Management of Biological Invasions (2016) Volume 7, Issue 3: 305–312
DOI: http://dx.doi.org/10.3391/mbi.2016.7.3.10

Education and Outreach

A fully illustrated web-based guide to distinguish native and introduced polychaetes of Australia

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Received: 5 April 2016 / Accepted: 27 May 2016 / Published online: 23 June 2016

Handling editor: Catherine de Rivera

Abstract

Introduction of non-native species threatens local marine biodiversity, generating substantial costs for the aquaculture and tourism industries when native (including commercial) species are displaced. It is important that non-indigenous species are identified and controlled before they establish locally becoming invasive pests. The important vectors contributing to human-related dispersal of marine species include ship hull biofouling, ballast water and the aquaculture trade. Among over 80 polychaete families, fouling (Serpulidae and Sabellidae) and burrowing (Spionidae) worms are most commonly introduced to new localities. To assist in identification of potentially invasive non-native polychaetes, a web-based guide fully illustrated with original photographs was developed at the Australian Museum. The guide covers 66 species including 38 species of Serpulidae, 14 species of Sabellidae, and 14 species of Spionidae. This guide is intended for use by biologists, environmental consultants, quarantine officers and port management authorities as correct identification of species is essential for marine pest monitoring and management. The "Polychaete Identifier" will be extended to include other potentially invasive marine species of polychaetes, as well as crustaceans and molluscs in the near future, subject to funding availability.

Key words: biofouling, biosecurity, marine, identification key, Serpulidae, Sabellidae, Spionidae

Introduction

Non-native marine species are introduced to Australia by shipping either as larvae in ballast water or via hull fouling (Bax et al. 2003; Hayes et al. 2005; Çinar 2013). Introduced species can become invasive pests that threaten local marine biodiversity by altering habitat structures and local recruitment or by introducing disease agents or parasites (Holloway and Keough 2002a, b; Bax et al. 2003; Çinar 2013; Blackburn et al. 2015; Berthon 2015), generating substantial costs for the aquaculture and tourism industries when native (including commercial) species are displaced (Carlton 2001; Colautti et al. 2006). Although evaluating the invasion costs is difficult, the International Maritime Organization (IMO) has estimated that marine invaders cost tens of billions of dollars worldwide each year (Raaymakers 2002) and this has increased since then as marine introductions are an ongoing problem. The most updated figure for the UK alone, for example, places the estimate at approximately £1.7 billion (Williams et al. 2010), even though the economic cost should be divided according to marine and fresh water components.

The Australian coast is known to be susceptible to polychaete invasions (Carlton 1987; Clapin and Evans 1995; Thresher 1999; Hewitt et al. 2004; Çinar 2013) likely due to its large number of seaports (85 according to https://www.searates.com/maritime/australia.html) around the coast and the large number of visits by transoceanic vessels annually. Ballast water introductions into Australian waters were highlighted in the late 1980's (Williams et al. 1988; Hutchings et al. 1987, 1989) associated with the changes in shipping such as dedicated bulk carriers arriving into Australian ports empty of cargo and as cargo (iron ore, coal) is loaded, the overseas ballast water is discharged directly into the local port. While hull fouling has had a long history of being an important vector since European settlement (Pollard and Hutchings 1990), its importance has recently been increased (Bax et al. 2003; Çinar et al. 2011) and with it an awareness of its role in potentially introducing marine species.

Australia recognised the threat of marine introductions in the early 1990's by establishing the Centre for Introduced Marine Pests (CRIMP) in Hobart, Tasmania. Along with port authorities, the centre, coordinated surveys of all Australian international harbours for introduced pests. These surveys highlighted the high percentage of undescribed species in all recorded taxa, especially in tropical areas of Australia. In the case of polychaetes, all the species reported as introduced belong to genera that also contain Australian native species. In fact this is a world-wide problem.

A large number of non-indigenous polychaetes have been introduced into Australian waters, although for many the impact on native ecosystems is unknown. A literature review by Çinar (2013) revealed that 292 polychaete species belonging to 164 genera were reported as introduced species in at least one locality in the world's oceans. Among 39 polychaete families, Sabellidae, Serpulidae, and Spionidae are represented by the highest number of non-indigenous species worldwide (122 species, 42% of the total number of non-indigenous species) as recognized by Çinar (2013). The former two commonly known as fan-worms (sabellids) and calcareous tube worms (serpulids) can form fouling communities on piles, blocking intake pipes to aquaculture facilities and power stations. Serpulids of the genus *Hydroides* can form dense aggregates on aquaculture nets, seawater intake pipes (Qiu and Qian 1997) and ship hulls and buoys (Wang and Huang 1993), thus, constitute a significant financial burden to marine aquaculture, navigation, shipping industries, and power plants. Millions of dollars are spent annually to prevent the fouling of marine organisms, especially larval settlement of *Hydroides*, on man-made structures (Dürr and Watson 2010). Foulers can modify ecosystem dynamics and species assemblages through competition for space and food. For example, outbreaks of introduced *H. elegans* caused serious damage to cultured oyster crops in Japan (Arakawa 1971). A report commissioned by the Federal Department of Agriculture Fisheries and Forestry estimated the cost of eradicating an invasive sabellid polychaete *Sabella spallanzanii* in Australia at up to $260 million (Aquaenal Pty Ltd 2009). Spionids can bore into shells of commercial molluscs (primarily oysters and mussels) reducing the commercial value of the mollusc. They have been moved between facilities both within Australia and overseas for decades in ballast water or inadvertently translocated to new habitats with global shellfish trading (Skeel 1979; Sato-Okoshi et al. 2012).

To facilitate rapid identification of marine species, an online fully illustrated Invasive Polychaete Identifier was developed that aims to help distinguishing Australian native and potentially invasive polychaetes of the families Sabellidae, Spionidae and Serpulidae. The guide is intended for use by not only biologists and environmental consultants, but is also suitable and oriented for quarantine officers and port management authorities, who may lack special knowledge in taxonomy.

Material and methods

Preparation of illustrations for "The Invasive Polychaete Identifier: an Australian Perspective" commenced in September 2012, using the wet-preserved polychaete collection at the Australian Museum, with additional donations and loans from the Zoological Museum of Amsterdam (Netherlands), Natural History Museum (UK), Tohoku University (Japan), Stellenbosch University (South Africa), the Hebrew University of Jerusalem (Israel), AV Zhirmunsky Institute of Marine Biology (Russia) and Geomare (Mexico).

The polychaetes were photographed under the Leica MZ16 dissection microscope fitted with Spot Flex 15.2 camera. Some specimens were stained with methylene blue or methyl green to visually enhance important diagnostic features. Permanent slides were made of chaetae and uncini of selected species to reveal diagnostic features of these structures. The Helicon Focus 5.3 Pro software was used to create completely focused images using the layers of partially focused images captured.

Identification keys and contents, including species descriptions, known distributions, and similar species comparisons, were written by Elena Kupriyanova and Harry ten Hove (family Serpulidae), Maria Capa and Pat Hutchings (family Sabellidae), Vasily Radashevsky (family Spionidae).

Status terminology (native, introduced established, cryptogenic, potential invaders) mostly followed Carlton (1996). Native species are naturally distributed within a region. Introduced are species transported to a new location as a result of human activities. Cryptogenic species are those that both lack clear evidence of introduction and clear records of native distribution. The status of the identified species was based on literature and our own data. Due to the poor knowledge of Australian polychaete fauna, the cryptogenic species were defined as those with wide geographic distribution, but limited distribution in Australia, strong association with artificial substrates or often found in ports, and known to be invasive in other localities.

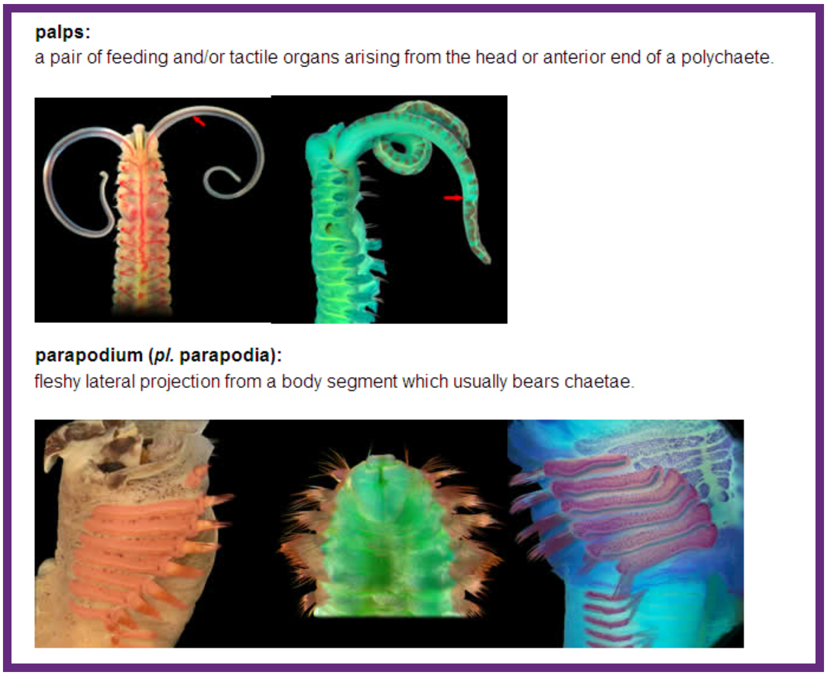


Figure 1. Comprehensive glossary of the Invasive Polychaete Identifier – illustrated by colour photographs of museum specimens.

Results

The resulting Invasive Polychaete Identifier: an Australian Perspective (Kupriyanova et al. 2013) is hosted on the Australian Museum web site and is available free of charge, but the users are asked to sign up so usage can be monitored and users are encouraged to contact the senior author for help and feedback. Currently the guide includes 66 species: 38 species of Serpulidae (3 genera), 14 species of Sabellidae (8 genera), 14 species of Spionidae (5 genera). Representatives of each of these species are deposited in the collections of the Australian Museum.

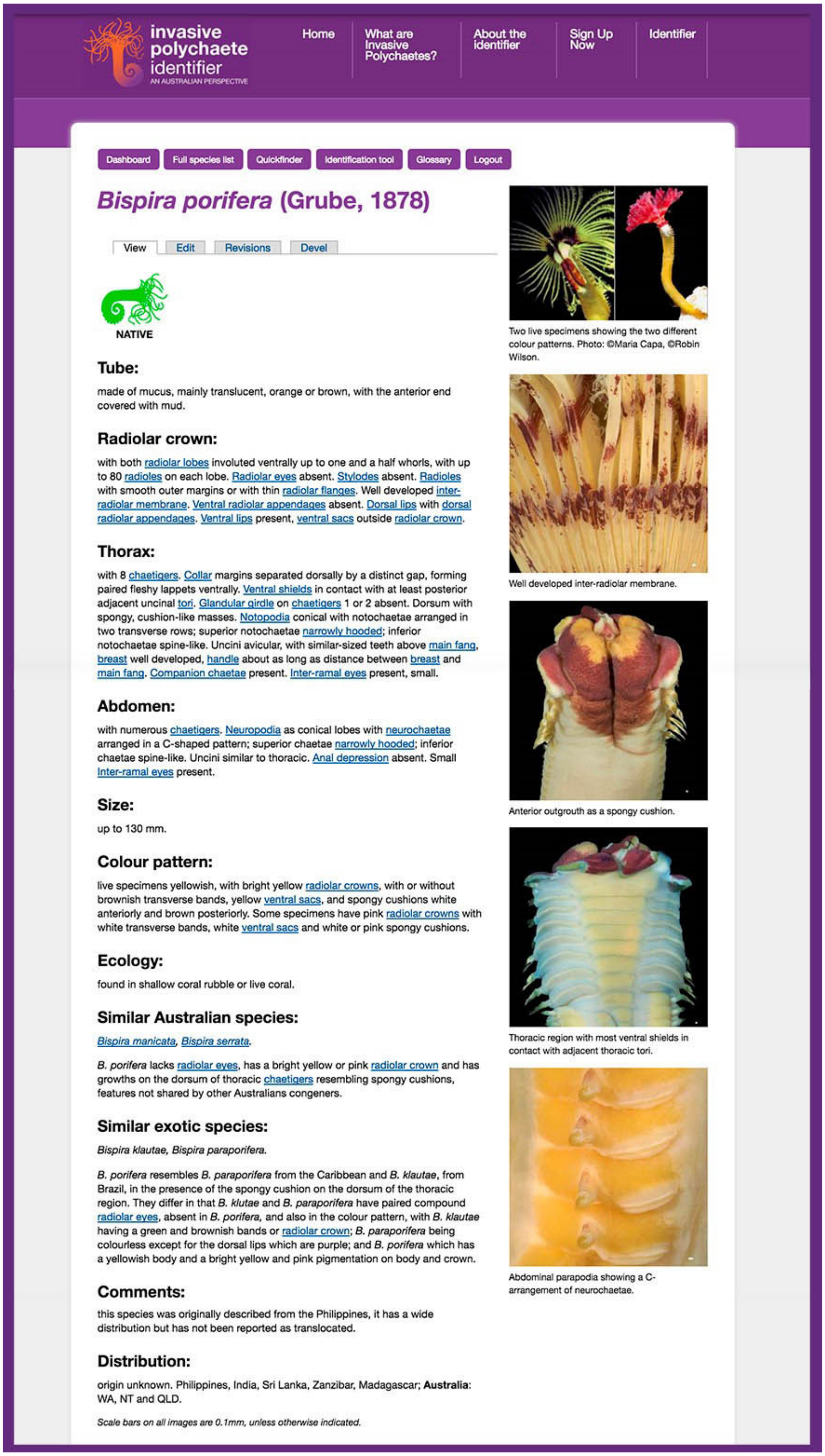
The guide has a general introduction that explains the terminology (native, introduced, cryptogenic, invasive, etc.), how non-native species arrive to Australia and what problems they cause. The additional information provided includes a description of methods used for polychaete fixation, preservation and examination as well as an overview of polychaete morphology where each special term is hyperlinked to the comprehensive glossary illustrated with colour photographs of the specimens used in the guide (Figure 1) (Wong et al. 2014). The section "Further reading" includes a list of the most relevant and recent taxonomic references, and is being regularly updated.

Species can be searched by three methods: by browsing a complete list of scientific species names (no accepted common names exist for these animals), by browsing the species list for each family, and by following a dichotomous key with photographic illustrations (Figure 2). Each species page is a factsheet (Figure 3) explaining diagnostic characters (illustrated with high resolution photographic images), providing data on distributions, ecology, and hyperlinks to pages of similar species. Colour codes of distribution statuses indicate whether a species is "native" (green), "cryptogenic" (blue), "introduced established" (yellow), or "possible invader" (red). While the guide focuses on species identification, it also includes aspects of distribution and impacts.

Discussion

A number of digital databases provide valuable biodiversity information, both in Australia and world-wide. The best known global online databases such as Encyclopedia of Life (http://eol.org/) and World Register of Marine Species (http://www.marinespecies.org) has the goal of capturing biodiversity information world-wide, but the latter is restricted to marine species only. Due to the very enormity of the goal, both so far are very incomplete, while the coverage and quality varies depending on availability of expert editors dedicated to the task as well as lack of information and knowledge. Similarly, Global Biodiversity Information Facility (http://www.gbif.org) and Oceanic Biogeographic Information System (http://iobis.org/home) provide distribution data for both terrestrial and marine species and marine only, respectively.

Figure 2. Species search in the Invasive Polychaete Identifier – by following an illustrated dichotomous identification key.



invasive polychaete identifier
AN AUSTRALIAN PERSPECTIVE

Home | What are Invasive Polychaetes? | About the identifier | Sign Up Now | Identifier

Dashboard | Full species list | Quickfinder | Identification tool | Glossary | Logout

Bispira porifera (Grube, 1878)

View | Edit | Revisions | Devel

NATIVE

Tube:

made of mucus, mainly translucent, orange or brown, with the anterior end covered with mud.

Radiolar crown:

with both radiolar lobes involuted ventrally up to one and a half whorls, with up to 80 radioles on each lobe. Radiolar eyes absent. Stylodes absent. Radioles with smooth outer margins or with thin radiolar flanges. Well developed inter-radiolar membrane. Ventral radiolar appendages absent. Dorsal lips with dorsal radiolar appendages. Ventral lips present, ventral sacs outside radiolar crown.

Thorax:

with 8 chaetigers. Collar margins separated dorsally by a distinct gap, forming paired fleshy lappets ventrally. Ventral shields in contact with at least posterior adjacent uncinal tori. Glandular girdle on chaetigers 1 or 2 absent. Dorsum with spongy, cushion-like masses. Notopodia conical with notochaetae arranged in two transverse rows; superior notochaetae narrowly hooded; inferior notochaetae spine-like. Uncini avicular, with similar-sized teeth above main fang, breast well developed, handle about as long as distance between breast and main fang. Companion chaetae present. Inter-ramal eyes present, small.

Abdomen:

with numerous chaetigers. Neuropodia as conical lobes with neurochaetae arranged in a C-shaped pattern; superior chaetae narrowly hooded; inferior chaetae spine-like. Uncini similar to thoracic. Anal depression absent. Small Inter-ramal eyes present.

Size:

up to 130 mm.

Colour pattern:

live specimens yellowish, with bright yellow radiolar crowns, with or without brownish transverse bands, yellow ventral sacs, and spongy cushions white anteriorly and brown posteriorly. Some specimens have pink radiolar crowns with white transverse bands, white ventral sacs and white or pink spongy cushions.

Ecology:

found in shallow coral rubble or live coral.

Similar Australian species:

Bispira manicata, Bispira serrata.

B. porifera lacks radiolar eyes, has a bright yellow or pink radiolar crown and has growths on the dorsum of thoracic chaetigers resembling spongy cushions, features not shared by other Australians congeners.

Similar exotic species:

Bispira klautae, Bispira paraporifera.

B. porifera resembles *B. paraporifera* from the Caribbean and *B. klautae*, from Brazil, in the presence of the spongy cushion on the dorsum of the thoracic region. They differ in that *B. klutae* and *B. paraporifera* have paired compound radiolar eyes, absent in *B. porifera*, and also in the colour pattern, with *B. klautae* having a green and brownish bands or radiolar crown; *B. paraporifera* being colourless except for the dorsal lips which are purple; and *B. porifera* which has a yellowish body and a bright yellow and pink pigmentation on body and crown.

Comments:

this species was originally described from the Philippines, it has a wide distribution but has not been reported as translocated.

Distribution:

origin unknown. Philippines, India, Sri Lanka, Zanzibar, Madagascar; **Australia**: WA, NT and QLD.

Scale bars on all images are 0.1mm, unless otherwise indicated.

Two live specimens showing the two different colour patterns. Photo: ©Maria Capa, ©Robin Wilson.

Well developed inter-radiolar membrane.

Anterior outgrouth as a spongy cushion.

Thoracic region with most ventral shields in contact with adjacent thoracic tori.

Abdominal parapodia showing a C-arrangement of neurochaetae.

Figure 3. Sample species fact sheet from the Invasive Polychaete Identifier, listing diagnostic characters, known distributions, ecology and similar species.

Regional databases, such as Australian Faunal Directory (AFD) (http://www.environment.gov.au/topics/science-and-research/abrs/databases-and-online-resources/australian-faunal-directory) and Atlas of Living Australia (http://www.ala.org.au/) maintain and update a checklist of species reported from Australia only, and as a result of a smaller scope, provide more comprehensive data on the regional fauna, including polychaetes. While the former supported by Australian Biological Resource Study is based on work of professional biologists, the latter relies on citizen science. Thus, ALA is naturally biased towards large vertebrates, and appears to be less reliable for groups of small invertebrates, such as polychaetes, which require additional knowledge and special equipment to examine. National Exotic Marine and Estuarine Species Information System (NEMESIS, http://invasions.si.edu/nemesis/index.jsp) developed and maintained by the Smithsonian Environmental Research Center (SERC) provides is an important resource for information on non-native species of the continental U.S. and Alaska.

While these online resources provide valuable species checklists, information on distribution data, ecology, and/or taxonomy, none of them are identification tools and they cannot be used for determining polychaete species.

The only dedicated digital guide to polychaetes is POLiKEY (Glasby and Fauchald 2003), to date the most comprehensive interactive tool for identification of polychaetes. It includes 104 taxa and 134 characters and is built using DELTA (Dallwitz et al. 2000), thus allowing efficient filtering of species based on large selections of diagnostic features. Moreover, it takes advantage of illustrations for species identification. However, it is already outdated and illustrations used are a combination of colour photographs and traditional line drawings of varying quality taken from primary taxonomic literature. Most importantly, POLiKEY does not include information regarding species invasion status.

A dedicated Australian National Introduced Marine Pest Information System (NIMPIS) is a central repository of information on the biology, ecology and distribution (international and Australian) of invasive marine pest species. It includes both known species introduced to Australia and species that are considered to pose a risk of potential introduction. It superseded the CRIMP database (http://crimp.marine.csiro.au/npl.html) that included information on introduced species, their invasion history and ecological/economic impacts, but is no longer available. The disadvantage of the NIMPIS database is very limited coverage of polychaetes – for example, it includes only one species of *Hydroides* (*H. elegans*), whereas 28 species have been recorded in Australia (Sun et al. 2015; Kupriyanova et al. 2015; Sun et al. 2016) and 16 species have been reported as non-indigenous, accounting for 11% of total number of introduced species world-wide (Çinar 2013).

The newly developed Invasive Polychaete Identifier is unique as it allows identifications based on original colour photographs of specimens confirmed by experts and deposited in the permanent databased collections of the Australian Museum and several other collaborating institutions. Moreover, the guide is designed with the aim of comparing native and morphologically similar non-native species, hence serving as the first illustrated database and identification tool for biosecurity monitoring purpose. It does not assume any prior knowledge of polychaete morphology and associated terminology as it includes interactive illustrated glossary of used terms.

Several issues need to be considered when accurate identification of a polychaete species and its potential invasion is needed. Even with the best illustrated taxonomic keys and detailed illustrated glossaries, identification of polychaetes will still remain challenging for non-specialists, as it requires access to a dissecting microscope and quite often a compound one and skills needed to use them. Moreover, some important diagnostic features even require use of sophisticated scanning electron microscopy (SEM). Quite often species boundaries are difficult to resolve using traditional morphological characters and many polychaete taxa belong to complexes of morphologically indistinguishable cryptic species that can only be separated using analyses of DNA sequences (Capa et al. 2013; Sun et al. 2015; Sun et al. 2016).

It is often claimed that DNA "barcoding" is a reliable, cost-effective alternative to routine taxonomic identification by experts even rendering traditional identification tools redundant (e.g., Mishra et al. 2016). However, the limitations of the barcoding technique are numerous and well understood (e.g., see Wheeler 2008; Jinbo et al. 2011). Most importantly, DNA barcoding is dependent on morphology-based traditional taxonomy because as an identification technique for previously characterized organisms it fails for undescribed species. Species identification using barcodes also depends on the number of representatives of each species included in the database. The most reliable way to obtain a DNA barcode that accurately represents a species is to base it on the type specimen of that species (reviewed in Jinbo et al. 2011). Thus, barcoding initiatives might be efficient for certain taxa or areas with well-known and thoroughly studied faunas, while not all the marine invertebrate fauna of Australia (especially of Northern Australia) are currently described and integrative taxonomic studies are needed.

Recent advances into integrative (morphological and molecular) approaches to polychaete biodiversity (Carr et al. 2011; Sun et al. 2012; Capa et al. 2013; Sun et al. 2015, 2016) will eventually lead to a better understanding of native Australian marine fauna and, as a result, a database allowing more efficient identifications of natives and potential invaders. Overall, the study of marine invasions has to be managed on a global scale, which requires broad international collaboration. Active taxonomic research means that new species are constantly described and distribution statuses change. For example, since the Invasive Polychaete Identifier was released in 2013, five new species of *Hydroides* have been described and the distribution of *Hydroides brachyacantha* Rioja, 1941 was changed as *H. brachyacantha* was recognised as a species complex and new species were described from this complex (Kupriyanova et al. 2015; Sun et al. 2015, 2016). It also means that effective integrative identification tools combined with good vouchering techniques and timely updates are crucial if existing databases are to be used for biosecurity purposes.

Acknowledgements

This guide was funded by the Australian Museum Foundation and the Fisheries Research and Development Corporation grants to PH and EK and Australian Biological Resource Study grant to EK and PH. Thanks are due to Dr Vasily Radashevsky, Dr Waka Sato-Okoshi, Dr Carol Simon, Dr Harry ten Hove, Dr Nechama Ben-Eliahu and Dr Mariana Tovar-Hernandez for specimen donations. Russ Weakley, Jen Cork and Sue Lindsay have provided tremendous help in website development and photography. Comments from Dr Erica Keppel and an anonymous reviewer and have greatly improved the manuscript.

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