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Research Article

A low number of invasive marine species in the tropics: a case study from Pilbara (Western Australia)

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Abstract

Invasive marine species (IMS) are thought to be one of the most serious anthropogenic threats to global marine biodiversity. There are numerous reports of IMS being introduced into new areas throughout the world, but relatively few are in tropical locations. It has been suggested that this is an artefact of our lack of knowledge species present in the megadiverse tropics and a lack of IMS surveys. The Pilbara in northern Western Australia (WA) is used as a case study to examine these questions. The area is at high risk of IMS because of extensive international shipping. A detailed literature search of marine biodiversity studies developed a database of 5,532 species recorded in the Pilbara. There have been numerous surveys for species on the Australian national and WA IMS lists but only one, the ascidian *Didemnum perlucidum* Monniot, 1983, has been found.

Key words: introduced marine pests, *Didemnum, Perna*, Western Australia

Introduction

Invasive marine species (IMS; also known as introduced marine pests) are widely regarded as one of the most serious anthropogenic threats to global marine biodiversity (Johnson and Chapman 2007; Molnar et al. 2008; Katsanevakis et al. 2014; Crowe and Frid 2015). There have been numerous reports of major changes to local environments through the addition of introduced marine species. For example, a detailed study reported 307 introduced marine and brackish water species in California waters, including 190 in San Francisco Bay alone (Foss 2008). Ninety-nine introduced marine species were recorded in Port Philip Bay, Melbourne, Australia (Hewitt et al. 2004) and 343 in Hawaii (Eldredge and Smith 2001). In addition, there were numerous cryptogenic species whose origins could not be confirmed and there have undoubtedly been introductions in these localities since the compilations were published. Only a small proportion of introduced marine species become invasive, but those that do can cause serious consequences. Relatively few introductions have been detected in most tropical waters, and even fewer marine pest species (Coles and Eldredge 2002; Hewitt 2002; Huisman et al. 2008; Freestone et al. 2011).

A number of reasons have been proposed for the low numbers of introduced marine species and IMS in the tropics, including "the higher diversity of native tropical communities conferring an increased resistance to invasions through an increase in biotic interactions". Alternatively, it has been suggested that tropical waters have been less surveyed, resulting in fewer detections, or our lack of taxonomic knowledge of the biodiverse tropics may result in introduced species remaining undetected (Hewitt 2002).

This study examines the question of whether the low number of IMS in the tropics is real or an artefact of a lack of taxonomic knowledge. The Pilbara region of Western Australia (WA) was chosen for examination for four reasons: it has a relatively well-known tropical marine biota; Australia has a well-developed list of target IMS species; studies of the IMS threats to Australian ports ranked the Pilbara ports of Dampier and Port Hedland among those with the most significant threats; and the Pilbara has been extensively surveyed for IMS.

Background

The Pilbara lies on the western edge of the Tropical Australian Province which extends across the north of the continent to the southern part of the Great Barrier Reef, Queensland. It is part of the extensive megadiverse tropical Indo-West Pacific (Wilson and Allen 1987; Morgan and Wells 1991). There are no major distributional barriers on the north coast of WA; if the required habitat is present, most species extend at least to North West Cape (Wells 1980). Roberts et al. (2002) examined the global distributions of 3,225 species of corals, fish, molluscs and rock lobsters in coral reef systems and identified 18 coral reef diversity hotspots. The Western Australian hotspot, which extends from Ningaloo Reef south to Rottnest Island off Perth, was second in restricted range species, seventh in total diversity in the groups studied, and 15th in anthropogenic threat.

The marine biota of the north coast of WA has been extensively investigated, primarily by the Western Australian Museum. The museum hired its first marine expert in the late 1950s. The staff rapidly grew to six marine curators plus technical staff. A coral reef survey program commenced in the Dampier Archipelago in 1972 (Wilson and Marsh 1974, 1975) that over the years surveyed most of the major coral reef systems on the north coast. From 1998 to 2002 the museum partnered with Woodside Energy Limited to survey the marine biodiversity of the Dampier Archipelago. Eighty scientists from around the world identified taxa in their area of expertise collected in numerous field surveys (Jones 2004). Most of the results were published in Wells et al. (2003) and Jones (2004, 2007).

The National Introduced Marine Pests Coordination Group (NIMPCG) developed a national system for the management of marine pests in Australia. A database was constructed on 1582 species worldwide that had been introduced into new areas through anthropogenic activities (Hayes et al. 2002, 2005; Hayes and Sliwa 2003). A national marine pest target list was developed of 55 species considered to present the greatest threat to the Australian marine environment (NIMPCG 2009a, 2009b). The list was later expanded in WA to 81 species by the WA Department of Fisheries (DoF 2014).

As part of the development of the national system, NIMPCG (2009a) ranked the IMS threat to 91 Australian ports. Mean annual sea surface temperatures and International Union for the Conservation of Nature bioregion data were used to analyse international vessel movements between 1998 and 2004 where the difference in mean water temperature at the departure and arrival ports was less than 8 °C. The analyses also included the extent to which each Australian port is connected to all other Australia ports. The Pilbara ports of Dampier (6) and Port Hedland (9) ranked very high on the IMS threat analysis; other Pilbara ports ranked much lower. Dampier and Port Hedland were among 18 ports chosen for IMS monitoring under the national system.

The NIMPCG (2009a) analysis was conducted prior to the start of a resources boom that substantially increased vessel movements into the Pilbara, including large numbers of high risk construction vessels such as dredges, barges and tugs from overseas. McDonald (2008) repeated the analysis using 2006 data and recorded the three ports at greatest risk in WA as being Dampier, Fremantle and Port Hedland. During 2006 Dampier received 1090 visits from international vessels and Port Hedland 853. The analysis was repeated again using data from 2011. International visits had increased to 1173 in Dampier and 1444 in Port Hedland (Bridgwood and McDonald 2014).

Pilbara region

For the present paper, the Pilbara includes coastal and shallow water marine habitats (≤ 50 m) between Coral Bay in the Ningaloo Marine Park (23º9′S; 113º46′E) and Port Hedland (20º18′S; 118º34′E) (Figure 1), a linear distance of about 800 km. Marine habitats in the region are diverse. Coral reefs are common, the largest of which is the fringing reef in the Ningaloo Marine Park, the third largest coral reef system in the world. Smaller reef systems occur off the numerous Pilbara islands such as the Montebello Islands and in the Dampier Archipelago. There are substantial mangrove communities in bays along the shoreline interspersed with limestone rocky shores and sand beaches. Exmouth Gulf is the largest marine embayment, with a variety of protected habitats. Subtidal bottoms are dominated by sand/mud with occasional shoals.

The Pilbara marine environment is recognised for its high environmental values, including biodiversity. Ningaloo Marine Park, which includes all of Ningaloo Reef, was established in 1987. The Dampier Archipelago has also been proposed as a marine park and there is a small marine park on the west side of Barrow Island. The Montebello Islands/Barrow Island Marine Management Area includes most of the remaining Barrow Island waters (Barrow Island port is excluded) and the nearby Montebello Islands. In addition, most of the Pilbara islands are terrestrial reserves, many of which extend to the low tide line.

The human population of the Pilbara is small, concentrated in Karratha/Dampier (16,475) and Port

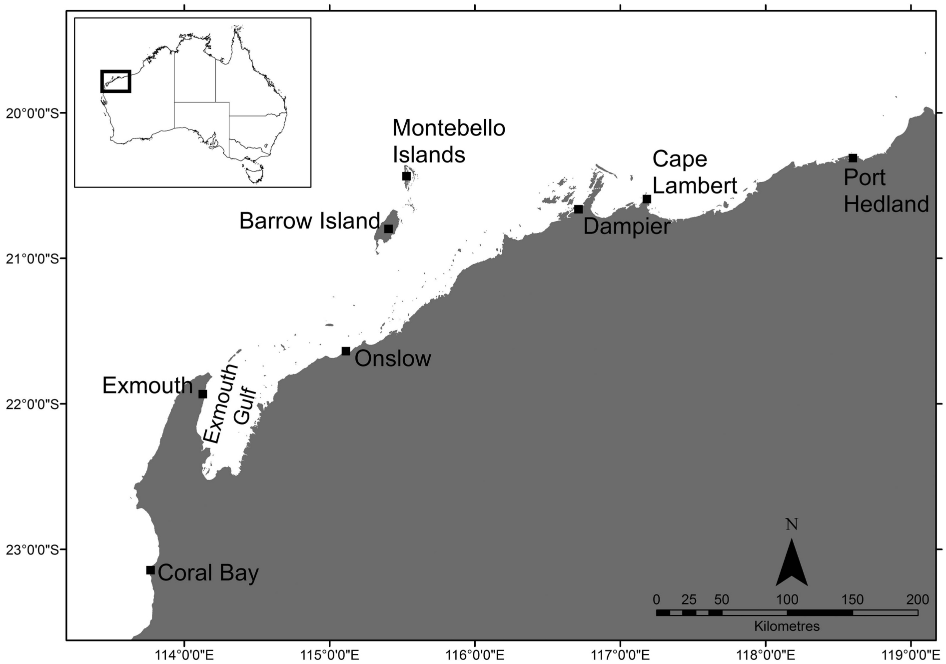

Figure 1. Map of the Pilbara region, Western Australia showing key landmarks.

Hedland (16,810 people in 2014) (ABS 2016); other communities are much smaller, with only a few hundred people. While the population is small, the Pilbara is a key economic hub. Exports are dominated by iron ore and liquefied natural gas (LNG). Iron ore exports commenced in the late 1960s and have grown exponentially in recent years. Western Australia is the largest iron ore producer in the world, accounting for 37% of global production and 49% of global iron ore exports in 2014, with 719 million tonnes originating in the Pilbara. The majority of the iron ore is exported through Port Hedland, the largest bulk commodities port in the world, Dampier and Cape Lambert (DSD 2016a).

The North West Shelf gas project commenced LNG exports in 1989 and was supplemented in 2012 by the Pluto project; both export through Dampier. In 2016 the Gorgon Project began exporting from Barrow Island. The Wheatstone Project began exporting in 2017 through a new port at Ashburton North, near Onslow. When they are completed in 2018 the LNG projects will have a combined capacity of 45 million tonnes per annum (DSD 2016b).

Materials and methods

A comprehensive literature search was undertaken to develop a database of species recorded from Pilbara. As described above, the WA Museum has conducted a number of surveys of Pilbara marine biota (Berry and Wells 2000; Wells et al. 2003; Jones 2004, 2007). All papers in these volumes were examined. All issues of the *Records of the Western Australian Museum* and supplements, dating back to 1939, were examined. The scientific journals of the Northern Territory Museum, Queensland Museum and Australian Museum, Sydney were also searched. A Google search was also undertaken for the primary localities in the region, including North West Cape, Montebello Islands, Dampier Archipelago and the ports of Exmouth, Onslow, Dampier and Port Hedland. Field guides to WA marine biota were consulted, including Wells and Bryce (1990, 1993), Jones and Morgan (1992) and Wilson (1993/94).

To avoid double counting species referred to in various papers as species A, species 1, etc., only taxa identified to species were included on the database. Identification guides such as Wells and Bryce (1990, 1993) and Wilson (1993/94) provide generalised ranges of a species, such as "Albany to North West Cape" or "Albany to Broome". Both ranges incorporate the Pilbara region, but only the one with a specific Pilbara locality (e.g. North West Cape) was included on the database in case there was a gap in the species range in the Pilbara region. ALA (2016/2017) provides extensive data on the biota of the Pilbara. As many of these records are unverified, only species reported in WA by another source or where there were more than two ALA records in WA were used. In addition, the ALA database was used to determine whether a species with a broader range had been recorded in the Pilbara.

Table 1. Numbers of species recorded in various taxonomic groups in the Pilbara, Western Australia, and the primary sources of information.

Taxonomic group	Number of species	Primary sources of information
Multiple groups		Berry and Wells 2000; Wells et al. 2003; Jones 2004; Wyatt et al. 2005; Kangas et al. 2007; Bryce and Sampey 2014; ALA 2016/2017
Molluscs	1533	Wilson and Stevenson 1977; Ponder 1978; Adam 1979; Wells 1977; 1980; Wells and Bryce 1990, 1993; Wilson 1993/1994
Fish	1565	Hutchins 1994; Moore et al. 2008
Crustaceans	826	George and Jones 1982; Jones and Morgan 1992; Jones 2007; Hughes 2013
Echinoderms	388	Marsh et al. 1999
Corals and other cnidarians	315	Veron and Marsh 1988; Alderslade 1998; Griffith and Fromont 1998; Cairns 1998
Marine plants	327	Huisman 2000
Sponges	275	Fromont 2004
Polychaetes	117	Hutchings and Glasby 1986, 1988; Hutchings et al. 2014
Ascidians	75	Rowe and Marshall 1979; Kott 1985, 1990a, 1990b, 1992a, 1992b, 2001, 2002, 2004a, 2004b, 2005a, 2005b, 2007
Oligochaetes	67	Erséus 1997
Marine mites	18	Bartsch 1994, 1996, 2003, 2005, 2007; Otto 2000; Smit 2001
Bryozoans	16	Bock and Cook 2004
Sipunculans	10	Bryce and Sampey 2014
TOTAL	5532	

The NIMPCG (2008) Monitoring Design Excel Template (MDET) was used to select species on the Australian national IMS list (NIMPCG 2009a, 2009b) that are most likely to be capable of surviving in Pilbara waters if they were introduced. The MDET is conservative, with a number of criteria to estimate whether a species could live in an area, primarily temperature and salinity. The MDET also provides recommendations on the number and type of samples to be made for each species. The MDET eliminates different life stages of individual species; thus, adults may survive in an area, but the larvae, which are generally more susceptible to adverse conditions, may not be able to live in the same conditions. For this paper species that cannot survive in the Pilbara at some stage in their life cycle were eliminated from the potential IMS list. Even if one or more adults are introduced, a population will not develop if all stages of the life cycle cannot be completed. Monitoring conducted for the Gorgon (Barrow Island, Dampier) and Wheatstone (Onslow, Exmouth) Projects and the DoF monitoring (Dampier, Port Hedland) all used the MDET methodology. Species taxonomy was updated following the World List of Marine Species (www.marinespecies.org/).

DoF (2014) published a watch list of 81 species that incorporated the national list. No specific monitoring methodology was provided for the additional species, but individual programs were required to also search for these species.

All surveys recognise that the IMS lists are based on species known to have invaded elsewhere and there may be other IMS that have not yet been recorded, so the monitoring programs also searched for species exhibiting invasive characteristics.

Results

A total of 5,532 species of marine invertebrates, fish and plants were recorded from the Pilbara. Fish (1565) were the most abundant group, followed by molluscs (1533) and crustaceans (826) (Table 1). Table 1 shows the primary sources for the various taxa; a total of over 100 sources were consulted.

Table 2 shows the species on the Australian national IMS list that were selected for specific monitoring.

Table 3 shows IMS surveys in the Pilbara for which information is publicly available. Other surveys have been undertaken but the information is commercial in confidence and not publicly available. However, detections must be reported to DoF, which then makes public information on the species detected, location and action taken. Only one species on the national (NIMPCG 2009a, 2009b) and/or DoF (2014) IMS list has been detected: the ascidian *Didemnum perlucidum* Monniot, 1983.

Discussion

Huisman et al. (2008) conducted an exhaustive analysis of 102 marine and estuarine species that had been reported as introduced into WA. Forty-two species were rejected as having arrived naturally, being cryptogenic or the records were unconfirmed.

Table 2. Species on the Australian national IMS list (NIMPCG 2009a; 2009b) that are most likely to be able to survive in the Pilbara region as determined using the MDET methodology (NIMPCG 2008).

Group	Species
Dinoflagellates	*Alexandrium monilatum* (J.F. Howell) Balech, 1995
	Pfiesteria piscicida K.A. Steidinger and J.M. Burkholder, 1996
Diatoms	*Chaetoceros concavicornis* Mangin, 1917
	Chaetoceros convolutus Castracane, 1886
Ctenophorans	*Beroe ovata* Bruguière, 1789
	Mnemiopsis leidyi A. Agassiz, 1865
Algae	*Bonnemaisonia hamifera* Hariot, 1891
	Caulerpa taxifolia (M. Vahl) C. Agardh, 1817
	Codium fragile fragile (Suringar) Hariot, 1889
	Grateloupia turuturu Yamada, 1941
	Womersleyella setacea (Hollenberg) R.E. Norris, 1992
Cnidarians	*Blackfordia virginica* Mayer, 1910
Polychaetes	*Hydroides dianthus* (Verrill, 1873)
Barnacles	*Amphibalanus eburneus* (Gould, 1841)
Crabs	*Hemigrapsus takanoi* Asakura and Watanabe, 2005
	Hemigrapsus penicillatus (De Haan, 1835)
	Hemigrapsus sanguineus (De Haan, 1835)
	Rhithropanopeus harrisii (Gould, 1841)
Gastropods	*Crepidula fornicata* (Linnaeus, 1758)
Bivalves	*Magallana gigas* (Thunberg, 1793)
	Mya arenaria Linnaeus, 1758
	Mytilopsis sallei (Récluz, 1849)
	Perna viridis (Linnaeus, 1758)
Ascidians	*Didemnum* sp. (Invasive forms only)

Table 3. Invasive marine species monitoring programs conducted in the Pilbara region, Western Australia. The list is incomplete as additional surveys have been undertaken at a number of sites but are commercial in confidence.

Port/Area	Years	Methods used	Information source
All WA	Up to 2008	Extensive literature search, stakeholder consultation, analysis of museum and herbarium specimens	Huisman et al. (2008)
Dampier and Port Hedland	2011, 2013, 2015 Dampier only	Shoreline visual surveys, crab traps, crab condos, plankton trawls, benthic sleds, beam trawls, sediment cores, molecular techniques	Hourston (2014)
Dampier and Port Hedland	2010, 2012, 2014	Early warning survey in alternate years using shoreline visual surveys, crab traps and settlement arrays	Muñoz and Bridgwood (2013), Anonymous (2015)
Dampier and Port Hedland	2015 onwards	Program re-evaluated and considered excessive. Replaced on 1 July 2015 with quarterly sampling using settlement arrays with settlement plates.	Anonymous (2015)
Dampier Supply Base	2010–2015	Quarterly intertidal surveys using shoreline visual surveys, sediment cores and settlement plates. Semi-annual subtidal surveys using remotely operated vehicles, sediment cores and epibenthic sleds.	Wells (2011)
Port Hedland	1999	Sediment cores, plankton nets, visual surveys, video transects, beam trawls, benthic sleds, seines	Hewitt (2002)
Barrow Island	2004	Shoreline visual surveys and diving	Wells and Jones (2005)
Barrow Island	2010–2015	Quarterly intertidal surveys using shoreline visual surveys, sediment cores and settlement plates. Semi-annual subtidal surveys using remotely operated vehicles (ROV), grabs and epibenthic sleds.	Wells (2011)
Onslow	2012–2016	Six monthly intertidal surveys using shoreline visual surveys, sediment cores and settlement plates and subtidal surveys using ROV, grabs and epibenthic sleds.	Chevron (2014)
Exmouth	2012–2014	Six monthly intertidal surveys using shoreline visual surveys, sediment cores and settlement plates and subtidal surveys using ROV, grabs and epibenthic sleds.	Chevron (2014)
Cape Lambert	2007; 2011 onwards	Surveys every three years for the life of the project to a standard acceptable to Monitoring Design Assessment Panel of the National Introduced Marine Pest Coordinating Group	EPA (2010)

Sixty species were considered to have been introduced through anthropogenic activity and become established in WA. Most (37) were temperate species that occurred from Geraldton south; only six were tropical species that occurred from Shark Bay north; 17 species were found in both the southern and northern halves of Western Australia. Sixteen introduced marine species were recorded in the Pilbara. Only three species introduced to WA were on the Australian national IMS list (NIMPCG (2009a, 2009b): the dinoflagellate *Alexandrium minutum* (Halim, 1960) Balech, 1995 the bivalve *Musculista senhousia* (Benson in Cantor, 1842) and the polychaete *Sabella spallanzanii* (Gmelin, 1791). All three of these species occur in the temperate Fremantle marine area (32.1ºS; 115.7ºE), with *S. spallanzanii* also being recorded in numerous localities further south. A detailed survey of potential IMS was conducted in 2007 at 43 stations in the Fremantle marine area but *M. senhousia* was not detected. The species may have been locally eliminated by a decaying cyclone in February 2000 that turned the Swan River estuary fresh overnight (McDonald and Wells 2010).

Two additional IMS have been subsequently reported in WA. The alga *Codium fragile fragile* (Suringar) Hariot, 1889 was detected at Albany on the south coast (McDonald et al. 2008) but has not spread to other harbours (Dr J. McDonald, DoF, pers. comm.). Several individuals of the Asian paddle crab *Charybdis japonica* (A. Milne-Edwards, 1861) were recorded at Mandurah and in the Swan River between 2010 and 2014 (DoF 2015), but the species is not believed to have become established. Both of these species have been detected in temperate habitats well south of the tropical Pilbara.

The invasive ascidian *Didemnum perlucidum* Monniot, 1983 was first recorded in the Fremantle marine area in 2010 (Smale and Childs 2011). Following the initial report *D. perlucidum* was rapidly found throughout WA from Esperance on the southeast coast, along the west coast, to the Kimberley in the northeast and in Darwin, Northern Territory. *Didemnum perlucidum* is widespread in the Pilbara and has been reported from Exmouth Boat Harbour, Mangrove Passage near Onslow, Barrow Island and Dampier (Bridgwood et al. 2014). To date *D. perlucidum* in the Pilbara has only been recorded on artificial surfaces, but in the temperate Fremantle marine area it also occurs on the seagrass *Halophila ovalis* (R. Brown) J.D. Hooker, 1858 in areas near colonies on artificial habitats (Simpson et al. 2016).

There have been many opportunities for IMS to have been distributed to the Pilbara. William Dampier on *HMS Roebuck* reached the present site of Dampier on 21 August 1699. In April 1863 Captain Peter Hedland aboard the cutter *Mystery* visited the present area of Port Hedland. In the same year the first shipment of cattle was made from the now ghost town of Cossack. Pearling and the cattle industry developed during the 19th century using vessels operating from Cossack and Port Hedland. The mining industry commenced exports from Port Hedland in the late 1960s, and the town of Dampier was established in 1965 for a mining company and nearby Karratha was founded in 1968. Thus, there has been over 300 years of European vessel movements to the Pilbara and a rapid expansion in vessel traffic since the late 1960s. McDonald (2008) recorded 4918 total vessel arrivals in Pilbara ports in 2006, nearly half (2276) of which were from international ports. By 2011 this had grown to 8195 vessel visits to the WA north coast (Bridgwood and McDonald 2014).

While *D. perlucidum* is the only IMS known to have been introduced into the Pilbara, the presence of 16 other introduced marine species (Huisman et al. 2008), demonstrates that the mechanisms for introduction of IMS are present. The first species known to have been introduced into WA was the barnacle *Amphibalanus amphitrite* (Darwin, 1854), reported from Broome, north of the Pilbara, in 1916; the species is widespread in the Pilbara (Huisman et al. (2008). In the 20 months from January 2014 through August 2015 DoF received notification of 19 vessels being found in WA with IMS species, most of which were in the Pilbara. Fifteen reports were Asian green mussels *Perna viridis* (Linnaeus, 1758) (R. Adams, DoF, pers. comm.; Wells 2017a). In a detailed analysis, Heersink et al. (2014) concluded that *P. viridis* has been introduced tens to hundreds of times to Australia over the last 50 years but has not established populations. Huhn et al. (2017) speculated that *P. viridis* introduced as biofouling are unsuccessful in establishing because they have been weakened by a lack of nutrition during their transit through the oligotrophic waters of the open ocean.

Initial concerns about the possible introduction of IMS into WA were crystallised by the arrival of the dredge *Leonardo da Vinci* in Geraldton on the west coast October 2002 for a port enhancement project. An alert inspector from the then Australian Quarantine and Inspection Service found barnacles growing along the waterline and reported the finding to DoF. Dives on the vessel showed that there was considerable biofouling at the stern that included known IMS species. The vessel was cleaned and no IMS are known to have been introduced (Wells et al. 2009). Since this incident, the WA Environmental Protection Authority (EPA) has required that all major new developments along the coast undertake a series of actions to minimize the introduction and establishment of IMS, including vessel risk assessments and cleaning and habitat monitoring for IMS. However, as these requirements apply only to new developments it has only been since 2010 that there have been many vessel IMS inspections. As knowledge of IMS issues has spread through industry many companies have taken proactive steps to clean and inspect vessels that are not under EPA requirements.

By the end of 2015 the Gorgon Project had risk assessed and/or inspected 641 vessels for IMS (Wells and Booth 2012; Wells 2017b) and Woodside Energy 363 (T. Box, Woodside, pers. comm.); other companies have inspected smaller numbers of vessels. However, even now not all high-risk vessels are risk assessed and/or inspected, and there have been few inspections of vessels considered to be low risk.

There have been numerous IMS surveys in the Pilbara, ranging from targeted surveys of one or a few days to multiyear intensive surveys. There have been more IMS surveys in the Pilbara than in anywhere else in Australia. The extensive, publicly available information on Pilbara surveys is summarized in Table 3. There have been many additional surveys undertaken but they are commercial in confidence. However, the results are provided to DoF. Despite this extensive, and unprecedented, IMS monitoring of nearshore marine environments, *D. perlucidum* remains the only IMS species known from the Pilbara. It should be acknowledged that offshore oil rigs in the Gulf of Mexico are known to have IMS species (e.g. Sammarco et al. 2010), but the rigs off the Pilbara coast have not yet been surveyed for IMS.

The concentration of IMS in temperate localities is not unique to WA; it occurs throughout Australia. Hewitt (2002) compared the results of four tropical and four temperate IMS surveys of Australian ports conducted with the same techniques; 48 introduced species were detected in the temperate ports and only 28 in the tropical ports. The national IMS database includes an interactive map of IMS records from 28 localities (DAFF 2017). No IMS are shown at the 12 northern localities (*D. perlucidum* is present in Dampier but is not shown on the map, which was last updated in 2014). In contrast, 11 IMS species are shown at the 16 temperate localities. However there have been IMS detections in northern Australia. Hallegraeff and Bolch (1991, 1992) detected viable cysts of toxic dinoflagellates in the ballast tanks of bulk cargo vessels at Port Hedland, but none have been found in the harbour. An IMS survey of Darwin, Northern Territory in March 1999 found dense populations of the Caribbean black striped mussel *Mytilopsis sallei* (Récluz, 1849) concentrated in the Cullen Bay Marina. The species was successfully eliminated (Willan et al. 2000). The successful eradication of this species emphasizes the value of the well-developed Australian IMS detection system, a framework that does not exist in most tropical regions. A small population of the Asian green mussel *Perna viridis* (Linnaeus, 1758) became established in Cairns in 2001, but has died out (Stafford et al. 2007). Russell et al. (2003) surveyed for introduced marine species at Ashmore Reef, WA. The only potential IMS detected was the barnacle *Austromegabalanus kratatauensis* (Nilsson-Cantell, 1934) on an Indonesian fishing vessel hull and on driftwood. The species was not located on the reef itself and does not appear to have become established there.

The relative paucity of IMS in tropical Australia parallels the situation found in some other Indo-West Pacific localities (Hutchings et al. 2002). For example, only 85 of the > 5500 marine species reported from Guam have been introduced, and only 23% of these have been found outside the harbour of Apra (Paulay et al. 2002). With 343 known introduced marine and estuarine species, Hawaii is an exception to the lack of introduced marine species in tropical waters. Most are in the disturbed areas of Pearl Harbour and other estuaries of Oahu (DeFelice et al. 2001; Coles et al. 2006). Hawaii is biogeographically isolated and the biota is less diverse than in other tropical areas (Hutchings et al. 2002), so the large number of introduced marine species does not conflict with data from localities in the megadiverse central Indo-West Pacific.

The presence of a single IMS species can have profound effects on local ecosystems. Perhaps the best example is the Indo-West Pacific lionfish *Pterois volitans* (Linnaeus, 1758) was introduced to Florida in the 1990s and is now widespread in the Caribbean (Albins and Hixon 2008).

The Pilbara study presents strong evidence that the relatively low numbers of IMS in the region is not due to either a lack of knowledge or a lack of sampling, but rather that there must be one or more underlying biological factors causing the relative lack of invasion success (Hewitt 2002). The niche size hypothesis is one potential mechanism for the lack of IMS in the Pilbara. In this hypothesis the higher diversity of native tropical communities confers increased resistance to invasions through an increase in biotic interactions (Hewitt 2002). This hypothesis is supported by the work of Zabin and Hadfield (2002) in Hawaii, who found the Caribbean barnacle *Chthamalus proteus* occurs higher on the shore than the native *Nesochthamalus intertexts* and the two are ecologically separated. Another mechanism was suggested by Freestone et al. (2011), who demonstrated experimentally that, at least in their study sites, predation pressure could explain the inability of species to invade tropical environments. Further studies are required in other tropical areas to determine whether the result obtained in the Pilbara are more generally applicable.

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References

ABS (2016) Population estimates by significant urban area, 2004-2014. Australian Bureau of Statistics, Canberra. Available at: http://www.abs.gov.au (accessed 25 August 2016)

Adam W (1979) The Sepiidae (Cephalopoda, Decapoda) in the collections of the Western Australian Museum. *Records of the Western Australian Museum* 7: 113–212

ALA (2016/2017) Atlas of Living Australia. The Australian node of the Global Biodiversity Information Facility. http://www.ala.org.au (accessed on 1 Nov 2017)

Albins MA, Hixon MA (2008) Invasive Indo-Pacific lionfish *Pterois volitans* reduce recruitment of Atlantic coral-reef fishes. *Marine Ecology Progress Series* 367: 233–238, https://doi.org/10.3354/meps07620

Alderslade P (1998) Revisionary systematics in the gorgonian family Isididae, with descriptions of numerous new taxa (Coelenterata: Octocorallia). *Records of the Western Australian Museum* Supplement 55: 1–359

Anonymous (2015) Activities of the Marine Biosecurity Research and Monitoring Group during 2013/14 In: Fletcher WJ, Santoro K (eds), Status Reports of the Fisheries and Aquatic Resources of Western Australia 2013/14: The State of the Fisheries. Department of Fisheries, Western Australia, pp 330–333

Bartsch I (1994) *Copidognathus* (Halacaridae: Acari) from Western Australia. Description of twelve species of the *gibbus* group. *Records of the Western Australian Museum* 16: 535–566

Bartsch I (1996) Halacarines (Acari: Halacaridae) from Rottnest Island, Western Australia: the genera *Agauopsis* Viets and *Halacaropsis* gen. nov. *Records of the Western Australian Museum* 18: 1–18

Bartsch I (2003) *Psammophilous halacarids* (Halacaridae, Acari) from Dampier, Western Australia. Description of species and faunal comparison of the mesopsammal halacarid fauna of western and eastern Australia. *Records of the Western Australian Museum* 22: 23–45, https://doi.org/10.18195/issn.0312-3162.22(1).2003.023-045

Bartsch I (2005) *Lohmannella* and *Simognathus* (Halacaridae: Acari) from Western Australia: description of two new species and reflections on the distribution of these genera. *Records of the Western Australian Museum* 22: 293–307, https://doi.org/10.18195/issn.0312-3162.22(4).2005.293-307

Bartsch I (2007) Halacarid mites (Acari: Halacaridae) from Esperance, Western Australia: Notes on taxonomy and faunal distribution of non-Copidognathinae. *Records of the Western Australian Museum* 23: 359–392, https://doi.org/10.18195/issn.0312-3162.23(4).2007.359-392

Berry PF, Wells FE (2000) Survey of the marine fauna of the Montebello Islands, Western Australia and Christmas Island, Indian Ocean. *Records of the Western Australian Museum* Supplement 59: 1–127

Bock PE, Cook PL (2004) A review of Australian Conescharellinidae (Bryozoa: Cheilostomata). *Memoirs of Museum Victoria* 61: 135–182, https://doi.org/10.24199/j.mmv.2004.61.11

Bridgwood S, McDonald J (2014) A likelihood analysis of the introduction of marine pests to Western Australian ports via commercial vessels. Department of Fisheries, Western Australia, Fisheries Research Report 259, pp 1–212

Bridgwood S, Muñoz J, McDonald JI (2014) Catch me if you can! The story of a colonial ascidian's takeover bid in Western Australia. *BioInvasions Records* 3: 217–223, https://doi.org/10.3391/bir.2014.3.4.02

Bryce C, Sampey A (2014) Kimberley marine biota. Historical data: additional phyla (Brachiopoda, Bryozoa, Annelida, Platyhelminthes, Sipuncula, Cnidaria and Chordata). *Records of the Western Australian Museum* Supplement 84: 345–361

Cairns SD (1998) Azooxanthellate Scleractinia (Cnidaria: Anthozoa) of Western Australia. *Records of the Western Australian Museum* 18: 361–417

Chevron (2014) Wheatstone Project Compliance Assessment Report 2014: Ministerial Implementation Statement No. 873. Chevron Australia Pty Ltd, Perth report to the WA Minister for the Environment. Document WS0-0000-HES-RPT-CVX-000-00186-000

Coles SL, Eldredge LG (2002) Nonindigenous species introduced on coral reefs: A need for information. *Pacific Science* 56: 191–209, https://doi.org/10.1353/psc.2002.0010

Coles SL, Kandel FLM, Reath PA, Longenecker K, Eldredge LG (2006) Rapid assessment of nonindigenous marine species on coral reefs in the Main Hawaiian Islands. *Pacific Science* 60: 483–507, https://doi.org/10.1353/psc.2006.0026

Crowe TP, Frid CLJ (2015) Marine Ecosystems: Human Impacts on Biodiversity, Functioning and Services. Cambridge University Press, Cambridge UK, https://doi.org/10.1017/CBO9781139794763

DAFF (2017) Marine Pests Interactive Map. Department of Agriculture Fisheries and Forestry, Canberra, Australian Capital Territory. http://www.marinepests.gov.au/Pages/marinepest-map.aspx

DeFelice RC, Eldredge LG, Carlton JT (2001) Nonindigenous marine invertebrates. In: Eldredge LG, Smith CM (eds), A Guidebook of Introduced Marine Species in Hawaii. Bishop Museum Technical Report 21, pp B1–B60

DoF (2014) Western Australian Prevention List for Introduced Marine Pests. Department of Fisheries, Perth, WA. Available at: http://www.fish.wa.gov.au (accessed 25 August 2015)

DoF (2015) Aquatic Biosecurity Pest Alert Asian paddle crab (*Charybdis japonica*). Department of Fisheries, Perth, WA. Available at: http://www.fish.wa.gov.au (accessed 25 August 2015)

DSD (2016a) Iron Ore Industry Profile March 2016. Western Australian Department of State Development, Perth, Western Australia, 4 pp

DSD (2016b) WA Liquefied Natural Gas Industry Profile July 2016. Western Australian Department of State Development, Perth, Western Australia, 5 pp

Eldredge LG, Smith CM (2001) A Guidebook of Introduced Marine Species in Hawai'i. Bishop Museum Technical Report 21, Bi-Bvi, B1-B60

EPA (2010) Cape Lambert Port B Pilbara Iron Pty Ltd. Report and Recommendations of the Environmental Protection Authority, Perth, Western Australia, Report 1357, pp 1–94

Erséus C (1997) Marine Tubificidae (Oligochaeta) from the Montebellos and Houtman Abrolhos Islands, Western Australia, with the description of twenty-three new species. In: Wells FE (ed), Proceedings of the seventh international marine biological workshop: The marine flora and fauna of the Houtman Abrolhos Islands, Western Australia. Western Australian Museum, Perth, pp 389–458

Foss S (2008) Introduced Aquatic Species in the Marine and Estuarine Waters of California. Report by the Office of Spill Prevention and Response, California Department of Fish and Game, Moss Landing Marine Laboratories, 67 pp

Freestone AL, Osman RW, Ruiz GM, Torchin ME (2011) Stronger predation in the tropics shapes species richness patterns in marine communities. *Ecology* 92: 983–993, https://doi.org/10.1890/09-2379.1

Fromont J (2004) Porifera (sponges) of the Dampier Archipelago, Western Australia: habitats and distributions. In: Jones DS (ed), Report on the results of the Western Australian Museum/ Woodside Energy Ltd partnership to explore the marine biodiversity of the Dampier Archipelago 1998-2002. *Records of the Western Australian Museum* Supplement 66: 69–100, https://doi.org/10.18195/issn.0313-122x.66.2004.069-100

George RW, Jones DS (1982) A revision of the fiddler crabs of Australia (Ocypodinae: *Uca*). *Records of the Western Australian Museum* Supplement 14: 1–99

Griffith JK, Fromont J (1998) A catalogue of recent Cnidaria type specimens in the Western Australian Museum of Natural Science, Perth. *Records of the Western Australian Museum* 19: 223–239

Hallegraeff GM, Bolch CJ (1991) Transport of toxic dinoflagellate cysts via ship's ballast water. *Marine Pollution Bulletin* 22: 27–30, https://doi.org/10.1016/0025-326X(91)90441-T

Hallegraeff GM, Bolch CJ (1992) Transport of diatom and dinoflagellate resting spores in ships' ballast water: implications for plankton biogeography and aquaculture. *Journal of Plankton Research* 14: 1067–1084, https://doi.org/10.1093/plankt/14.8.1067

Hayes KR, McEnnulty F, Sliwa C (2002) Identifying Potential Marine Pests – An Inductive Approach. CSIRO Division of Marine Research, Hobart, Tasmania, 40 pp

Hayes KR, Sliwa C (2003) Identifying potential marine pests – a deductive approach applied to Australia. *Marine Pollution Bulletin* 46: 91–98, https://doi.org/10.1016/S0025-326X(02)00321-1

Hayes KR, Sliwa C, Migus S, McEnnulty F, Dunstan P (2005) National Priority Pests: Part II Ranking of Australian Marine Pests. Report to Department of Environment and Heritage by CSIRO Marine Research, Hobart, Tasmania, 94 pp

Heersink D, Paini D, Caley P, Barry S (2014) Asian green mussel: Estimation of approach rate and probability of invasion via biofouling. Research Services Final Report, Plant Biosecurity Cooperative Research Centre, Bruce, ACT, 28 pp

Hewitt CL (2002) The distribution and diversity of tropical Australian marine bioinvasions. *Pacific Science* 56: 213–222, https://doi.org/10.1353/psc.2002.0016

Hewitt CL, Campbell ML, Thresher RE, Martin RB, Boyd S, Cohen BF, Currie DR, Gomon MF, Keough MJ, Lewis JA, Lockett MM, Mays N, McArthur MA, O'Hara TD, Poore GCB, Ross DJ, Storey MJ, Watson JE, Wilson RS (2004) Introduced and cryptogenic species in Port Phillip Bay, Victoria, Australia. *Marine Biology* 144: 183–202, https://doi.org/10.1007/s00227-003-1173-x

Hourston M (2014) Port of Dampier Marine Pest Monitoring Survey Post Implementation Report 2013. Port of Dampier (AUDAM). Western Australian Department of Fisheries, Perth, 37 pp

Hughes LE (2013) Podoceridae of tropical Australia (Peracarida: Amphipoda). *Records of the Australian Museum* 65: 1–37, https://doi.org/10.3853/j.2201-4349.65.2013.1592

Huhn M, Zamani NP, Lenz M (2017) Tolerance to hypoxia in Asian green mussels, *Perna viridis*, collected from a ship hull in the non-native range in eastern Indonesia. *Management of Biological Invasions* 8: 227–233, https://doi.org/10.3391/mbi.2017.8.2.10

Huisman JM (2000) Marine Plants of Australia. University of Western Australia Press. Perth, 300 pp

Huisman JM, Jones DS, Wells FE, Burton T (2008) Introduced marine biota in Western Australian waters. *Records of the Western Australian Museum* 25: 1–44, https://doi.org/10.18195/issn.0312-3162.25(1).2008.001-044

Hutchings PA, Glasby C (1986) The Polycirrinae (Polychaeta: Terebellidae) from Australia. *Records of the Australian Museum* 38: 319–350, https://doi.org/10.3853/j.0067-1975.38.1986.185

Hutchings PA, Glasby CJ (1988) The Amphitritinae (Polychaeta: Terebellidae) from Australia. *Records of the Australian Museum* 40: 1–60, https://doi.org/10.3853/j.0067-1975.40.1988.150

Hutchings PA, Hilliard RW, Coles SKL (2002) Species introductions and potential for marine pest invasions into tropical marine communities, with special reference to the Indo-Pacific. *Pacific Science* 56: 223–233, https://doi.org/10.1353/psc.2002.0017

Hutchings PA, Glasby C, Capal M, Sampey A (2014) Kimberley marine biota. Historical data: polychaetes (Annelida). *Records of the Western Australian Museum* Supplement 84: 133–159, https://doi.org/10.18195/issn.0313-122x.84.2014.133-159

Hutchins JB (1994) A survey of the nearshore reef fish fauna of Western Australia's west and south coasts – The Leeuwin Province. *Records of the Western Australian Museum* Supplement 46: 1–66

Johnson CR, Chapman RDO (2007) Seaweed invasions: Introduction and scope. *Botanica Marina* 50: 321–325, https://doi.org/10.1515/BOT.2007.037

Jones DS (2004) Report on the results of the Western Australian Museum/Woodside Energy Ltd partnership to explore the marine biodiversity of the Dampier Archipelago 1998-2002. *Records of the Western Australian Museum* Supplement 66: 1–401

Jones DS (2007) Crustaceans collected by the Western Australian Museum/Woodside Energy Ltd partnership to explore the marine biodiversity of the Dampier Archipelago 1998-2002. *Records of the Western Australian Museum* Supplement 73: 1–342

Jones D, Morgan G (1992) A Field Guide to Crustaceans of Australian Waters. Reed New Holland, Sydney, NSW, 224 pp

Kangas MI, Morrison S, Unsworth P, Lai E, Wright I, Thomson A (2007) Development of biodiversity and habitat monitoring systems for key trawl fisheries in Western Australia. Final report to Fisheries Research and Development Corporation on Project No. 2002/038. Department of Fisheries, Western Australia, Fisheries Research Report 160, pp 1–334

Katsanevakis S, Wallentinus I, Zenetos A, Leppäkoski E, Çinar ME, Oztürk B, Grabowski M, Golani D, Cardoso AC (2014) Impacts of invasive alien marine species on ecosystem services and biodiversity: a pan-European review. *Aquatic Invasions* 9: 391–423, https://doi.org/10.3391/ai.2014.9.4.01

Kott P (1985) The Australian Ascidacea. Pt. 1. Plebobranchia and Stolidobranchia. *Memoirs of the Queensland Museum* 23: 1–440

Kott P (1990a) The Australian Ascidacea. Pt. 2. Aplousobranchia (1). *Memoirs of the Queensland Museum* 29: 1–266

Kott P (1990b) The Australian Ascidacea. Plebobranchia and Stolidobranchia supplement. *Memoirs of the Queensland Museum* 29: 267–298

Kott P (1992a) The Australian Ascidacea. Pt. 3. Aplousobranchia (2). *Memoirs of the Queensland Museum* 32: 377–620

Kott P (1992b) The Australian Ascidacea, supplement 2. *Memoirs of the Queensland Museum* 32: 621–655

Kott P (2001) The Australian Ascidiacea Part 4, Aplousobranchia (3), Didemnidae. *Memoirs of the Queensland Museum* 47(1): 1–407

Kott P (2002) The genus *Herdmania* Lahille, 1888 (Tunicata, Ascidiacea) in Australian waters. *Zoological Journal of the Linnean Society* 134: 359–374, https://doi.org/10.1046/j.1096-3642.2002.00009.x

Kott P (2004a) New and little-known species of Didemnidae (Ascidiacea, Tunicata) from Australia (part 1). *Journal of Natural History* 38: 731–774, https://doi.org/10.1080/0022293321000041725

Kott P (2004b) New and little-known species of Didemnidae (Ascidiacea, Tunicata) from Australia (part 2). *Journal of Natural History* 38: 2455–2526, https://doi.org/10.1080/00222930310001647334

Kott P (2005a) New and little-known species of Didemnidae (Ascidiacea, Tunicata) from Australia (Part 3). *Journal of Natural History* 39: 2409–2479, https://doi.org/10.1080/00222930500087077

Kott P (2005b) Catalogue of Tunicata in Australian Waters. Australian Biological Resources Study, Canberra, ACT, 301 pp

Kott P (2007) Observations on non-didemnid ascidians from Australian waters (1). *Journal of Natural History* 40: 169–234, https://doi.org/10.1080/00222930600621601

Marsh LM, Fromont J, Salotti M (1999) A catalogue of Recent echinoderm type specimens in the Western Australian Museum, Perth. *Records of the Western Australian Museum* 19: 391–411

McDonald JI (2008) A likelihood analysis of non-indigenous marine species introduction to fifteen ports in Western Australia. Department of Fisheries, Western Australia, Fisheries Research Report 182, pp 1–36

McDonald JI, Wells FE (2010) The apparent demise of the Asian date mussel *Musculista senhousia* in Western Australia: or using acts of god as an eradication tool. *Biological Invasions* 12: 715–719, https://doi.org/10.1007/s10530-009-9478-4

McDonald JI, Wells FE, Travers MJ (2008) Results of the 2007 survey of the Albany marine area for introduced marine species. Department of Fisheries, Western Australia, Fisheries Research Report 188, pp 1–30

Molnar JL, Gamboa RL, Revenga C, Spalding MD (2008) Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment* 6: 485–492, https://doi.org/10.1890/070064

Moore GI, Hutchins, JB, Smith KN, Morrison SM (2008) Catalogue of type specimens of fishes in the Western Australian Museum (Second Edition). *Records of the Western Australian Museum* Supplement 74: 1–69, https://doi.org/10.18195/issn.0313-122x.74.2008.001-069

Morgan GJ, Wells FE (1991) Zoogeographic provinces of the Humboldt, Benguela and Leeuwin Current systems. *Journal of the Royal Society of Western Australia* 74: 59–69

Muñoz J, Bridgwood S (2013) Early warning system for the monitoring of introduced marine pests. Dampier port 2012 report. Western Australian Department of Fisheries, Perth, 30 pp

NIMPCG (2008) Monitoring Design Excel Template. National Introduced Marine Pests Monitoring Group, Department of Agriculture, Fisheries and Forestry, Canberra

NIMPCG (2009a) Marine pests monitoring manual: Version 1c. National Introduced Marine Pests Coordination Group, Department of Agriculture, Fisheries and Forestry, Canberra, 142 pp

NIMPCG (2009b) Australian marine pests monitoring guidelines: Version 1c. National Introduced Marine Pests Coordination Group, Department of Agriculture, Fisheries and Forestry, Canberra, 55 pp

Otto JC (2000) *Australacarus* (Acari: Halacaridae) from northern Australia, with the description of three new species. *Records of the Western Australian Museum* 20: 103–114

Paulay G, Kirkendale L, Lambert G, Meyer C (2002) Anthropogenic biotic interchange in a coral reef ecosystem: a case study from Guam. *Pacific Science* 56: 403–422, https://doi.org/10.1353/psc.2002.0036

Ponder WF (1978) The unfigured Mollusca of J. Thiele, 1930 published in Die Fauna Sudwest-Australiens. *Records of the Western Australian Museum* 6: 423–441

Roberts CM, McClean CJ, Veron JEN, Hawkins JP, Allen GR, McAllister DE, Mittermeier CG, Schueler FW, Spalding M, Wells F, Vynne C, Werner TB (2002) Marine biodiversity hotspots and conservation priorities for tropical reefs. *Science* 295: 1280–1285, https://doi.org/10.1126/science.1067728

Rowe FEW, Marshall JI (1979) A catalogue of the ascidian type specimens in the Australian Museum, Sydney. *Records of the Australian Museum* 32: 547–562, https://doi.org/10.3853/j.0067-1975.32.1979.465

Russell BC, Neil K, Hilliard R (2003) Marine and Terrestrial Introduced Species Prevention and Management Strategy: Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve. Department of Environment and Heritage, Canberra, 22 pp

Sammarco PW, Porter SA, Cairns SD (2010) A new coral species introduced into the Atlantic Ocean - *Tubastraea micranthus* (Ehrenberg 1834) (Cnidaria, Anthozoa, Scleractinia): An invasive threat? *Aquatic Invasions* 10: 131–140, https://doi.org/10.3391/ai.2010.5.2.02

Simpson TS, Wernberg T, McDonald JI (2016) Distribution and localised effects of the invasive ascidian *Didemnum perlucidum* (Monniot, 1983) in an urban estuary. *PloS ONE* 11: e0154201, https://doi.org/10.1371/journal.pone.0154201

Smale DA, Childs S (2011) The occurrence of a widespread marine invader, *Didemnum perlucidum* (Tunicata, Ascidiacea) in Western Australia. *Biological Invasions* 14: 1325–1330, https://doi.org/10.1007/s10530-011-0167-8

Smit H (2001) New records of the water mite family Hygrobatidae from Australia, with the description of ten new species (Acari: Hydrachnidia). *Records of the Western Australian Museum* 20: 137–158

Stafford H, Willan RC, Neil KM (2007) The invasive Asian green mussel, *Perna viridis* (Linnaeus, 1758) (Bivalvia: Mytilidae), breeds in Trinity Inlet, tropical northern Australia. *Molluscan Research* 27: 105–109

Veron JEN, Marsh LM (1988) Hermatypic corals of Western Australia: records and annotated species list. *Records of the Western Australian Museum* Supplement 29: 1–136, https://doi.org/10.5962/bhl.title.60555

Wells FE (1977) Type specimens in the Department of Molluscs, Western Australian Museum. *Records of the Western Australian Museum* 6: 33–61

Wells FE (1980) The distribution of shallow-water marine prosobranch gastropod molluscs along the coastline of Western Australia. *Veliger* 22: 232–247

Wells F (2011) Monitoring for introduced marine pests for the Gorgon LNG Project. *The APPEA Journal* 51; 674–674, https://doi.org/10.1071/AJ10054

Wells FE (2017a) If the Asian green mussel, *Perna viridis* (Linnaeus, 1758), poses the greatest invasive marine species threat to Australia, why has it not invaded? *Molluscan Research* 37: 167–174, https://doi.org/10.1080/13235818.2017.1322676

Wells FE (2017b) Marine pest management at Barrow Island, Western Australia. Paper presented at 3rd ANZPAC Workshop on Biofouling Management for Sustainable Shipping Melbourne, Australia. 12–15 September 2017, 23 slides

Wells FE, Bryce CW (1990) Seashells of Western Australia. Western Australian Museum, Perth, 207 pp

Wells FE, Bryce CW (1993) Sea Slugs and Their Relatives of Western Australia. Western Australian Museum, Perth, 184 pp

Wells FE, Jones DS (2005) Barrow Island Preliminary Survey for Introduced Marine Pest Species. Appendix D7. In: Chevron, Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development. Gorgon Australian Gas, Chevron Australia Pty Ltd, Perth

Wells FE, Booth G (2012) Setting a new benchmark in managing biofouling on vessels in a sensitive marine environment. Paper presented at the SPE/APPEA International Conference on Health, Safety and Environment in Gas Production and Exploration, Perth, Australia. SPE 156749, 12 pp

Wells FE, Walker DI, Jones DS (2003) Proceedings of the eleventh international marine biological workshop: The marine flora and fauna of Dampier, Western Australia. Western Australian Museum, Perth, 587 pp

Wells FE, McDonald JI, Huisman JM (2009) Introduced Marine Species in Western Australia. Western Australian Department of Fisheries, Perth Fisheries Occasional Publications 57, pp 1–97

Willan RC, Russell BC, Mufet NB, Moore KL, McEnnulty FR, Horner SK, Hewitt CL, Dally GM, Campbell ML, Borke ST (2000) Outbreak of *Mytilopsis sallei* (Récluz, 1849) (Bivalvia: Dresseinidae) in Australia. *Molluscan Research* 20: 25–30, https://doi.org/10.1080/13235818.2000.10673730

Wilson BR (1993/1994) Australian Marine Shells Prosobranch Gastropods. Odyssey Publishing, Kallaroo, Western Australia, 408, 370 pp

Wilson BR, Allen GR (1987) Major components and distribution of marine fauna. In: Dyne GR, Walton DW (eds), Fauna of

Australia. General Articles. Australian Government Publishing Service, Canberra. Volume 1A, pp 43–68

Wilson BR, Marsh LM (1974) *Acanthaster* studies on a Western Australian Coral Reef. In: Cameron AM, Cambell BM, Cribb AB, Endean R, Jell JS, Jones OA, Mather P, Talbot FH (eds), Proceedings of the 2nd International Symposium on Coral Reefs, Brisbane 1973 1, pp 621–630

Wilson BR, Marsh LM (1975) Seasonal behaviour of a 'normal' population of *Acanthaster* in Western Australia. In: Proceedings of the Crown-of-thorns Starfish Seminar. Brisbane, September 6th 1974. Australian Government Publishing Service, Canberra, pp 167–179

Wilson BR, Stevenson SE (1977) Cardiidae of Western Australia. *Western Australian Museum Special Publication* 9: 1–114

Wyatt A, Hewitt C, Walker D, Ward T (2005) Marine introductions in the Shark Bay World Heritage Property, Western Australia: a preliminary assessment. *Diversity and Distributions* 11: 33–44, https://doi.org/10.1111/j.1366-9516.2005.00109.x

Zabin C, Hadfield MG (2002) Do locals rule? Interactions between native intertidal barnacles and a Caribbean barnacle in Hawai'i. *Pacific Science* 56: 235–236, https://doi.org/10.1353/psc.2002.0020