also known as upside-down jellyfish because they spend a majority of the medusa phase of their lifecycle upside-down, resting their bell on the sediment and extending their oral arms into the water column. *Cassiopea* occur world-wide, typically in tropical to sub-tropical regions in shallow and sheltered habitats, such as coral reefs or mangrove forests (Stoner et al., 2014; Rowe et al., 2022a). Some species of *Cassiopea* are reported to be expanding their range either through local dispersal or direct anthropogenic means such as ballast water, and in some cases these jellyfish have become invasive (Graham and Bayha, 2008; Morandini et al., 2017). The reason *Cassiopea* can be successful invaders is because they have high reproductive rates, a tolerance to a wide range of environmental conditions, and ability to reproduce both sexually and asexually (Holland et al., 2004; Stoner et al., 2014; Keable and Ahyong, 2016; Morandini et al., 2016; Rowe et al., 2022b). *Cassiopea* are also considered to be ecosystem engineers with the benthic medusae stage altering community structure through direct impacts including predation on zooplankton, or indirect impacts such as competition (Stoner et al., 2011; Stoner et al., 2014).

On the east coast of Australia, there have been new records of two species of *Cassiopea* occurring in temperate coastal lakes in New South Wales, including *C. maremetens* in Wallis Lake in 2009 and *C. ndrosia* in Lake Illawarra in 2013 (Keable and Ahyong, 2016). However, *Cassiopea* is considered to be a cryptic genus, with species difficult to distinguish based on morphological characters alone. As a result, when *Cassiopea* was reported in Lake Macquarie, New South Wales in 2017, a study by Rowe et al. (2025, Fig. 3) used a combination of genetics and morphology to correctly identify the species occurring. This study found that the species in Lake Macquarie was the same species as in Wallis Lake in New South Wales and Pelican Waters in Queensland, which is where *C. maremetens* was first described. However, the specimens from these localities were genetically and morphologically referable to *C. xamachana*, and so the authors synomised *C. maremetens*. This is

Fig. 3 Photograph of upside-down jellyfish, *Cassiopea xamachana* from NSW, Claire Rowe et al., 2010, Australian Museum.

significant as *C. xamachana* was first described from Kingston Harbour, Jamaica (Bigelow, 1892), and the species is most likely a recent arrival to the east coast of Australia rather than a native species. Correct identification of this invasive species is essential because the *C. xamachana* could continue to expand its range along the east coast of Australia and have potential negative impacts in novel environments.

3. Challenges

The key challenges facing taxonomy in Australia are numerous, connected, and complex. Although there are challenges particular to discrete groups (e.g. polychaetes in Hutchings et al., 2025, this volume), most challenges are applicable across the discipline, and we list these here:

- Australia is suffering from serious declines in the number of active marine taxonomists, and this is reflected in the extensive benthic collections in all the Australian museums waiting to be identified. Over the past 25 years the taxonomic capacity has declined by 10 % (Taxonomy Decadal Plan Working Group 2018), and we suggest it has continued to decline since 2018. In part this has been as retired (but working) taxonomists die, and staff have not been replaced as they retire, particularly at museums.

- Taxonomists have limited venues for obtaining research funds, and over the past 20 + years the funding allocated to taxonomy has declined. The Australian Biological Resources Study (ABRS) which provides funding for research on the Australian biota or developing taxonomic tools, has not had its budget increased since the 1990s to reflect inflation and increasing salaries etc. While a recent review of ABRS in 2023, recommended a substantial increase in the grants program, this has not happened as of 2025 (Austin et al., 2023). Also, from 2012 museum researchers can no longer apply for the major funding agency for research in Australia (Australian Research Scheme) as Principal Investigators, so obtaining research funds for taxonomic research has become more difficult.
- In parallel, universities are no longer teaching taxonomy, making it difficult to recruit the next generation of taxonomists (Hutchings, 2020), and many are not teaching whole animal biology or courses on the major invertebrate groups. Universities appoint researchers with publications in high profile journals and thus more likely to attract large grants. Taxonomic literature is largely published in journals with a low impact factor (Green et al., 2023, 2025).
- This means that students are not being exposed to invertebrates and learning how important they are in both marine and terrestrial environments, including how much of this fauna is still undescribed. Field trips where students see live animals are becoming rarer given the costs and increasing OH&S regulations which are becoming increasingly onerous.
- Students wanting to undertake a taxonomic based PhD must enrol at a University with a University supervisor, with museum taxonomists acting as co-supervisors. It is therefore critical that museum taxonomists develop good working relationships with university staff to engage university staff in supervision of taxonomic PhDs. Such relationships also highlight the value of taxonomists to other disciplines of the primary university supervisor.
- Taxonomists are often poorly engaged with the users of taxonomy such as marine park managers, fisheries agencies, departments responsible for detecting, identifying marine pests and their management, conservationists and those involved in citizen science, and bioprospecting companies.

So, while we have had numerous reports about the importance of taxonomy and the need to document biodiversity and even a report prepared for the Australian Academy of Sciences as to the cost of failing to do

this (Deloitte Access Economics, 2021), we have had little or no actual improvements. Indeed, the reverse has occurred with the loss of taxonomic positions and expertise.

All of these challenges are interconnected and therefore all must be addressed to improve the situation. For example, without university training or appropriate funding, there will be no new taxonomists to replace senior researchers as they retire.

4. Moving forward

Globally we need to better promote the importance of correct taxonomy and appropriately document marine biodiversity, in particular the importance of marine invertebrates, which despite their extraordinary high species richness are poorly studied in comparison to marine vertebrates. Taxonomic expertise is needed to deliver key national and international policy commitments such as control of invasive species, protection of biodiversity, biodiscovery, management of living resources, ecosystem-based approaches to management and development of a sustainable "Blue Economy". Below, we have listed key recommendations to address the challenges described in the previous section.

1. Universities should reinstate the discipline of taxonomy in their courses to address the critical lack of skills/resources and that taxonomy be closely integrated into the disciplines of biology and environmental science in university life science degree programs. This needs to be embedded with modern molecular taxonomy. There is great potential for institutions globally to position themselves as specialist educators in taxonomy across all its aspects from molecules to morphology.
2. Museums and universities should encourage joint academic appointments to ensure that the discipline of taxonomy can be taught.
3. Where possible, museums should seek sponsorship from the private sector to create new research positions, provide support for maintaining museum collections and cutting- edge equipment (i.e. molecular labs, SEM, CT scanners) to facilitate identification and description of new taxa.
4. Schools, universities, and educational policymakers must create career pathways to ensure students interested in pursuing taxonomy have the support to do so. For students wanting to undertake a taxonomic PhD,

they must be able to see that there are permanent jobs available, not just short-term fellowships. An urgent priority is the need to support early career researchers for successional planning to ensure the expertise needed to fill permanent positions as researchers retire.

5. Taxonomists, ecologists, conservationists, pest managers, marine park managers, ecological and environmental consultants and citizen scientists must all collaborate better and earlier during relevant projects. This will ensure that the correct names are used in all outputs and advance species discovery through many eyes on the water.
6. Marine chemists working on bioactive compounds for pharmaceutical or cosmeceutical applications should engage taxonomists to ensure that the same species is being repeatedly collected for efficient product development. Marine organisms represent a diverse resource for novel chemical compounds often based on species specific microbiome associations for pharmaceutical applications to treat disease and illness in humans.
7. Museum curators and collection users should ensure that museum collections maintain correct species identification for monitoring changes in species distributions associated with climate change driven range extensions and local extirpations due to ocean warming and alterations in ocean currents.
8. Marine survey leaders and chief scientists of major ecological expeditions must develop survey plans in collaboration with taxonomists to ensure that adequate funds are available to ensure that all material collected is sorted, identified and that a reference collection is deposited in the relevant museum. This should include funds for incorporation of this material into collections and data portals data based (Przeslawski and Foster, 2024), thus making its material and associated information \ available for researchers to work on it.
9. Taxonomists should seek support so they can develop accessible interactive keys to help all potential users such as ecologists, consultants and citizen scientists to empower them to be able to identify fauna (eg. Glasby et al., 2025) and pest/range changing species.
10. All researchers who use taxonomy are responsible for ensuring that taxonomy is fully appreciated as the foundational tool for new and emerging technologies such as eDNA, metagenomics and automated image classification new developments in marine science technology (Naveen, 2025; Pastor Rollan et al., 2024; Yang et al., 2024). These methods can only be effective if based on solid taxonomic

identification and classifications in molecular reference databases. These databases must be built in collaboration with taxonomists to ensure the correct species names are attached to the corresponding sequence data and sequences are linked to voucher specimen in the museums and in their taxonomic catalogues which are fed into national (e.g. ALA) and global (e.g., WoRMS) data bases.

11. Museums must acknowledge the core role of museum research in taxonomy and role of collections and research, particularly in light of the current trend for museum management to prioritise exhibitions.

While our review and associated case studies have focussed on Australia, our findings are also true for other regions like SE Asia, South America, sub-Antarctic and West Africa, re the lack of funding for taxonomic research as shown by other chapters in this volume. In contrast there are major initiatives in the UK and Europe which could be duplicated in Australia and elsewhere but this requires major commitments in terms of $$ funding from people who want to use the data. However, before this they have to recognise they need it!

References

AMSA, 2021. Position Statement: The Importance of Taxonomy To Marine ScienceAustralian Marine Sciences Association. https://www.amsa.asn.au/wp-content/uploads/2014/04/AMSA-Taxonomy-Position-Statement-2021.pdf.

Austin, A., Harvey, M., Hutchings, P., May, T., 2023. Unpublished Report to ABRS Austin, A., Harvey, M., hutchings. P., May, T. 2023. Rev. Australian Biol. Resour. Study.

Bigelow, R.P., 1892. On a new species of *Cassiopea* from Jamaica. Zool. Anz. 15, 212–214.

Bond, T., Jamieson, A., 2022. The extent and protection of Australia's deep sea. Mar. Freshw. Res. 73 (12), 1520–1526. https://doi.org/10.1071/MF22156.

Burn, D., Matthews, S., Caballes, J.F., Pratchett, M.S., 2020. Biogeographical variation in diurnal behaviour of *Acanthaster planci* versus *Acanthaster* cf. *solaris*. PLoS ONE 15, e0228796.

Byrne, M., O'Hara, T., Uthicke, S., Conand, C., Rowe, F.W.E., Eriksson, H., et al., 2022. The importance of taxonomy in conservation outcomes for beche-de-mer: the teatfish and Great Barrier Reef fishery case studies. SPC Beche-de-mer Info Bull 42, 4–10.

Byrne, M., Rowe, F.W., Uthicke, S., 2010. Molecular taxonomy, phylogeny and evolution in the family Stichopodidae (Aspidochirotida: Holothuroidea) based on COI and 16S mitochondrial DNA. Mol. Phylo Evol. l6, 1068–1081.

Cherbonnier, G., 1980. Holothuries de Nouvelle-Calédonie. Bull. Mus. Natl. Hist. Nat. Paris 2, 615–667.

Conand, C., 1981. Sexual cycle of three commercially important holothurian species (Echinodermata) from the lagoon of New Caledonia. Bull. Mar. Sci. 31, 523–543.

Conand, C., 1989. Les holothuries aspidochirotes du lagon de Nouvelle-Caledonie: biologie, ecologie et exploitation. Etudes et Theses 393 (O.R.S.T.O.M., Paris).

Conand, C., Byrne, M., 1993. A review of recent developments in the world sea cucumber fisheries. Mar. Fish. Rev. 55, 1–13.

Deaker, D.J., Byrne, M., 2022. Crown of thorns starfish life-history traits contribute to outbreaks, a continuing concern for coral reefs. Emerg. Top. Life Sci. 6, 67–79.

Decadal Plan Working Group, 2018. A decadal plan for taxonomy and biosystematics in Australia and New Zealand 2018–2027. Australian Acad. Sci. R. Soc. Te Apãrangi, Canberra Wellingt 63. https://www.science.org.au/files/userfiles/support/reportsand-plans/2018/taxonomy-decadal-planhi-res-v200618.pdf Accessed 26 May 2025.

Deloitte Access Economics, 2021. Cost benefit analysis of a mission to discover and document Australia's species. Prepared for the Australian Academy of Science. https://www.science.org.au/files/userfiles/support/reports-and-plans/2021/cost-benefit-analysis-of-taxonomy-australias-mission-deloitte-2021.pdf.

Di Simone, M., Conand, C., Horellou, A., 2020. Three species of teatfish to be protected by CITES. SPC Beche-de-mer Info Bull 40, 3–4.

FAO, 2019. Food and Agriculture Organization expert advisory panel assessment report: COP18 proposal 45. Pages 62–105 Report of the Sixth FAO Expert Advisory Panel for the Assessment of Proposals to Amend Appendices I and II of CITES Concerning Commercially Exploited Aquatic Species FAO Fisheries and Aquaculture Report No 1255 Rome.

Foo, S.A., Millican, H.R., Byrne, M., 2024. Crown-of-thorns seastar (*Acanthaster* spp.) feeding ecology across species and regions. Sci. Tot Env. 930, 172691.

Geoscience Australia, 2024. Australia's Seabed: How much is mapped? A national metadata assessment – 2024. https://ecat.ga.gov.au/geonetwork/srv/api/records/12dd3c6c-16a3–487c-bc8f-d9114e707e25.

Glasby, C.J., Biriukova, O., Martin, P., Dyne, G.R., Utevsky, S., Wilson, R.S., 2025. ANNiKEY Linear – diagnoses, descriptions, and a single-access identification key to Annelida family-level taxa. Zookeys 1247, 217–403. https://doi.org/10.3897/zookeys.1247.137606.

Graham, W.M., Bayha, K.M., 2008. Biological invasions by marine jellyfish. Biological Invasions. Springer, pp. 239–255.

Green, T.A., Hutchings, P.A., Calver, M.C., 2025. Regional service, global recognition: international benchmarking for the research publications of Australia's natural history museums, 1981-2020. Aust. Zool. https://doi.org/10.7882/AZ.2025.019.

Green, T.A., Hutchings, P.A., Scarff, F.R., Tweedley, J.R., Calver, M.C., 2023. Research publications of Australia's natural history museums, 1981-2020: enduring relevance in a changing world. PLoS ONE 18 (6), e02877659. https://doi.org/10.1371/journal.pone.028765.

Haszprunar, G., Spies, M., 2014. An integrative approach to the taxonomy of the crown-of-thorns starfish species group (Asteroidea: *Acanthaster*): a review of names and comparison to recent molecular data. Zootaxa 3841 (2), 271–284.

Haszprunar, G., Vogler, C., Worheide, G., 2017. Persistent gaps of knowledge for naming and distinguishing multiple species of crown-of-thorns seastar in the *Acanthaster planci* species complex. Diversity 9 (2), 22.

Holland, B.S., Dawson, M.N., Crow, G.L., Hofmann, D.K., 2004. Global phylogeography of *Cassiopea* (Scyphozoa: Rhizostomeae): molecular evidence for cryptic species and multiple invasions of the Hawaiian Islands. Mar. Biol. 145, 1119–1128.

Hutchings, P.A., 2020. Major issues facing taxonomy—a personal perspective. Megataxa 1, 46–48.

Hutchings, P., McLaren, Kupriyanova, E., Gunton, L., Lavesque, N., Przeslawski, R., 2025. The taxonomy of Australian polychaetes: current understanding, knowledge gaps and steps forward for management. Adv. Mar Biol. 154.

Keable, S.J., Ahyong, S.T., 2016. First records of the invasive "upside-down jellyfish", *Cassiopea* (Cnidaria: Scyphozoa: Rhizostomeae: Cassiopeidae), from coastal lakes of New South Wales, Australia. Rec. Aust. Mus. 68 (1), 23–30.

Keesing, J.K., Mortimer, N., Hellmrich, L., Godoy, D., Babcock, R.C., Heyward, A., et al., 2023. The short spined crown-of-thorns starfish *Acanthaster brevispinus* is a corallivore too. Coral Reefs. 42, 399–404.

Lalavanua, W., Mangubhai, S., Vandervord, C., Dulunaqio, S., Fox, M., Naisilisili, W., et al., 2017. Sea cucumber species richness and densities within locally managed marine areas. In: Mangubhai, S., Lalavanua, W., Purcell, S.W. (Eds.), Fiji's Sea Cucumber Fishery: Advances in Science for Improved Management. Wildlife Conservation Society, Suva, Fiji, pp. 4–15 Report No. 01/17.

Morandini, A.C., Schiariti, A., Stampar, S.N., Straehler-Pohl I, M.M., Marques, A.C., 2016. Succession of generations is still the general paradigm for scyphozoan life cycles. Bull. Mar. Sci. 92 (3), 343–351. https://doi.org/10.5343/bms.2016.1018.

Morandini, A.C., Stampar, S.N., Maronna, M.M., Da Silveira, F.L., 2017. All non-indigenous species were introduced recently? The case study of *Cassiopea* (Cnidaria: Scyphozoa) in Brazilian waters. J. Mar. Biol. Assoc. UK 97 (2), 321–328.

Naveen, P., 2025. Advancements in underwater imaging through machine learning: techniques, challenges, and applications. Multimed. Tools Appl Springer.

Pakoa, K., Salandrau, W., Lalavanua, S., 2013. The status of sea cucumber resources and fisheries management in Fiji. Secretariat Pac. Community 62 Noumea.

Pastor Rollan, A., Sherman, C.D.H., Ellis, M.R., Tuohey, K., Vennell, R., Foster-Thorpe, C., et al., 2024. Current trends in biophysical modeling of eDNA dynamics for the detection of marine species. Environ. DNA 6, e70021.

Przeslawski, R., Foster, S., (Eds.), 2024. Field manuals for marine sampling to monitor Australian waters, Version 3. Report to the National Environmental Science Program, Marine Biodiversity Hub. Geoscience Australia and CSIRO. https://doi.org/10.11636/978192584875.

Purcell, S.W., Ngaluafe, P., Wang, G., Lalavanua, W., 2017. Market value of flower teatfish ("pentard"): a highly exploited Indian Ocean holothuroid. SPC Beche-de-Mer Info Bull. 37, 53–56.

Purcell, S.W., Polidoro, B.A., Hamel, J.-F., Gamboa, R.U., Mercier, A., 2014. The cost of being valuable: predictors of extinction risk in marine invertebrates exploited as luxury seafood. Proc. Roy. Soc. B. 281, 20133296.

Purcell, S.W., Samyn, Y., Conand, C., 2012. Commercially important sea cucumbers of the world. FAO Species Catalogue for Fishery Purposes. No. 6. Rome, FAO. 150 pp. 30 colour plates.

Rowe, C.E., Ahyong, S.T., Figueira, W.F., Burghardt, I., Keable, S.J., 2025. Identification of *Cassiopea* sp. in Lake Macquarie, Australia and revision of the taxonomic status of *Cassiopea maremetens* Gershwin Zeilder, Davie, 2010 (Cnidaria: Scyphozoa: Cassiopeidae). PeerJ. 13, e19669. https://doi.org/10.7717/peerj.19669.

Rowe, C.E., Figueira, W.F., Kelaher, B.P., Giles, A., Mamo, L.T., Ahyong, S.T., et al., 2022a. Evaluating the effectiveness of drones for quantifying invasive upside-down jellyfish (*Cassiopea* sp.) in Lake Macquarie, Australia. PLoS one 17, e0262721. https://doi.org/10.1371/journal.pone.0262721.

Rowe, F.W.E., Gates, J., 1995. Zoological Catalogue of Australia. Vol. 33. Echinodermata. CSIRO Publishing, Melbourne.

Rowe, C.E., Keable, S.J., Ahyong, S.T., Figueira, W.F., 2022b. Physiological responses of the upside-down jellyfish, *Cassiopea* (Cnidaria: Scyphozoa: Cassiopeidae) to temperature and implications for *Cassiopea*'s range expansion along the east coast of Australia. J. Exp. Mar. Biol. Ecol. 554, 151765. https://doi.org/10.1016/j.jembe.2022.151765.

Selenka, E., 1867. Beitrage zur anatomie und systematik der holothurien. Zeit der Wiss. Zool. 17, 291–374.

Sommer, B., Malcolm, H., Cooney, C., Dalton, S., Foo, S., Fraser, N., et al., 2025. Understanding and managing species range shifts: first observed mixed-species outbreak and coral predation by crown-of-thorns starfish (Acanthaster brevispinus and A. cf. solaris) on subtropical reefs. Mar. Env. Res. 212, 107556.

Stoner, E.W., Layman, C.A., Yeager, L.A., Hassett, H.M., 2011. Effects of anthropogenic disturbance on the abundance and size of epibenthic jellyfish *Cassiopea* spp. Mar. Pollut. Bull. 62, 1109–1114. https://doi.org/10.1016/j.marpolbul.2011.03.023.

Stoner, E.W., Yeager, L.A., Sweatman, J.L., Sebilian, S.S., Layman, C.A., 2014. Modification of a seagrass community by benthic jellyfish blooms and nutrient enrichment. J. Exp. Mar. Biol. Ecol. 461, 185–192. https://doi.org/10.1016/j.jembe.2014.08.005.

Uthicke, S., Byrne, M., Conand, C., 2010. Genetic barcoding of commercial beche-de-mer species (Echinodermata: Holothuroidea. Mol. Ecol. Res. 10, 634–646.

Uthicke, S., O'Hara, T.D., Byrne, M., 2004. Species composition and molecular phylogeny of the Indo-Pacific teatfish (Echinodermata: Holothuroidea) beche-de-mer fishery. Mar. Freshw. Res. 55, 1–12.

Uthicke, S., Pratchett, M.S., Bronstein, O., Alvarado, J.J., Wörheide, G., 2024. The crown-of-thorns seastar species complex: knowledge on the biology and ecology of five corallivorous *Acanthaster* species. Mar. Biol. 171 (1), 1–24.

Wolfe, K., Byrne, M., 2022. Overview of the great barrier reef sea cucumber fishery with a focus on vulnerable and endangered species. Biol. Cons. 266, 109451.

Worheide, G., Kaltenbacher, E., Cowan, Z.L., Haszprunar, G., 2022. A new species of crown-of-thorns sea star, *Acanthaster benziei* sp. nov. (Valvatida: Acanthasteridae), from the Red Sea. Zootaxa 5209 (3), 379–393.

Yang, N., Jin, D., Govindarajan, A.F., 2024. Applying environmental DNA approaches to inform marine biodiversity conservation: the case of the ocean twilight zone. Mar. Policy 165, 106151.

Further reading

Conand, C., Polidoro, B., Mercier, A., Gamboa, R., Hamel, J.-F., Purcell, S., 2014. The IUCN red list assessment of aspidochirotid sea cucumbers and its implications. SPC Beche-de-mer Info Bull. 34, 3–7.

Purcell, S.W., Mercier, A., Conand, C., Hamel, J.-F., Toral-Granda, V., Lovatelli, A., Uthicke, S., 2013. Sea cucumber fisheries: global analysis of stocks, management measures and drivers of overfishing. Fish Fish. 14, 34–59.