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A Review of Exotic Marine Organisms Introduced to the Australian Region. II. Invertebrates and Algae

D.A. POLLARD

Fisheries Research Institute
N.S.W. Agriculture and Fisheries
P.O. Box 21, Cronulla, N.S.W. 2230
Australia

P.A. HUTCHINGS

Australian Museum
P.O. Box A285
Sydney South, N.S.W. 2000
Australia

Abstract

The occurrence of exotic marine invertebrates and algae in the Australian region is reviewed, with particular emphasis being placed on those species which might have significant ecological impacts on endemic biota and/or their habitats or on fisheries in this region. All marine and estuarine invertebrates and algae known or thought to have been introduced, either deliberately or accidentally, are listed, together with their probable areas of origin, probable dates and means of introduction, their present areas of occurrence, and general comments on relevant aspects of their biology and status, as appropriate. Those species which might have significant ecological impacts are discussed in some detail, probable pathways for their introduction (particularly ships' ballast water) discussed, and some recommendations made regarding their future control.

Introduction

Until relatively recently, few reports have appeared on introduced marine invertebrates and algae which might have significant ecological impacts on endemic fauna and habitats in the Australian region.

With regard to exotic marine organisms in general, Williams et al. (1978) listed 20 such species which had apparently been introduced to Australian waters. Carlton (1985), in his worldwide review of marine introductions attributed to the discharge of ships' ballast water, also listed a number of marine organisms which were thought to have been introduced to Australian waters by this means. Carlton (1987) subsequently identified 14 major routes of transoceanic dispersal of introduced species in the Pacific, and listed Australia as one of the major receiver areas. The most recent and comprehensive listing of introduced marine organisms in Australia was that by Hutchings et al. (1987). These authors have also discussed in more detail those species thought to have been introduced into Twofold Bay, southern New South Wales (NSW), in the ballast water of woodchip carriers from Japan (Hutchings et al. 1988).

Some caution needs to be used in interpreting the species listings presented in the above reviews, as the authors have of necessity been obliged to accept the identifications given in the literature they reviewed. In many cases voucher material necessary for confirming these identifications was not available, and as many invertebrate groups are poorly known in the Pacific area, it is possible that some of the so-called "introduced" species listed have been misidentified and in fact represent undescribed endemic Australian species.

The present paper assesses the extent of both deliberate and accidental introductions of invertebrates and algae to marine and estuarine waters in the Australian region, with particular emphasis being placed on those species which might have significant impacts on native marine fauna and habitats, or on fisheries, in this region. The probable pathways by which these introduced marine organisms may have entered Australian waters are then discussed, and some recommendations made regarding their future control. A previous paper (Pollard and Hutchings, this vol.) reviews the occurrence of exotic marine fishes from the same perspectives.

Introduced Marine Organisms

Table 1, which is based primarily on and updates the checklist presented by Hutchings et al. (1987), lists those species of exotic marine invertebrates and algae known or claimed to have been introduced to Australian waters. This table includes notes on their probable areas of origin, probable dates and means of introduction, their present areas of occurrence within Australia, and also other

Table 1. List of exotic marine invertebrates and algae introduced to Australia. For explanation of symbols and abbreviations used, see end of table.

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
CRUSTACEA Decapoda .. (crabs and shrimps)						
Carcinus maenas (Linnaeus)	Europe	1900	H	VIC	Fulton and Grant 1900, 1901.	See text.
	Unknown	1976, 1980	U, H	SA	Zeidler 1978, 1988; Rosenzweig 1984.	
	Unknown	1965	U	WA	Zeidler 1978.	
Cancer novaezealandiae (Jacquinot & Lucas)	New Zealand	1880-1930 ?	0 ?	TAS VIC	McNeil and Ward 1930.	Most recently recorded from TAS in 1978, though not recorded from VIC since 1930.
Halicarcinus innominatus Richardson	New Zealand	1926	O, H	TAS	Lucas 1980; Dartnall 1969.	Most recently recorded from TAS in 1970.
Palaemon macrodactylus Rathbun	China, Korea, Japan, west coast of USA	1979	U	NSW	Buckworth 1979.	See text.
Isopoda .. (slaters)						
Cirolana hardfordi (Lockington)	West coast of USA	1972 1980	H H	NSW, WA, VIC	Bruce 1986.	Australian records mainly limited to ports. A potential pest species which can rapidly reach high population densities.
Eurylana arcuata (Hale)	New Zealand or Chile	1925	H or B	NSW, SA	Bowman et al. 1981; Hutchings et al. 1986a (both as *Cirolana arcuata*); Bruce 1986.	Also introduced to California
Paracerceis sculpta (Holmes)	California USA, Brazil, Mexico or Hawaii	1975	H	QLD	Harrison and Holdich 1982b.	
Paradella dianae (Menzies)	California USA, Brazil, Puerto Rico or Marshall Islands	1971 1980	H H	QLD WA	Harrison and Holdich 1982a.	Only found in Australia near international ports, often associated with fouling organisms.

Continued

Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
Sphaeroma serratum (Fabricius)	Widespread	1980	H	WA	Holdich and Harrison 1983.	
Sphaeroma walkeri Stebbing	Indian Ocean	1927 1967	H H	NSW QLD	Carlton and Iverson 1981; Harrison and Holdich 1984.	Also introduced to California.
Mysidacea .. (shrimps)						
Neomysis japonica Nakazawa	Japan	1977	B	NSW	Hutchings 1983.	
Cirrepedia .. (barnacles)						
Balanus improvisus Darwin	Atlantic coasts	?1940s	H	"Southern Australia"	Bishop 1951.	No recent records of this species in Australia to confirm its presence.
Megabalanus rosa (Pilsbry)	Japan	1981	?H	WA	Jones 1987.	Recorded from near ports in WA.
Megabalanus tintinnabulum (Linnaeus)	Cosmopolitan	1949	H	WA	Jones 1987.	Most WA records from near ports. A noted fouling organism overseas.
Notomegabalanus algicola (Pilsbry)	South Africa	1943	H	NSW	Allen 1953 (as *Balanus algicola*).	
MOLLUSCA Bivalvia .. (clams)						
Crassostrea gigas (Thunberg)	Japan	1947 1953 ? 1951 mid 1970s 1985 1986	D D U D U U	TAS, WA VIC NSW SA, QLD VIC	Thomson 1952 (as *Gryphaea gigas*). Thomson 1959. Medcof and Wolf 1975. Coleman 1986. Coleman and Hickman 1986.	See text.
Ostrea lutaria Hutton	New Zealand	1880s	D	TAS	Dartnall 1969; Sumner 1974.	See text.

Continued

Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
Musculista senhousia (Benson in Cantor)	Pacific coast of Asia	1982	H, B	WA	Willan, 1985b, 1987; Slack-Smith and Brearley 1987.	See text.
Perna canaliculus (Martyn)	New Zealand	? 1876	O, H	TAS	May 1923; Dartnall 1969 (as *Mytilus canaliculus*); Lucas 1980.	See text.
Neilo australis (Quoy and Gaimard)	New Zealand	1965	O	TAS	Greenhill 1965; Dartnall 1969.	May have arrived with shipments of *Ostrea lutaria*.
Paphirus largillierti (Philippi)	New Zealand	1950s or earlier	O	TAS	Greenhill 1965; Dartnall 1969	Most recently recorded in TAS in 1985. May have arrived in shipments of *Ostrea lutaria*.
Theora lubrica Gould	Pacific coast of Asia	1971	B	WA	Chalmer et al. 1976; Slack-Smith and Brearley 1987.	Possibly a naturally occurring species in Australia and New Zealand.
Polyplacophora .. (chitons)						
Amaurochiton glaucus (Gray)	New Zealand	? 1910	O	TAS	May 1923; Dartnall 1969.	Numerous specimens collected in TAS up to 1985.
Gastropoda .. (snails and slugs)						
Aeolidiella indica Bergh	Japan, New Zealand, South Africa, Mediterranean or New Zealand	?	H or B	NSW, QLD	Willan and Coleman 1984.	May be a widespread Indo-Pacific species occurring naturally in Australia.
Janolus hyalinus (Alder and Hancock)	Europe ?	1958	H	VIC	Burn 1958 (as *Janolus hyalina*); Miller and Willan 1986.	
Maoricolpus roseus (Quoy and Gaimard)	New Zealand	Between 1920s and 1940s	O	TAS	Greenhill 1965; Dartnall 1969; Turner 1983.	Most recently recorded from TAS in 1986. May have arrived in shipments of *Ostrea lutaria*.

Continued

Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
Okenia plana Babe	Japan	1977	H	NSW, QLD VIC	Willan and Coleman 1984. R. Burn (pers. comm.).	Also apparently introduced to New Zealand and California.
Polycera capensis (Quoy and Gaimard)	S. Africa	1927	H	NSW	Allan 1932 (as *Polycera conspicua*); Thompson 1975; Burn 1978; Willan and Coleman 1984.	Most recently recorded from Twofold Bay in 1986.
Polycera hedgpethi Marcus	California	1973 1973 1970s	H H H	NSW, VIC WA	Willan and Coleman 1984; R. Burn (pers. comm.).	Also apparently introduced to New Zealand and South Africa.
Thecacera pennigera (Montagu)	Unknown	1951	H	NSW	Allen 1953; Allan 1957; Willan 1976; Burn 1978; Willan and Coleman 1984.	
Zeacumantus subcarinatus (Sowerby)	New Zealand	1920s	U	NSW	Finlay 1927; Iredale 1936 (as *Zeacumantus subcarinata*).	
A TDIACEA .. (sea squirts)						
Molgula manhattensis (De Kay)	North Atlantic	1967 1975	H H	VIC QLD	Kott 1976. Kott 1985.	Australian populations may be ephemeral.
Styela clava Herdman	North western Pacific or Europe	1972	H	VIC	Holmes 1976; Kott 1985.	
Styela plicata (Lesueur)	Widespread	? 1878	H	NSW, subsequently reported from WA, SA, QLD.	Kott 1985.	
ECHINODERMATA .. (starfishes)						
Patiriella regularis (Verrill)	New Zealand	1930-1952	O	TAS	Dartnall 1969; Turner 1983; Turner 1986.	Appears to be expanding range in TAS at expense of native fauna.

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Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
BRACHIOPODA .. (lamp shells)						
Terebratella inconspicua (Sowerby)	New Zealand	? 1901	O	TAS	Tate and May 1901; Lodder 1902 (as *Terebratella rubicunda*); Dartnall 1969 (as *Terebratula inconspicua*).	Does not appear to have become established. No recent records.
POLYCHAETA .. (worms)						
Hydroides norvegica Gunnerus	European coasts	1885	H	Australia generally	Haswell 1884 (in Allen 1953).	May be a misidentification.
Mercierella enigmatica Fauvel	India	1932 1938	H H ? B	NSW WA Southern Australia	Allen 1953. Monro 1938 (in Allen 1953). ten Hove and Weerdenburg 1978.	Recorded from a wide variety of localities worldwide, including southern temperate waters.
Boccardia proboscidea Hartman	Japan or North-eastern Pacific	1977	B or H	VIC WA SA	Blake and Kudenov 1978 (in Carlton 1985); Dorsey 1982. Hartmann-Schröder 1981 Hutchings and Turvey 1984.	Although thought to be a recent migrant, now widespread in VIC.
Polydora ciliata Johnston	Europe	? 1885 1972	U U	NSW WA	Haswell 1885. Day 1975.	Possibly a misidentification.
Pseudopolydora paucibranchiata (Okudu)	Japan, New Zealand or northeastern Pacific	1973 1975 1979	B or H B or H ?	NSW VIC SA	Blake and Kudenov 1978. Blake and Kudenov 1978; Carlton 1985. Hutchings and Turvey 1984.	May occur naturally in Australia.
HYDROZOA .. (anemones)						
Bougainvillia ramosa van Beneden	Northern hemisphere	1918 or earlier	H	NSW	Briggs 1931; Allen 1953.	

Continued

Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
BRYOZOA .. (lace corals)						
Anguinella palmata van Benden	Atlantic coasts	1953	H	NSW	Allen 1953.	
Bugula flabellata Thompson	Atlantic and Mediterranean coasts	? 1950s	H	NSW, SA	Allen and Ferguson Wood 1950; Allen 1953.	
Conopeum tubigerum Osburn	Atlantic coast (West Indies)	1953	H	QLD	Allen 1953.	
Schizoporella unicornis Johnston	Japan	? 1940s post 1953	? H H	QLD, NSW WA, SA	Allen 1953. Ferguson Wood and Allen 1958.	
Watersipora arcuata Banta	Mexico	(post ? 1889)	H	QLD, NSW SA, WA	Allen 1953. Ferguson Wood and Allen 1958; Wisely 1958 (as *W. cucullata*); Banta 1969a, b; Brock 1985.	
RHODOPHYTA .. (red seaweeds)						
Antithamnionella spirographidis (Schiffner)	Europe	? 1968	H	SA NSW	Wollaston 1968. Womersley 1981.	
Polysiphonia brodiaei (Dillwyn)	Northern Europe, Washington California or Japan	1940 1959 1973	H H H	TAS, VIC SA	Womersley 1979 Womersley 1981.	
Polysiphonia pungens Hollenberg	Pacific coast of Canada	1969	H	VIC	Womersley 1979; Womersley 1981.	
PHAEOPHYTA .. (brown seaweeds)						
Arthrocladia villosa (Hudson)	Temperate North Atlantic or Mediterranean	1981	"by shipping"	SA	Skinner and Womersley 1983.	

Continued

Table 1. Continued

Species	Possible origin of introduction	Possible date of introduction	Probable means of introduction	Locations within Australia	References	General comments
Stictyosiphon soriferus (Reinke)	North Atlantic or Mediterranean	1969 1975 1979	"by shipping"	VIC, SA, WA	Skinner and Womersley 1983.	
Striaria attenuata Greville	North Atlantic, Mediterranean or New Zealand	1950 1978 1985	"by shipping"	TAS, WA NSW	Skinner and Womersley 1983. King and Wheeler 1985.	
Undaria pinnatifida (Harvey)	Japan	1987	B	TAS	Sanderson 1988	See text.
DINOPHYCEAE .. (dinoflagellates)						
Gymnodinium catenatum	Japan	1980	B	TAS	Hallegraeff and Sumner 1986; Hallegraeff et al. 1988a, b	See text.

Key to probable means of introduction:

B = Ballast water
D = Deliberate
H = Hull fouling
O = With oysters
U = Uncertain

Abbreviations:

NSW = New South Wales
QLD = Queensland
SA = South Australia
TAS = Tasmania
VIC = Victoria
WA = Western Australia

general comments on relevant aspects of their biology and status, as appropriate. Species from this list which it is considered could have significant ecological impacts are discussed in more detail below.

Decapod Crustaceans

The European shore crab Carcinus maenas

Carcinus maenas is a brachyuran decapod belonging to the family Portunidae, and is known under a variety of common names, including the European shore crab, North Atlantic edible shore crab and green crab. It is native to Europe, but has a wide distribution elsewhere, often attributed to introductions (Stephenson 1972; Joska and Branch 1986). A description of this species, including its main distinguishing characters, appears in Joska and Branch (1986). It is also included in the keys of Stephenson (1972) to the Portunidae of the Indo-Pacific.

The first records of *C. maenas* in Australia date back to the turn of this century (Fulton and Grant 1900, 1901), when it was common in Port Phillip Bay, Victoria. It was thought to have been introduced to Australia via Port Phillip Bay sometime after 1856, and Fulton and Grant (1901) suggested that the vector for its introduction could have been the hull fouling communities of ships arriving from Europe, attracted by the gold rushes of the 1850s.

Another possible dispersal mechanism had earlier been noted by G.M. Thomson, a crustacean taxonomist who is quoted by Fulton and Grant (1900) as saying: "There is no great difficulty in its being introduced, say in ballast, etc., for it is most abundant in the old country." It is unclear whether Thomson was referring to solid ballast, which had long been used, or to ballast water, which had only recently come into vogue (Carlton 1985). In either case, this is one of the earliest literature records of ballast as a possible dispersal mechanism for marine animals.

Since that original record of *C. maenas* in Victoria, the species has considerably extended its geographical range in Australia. Allen (1953) reported that it ranged from Western Port to Mallacoota, Victoria. It now occurs from Port Phillip Bay, Victoria, to as far north as Narooma, NSW (Zeidler 1978), being common at Twofold Bay in southern NSW (Hutchings et al. 1986a).

Carcinus maenas was also recorded from South Australia and Western Australia by Zeidler (1978, 1988) and Rosenzweig (1984). Both of these authors state that these isolated colonies are unlikely to have resulted from natural dispersal of the species within Australia, but rather from separate recent introductions.

Rosenzweig (1984) suggests that the introduction vector could have been ships' fouling communities, as suggested by Fulton and Grant (1901). However, ballast water as a dispersal mechanism would seem equally plausible.

Overseas studies have revealed that the reproductive activity of this species is limited by low temperatures (Vermeij 1981) and exposure to wave action (Joska and Branch 1986). Unfortunately, the factors which may restrict its spread in Australia, such as the presence of predators or competitors, and its reproductive activity here, are unknown. Without some study of the biology of this species in Australia, it is difficult to predict its final geographical distribution. Attention to the continued spread of *C. maenas* in Australia, and study of it, would be wise for two reasons: (1) Fears expressed by Joska and Branch (1986) that the introduction of this large aggressive predator to South Africa could threaten the existence of a number of native species appear to be well founded. They may be equally applicable to the Australian situation in view of the problems *C. maenas* has caused the American shellfish industry, as reported by Joska and Branch (1986). (2) This species could possibly represent an untapped and potentially exploitable marine resource in Australia in that future opportunities may exist for aquaculture or fishing of this species.

The Japanese shrimp Palaemon macrodactylus

Although Williams et al. (1978, 1982) noted this palaemonid shrimp as an introduction to South Australia via ballast water, we have not been able to verify these records. The only substantiated Australian record appears in Buckworth (1979), who recorded *P. macrodactylus* from a fly ash dam near Vales Point Power Station, which is connected via Mannering Hole to Lake Macquarie, near Newcastle, NSW.

Carlton (1985) repeated the record of Williams et al. (1978) and also cited Holthuis (1980) as noting an introduction of *P. macrodactylus* to Australia. Holthuis (1980), however, simply states

"Now also found in Australia", and gives no further details, though it is likely that he was referring to Buckworth's (1979) record.

Buckworth (1979) does not discuss a dispersal mechanism for the introduction. Newman (1963), however, considered transport of this species to San Francisco Bay, USA, via oysters or ships' hull fouling, and rejected both possibilities as being unlikely for such a subtidal swimming organism. Newman (1963) proposed that the dispersal mechanism was possibly the seawater system of a ship (i.e., internal plumbing using seawater).

Carlton (1985) considered that the introduction of this shrimp, which was first known from the northwestern Pacific (Newman 1963; Holthuis 1980), to San Francisco Bay could have involved ballast water transport and notes that subsequent introductions to other areas of California may have been the result of accidental or deliberate releases by fishermen using the species for bait.

Bivalve Molluscs

The Pacific oyster Crassostrea gigas

The bulk of the information on the Pacific oyster outlined below has been extracted from a recent report on its current status in Australian waters by Holliday and Nell (1987).

Australia has an efficient and highly profitable (worth about A$35 million per year) intertidal oyster industry, based on the native Sydney rock oyster *Saccostrea commercialis* (Ostreidae), and centered on the coasts of NSW and southern Queensland.

The farming of the introduced Pacific or Japanese oyster *Crassostrea gigas*, which was introduced to Australia by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in the late 1940s and early 1950s, began in Tasmania in the early 1970s. This oyster is now also cultivated in South Australia, and present annual production is about 4 million dozen oysters valued at about A$10 million.

The Pacific oyster, which is native to Japan (Korringa 1976), was deliberately introduced to many countries in the northern hemisphere, in some cases to create an oyster culture industry and in others to replace an existing industry based on indigenous species affected by disease (Coleman 1986). It is also cultivated in South America and has been widely introduced to various countries in the South Pacific and the Indian Ocean.

In New Zealand, live Pacific oysters were first reported in 1971, but old shell specimens date back as far as 1958. Since 1978 New Zealand oyster farmers have been cultivating the Pacific oyster instead of the native rock oyster (*S. commercialis*), as the market price obtained for both species was similar, while the more rapid growth of the Pacific oyster meant that it could meet the local and export market size in a shorter period.

The Pacific oyster was introduced to Australia on the basis that cultivation of native oysters in the more southern states was marginal (Sumner 1972), and NSW production was unlikely to increase while cultivation was restricted to the Sydney rock oyster. NSW Fisheries officers strongly opposed the introduction and, in fact, an initial shipment which arrived from Japan was destroyed in 1940.

Introductions were, however, subsequently made during the period 1947 to 1970. The "Miyagi" strain is grown in New Zealand and Tasmania and is thought to be the strain presently spreading in Port Stephens and other areas of NSW.

Plantings were made in Oyster Bay, Western Australia (where they did not survive) and in Pittwater, Tasmania (Ferguson Wood 1948). Oysters from Pittwater were later transported to both Port Sorell, Tasmania, and Mallacoota, Victoria, and (unsuccessfully) to South Australia. Today, Pacific oysters form the basis of a significant industry in Tasmania.

After the first settlement of Pacific oysters in NSW was recorded in the Pambula River in 1967, an extensive survey of other NSW estuaries was begun. The spread continued along the NSW coastline to Port Stephens in 1973, the Richmond River at Ballina in 1975, and eventually as far as Moreton Bay in southern Queensland. Oyster farmers were notified of the spread and were educated to identify and destroy these oysters (Wolf and Medcof 1974; Medcof and Wolf 1975).

The Pacific oyster became well established in Port Stephens over the summers of 1984-85 and 1985-86, where it was largely confined to the inner estuary, the traditional growing area for the Sydney rock oyster (Holliday and Nell 1985).

Pacific oysters grow more rapidly than Sydney rock oysters and interfere with conventional stick culture by overgrowing the native oysters. The shells of Pacific oysters are usually thinner and open wider when feeding than those of the Sydney rock oyster and the former are, therefore, more susceptible to fish, crab and stingray predation. Its susceptibility to a major disease affecting the Sydney rock oyster in the northern estuaries of NSW (QX disease), however, is as yet unknown, but it has been shown to be resistant to similar parasitic diseases overseas.

The future of the Pacific oyster in NSW will largely depend on its ability to spread and survive, and on efforts made by oyster farmers to minimize its occurrence. Its keeping quality could also present a problem if it were to be farmed and marketed using the traditional systems employed for the Sydney rock oyster (e.g., because of their shorter survival time out of water, Pacific oysters would have to be opened and refrigerated much sooner after depuration; this could disadvantage oyster farmers who do not have their own processing facilities close to the growing area).

The greatest difficulty facing NSW oyster farmers with the impending spread of the Pacific oyster is the potential problem associated with "overcatch" (the settlement of juvenile oysters on the established crop), which may greatly increase costly culling operations needed to remove unwanted "jockey" oysters.

In 1985, in an attempt to prevent the spread of the Pacific oyster throughout NSW and reduce its abundance in Port Stephens, the NSW Agriculture and Fisheries Department declared the Pacific oyster a noxious fish, making the cultivation and the presence of this oyster on leases an offense. Oyster farmers in NSW are obliged to make every reasonable effort to destroy any Pacific oysters on their leases, and all Pacific oysters on a lease must be destroyed before any Sydney rock oysters are removed. The shipment of oysters out of Port Stephens for further cultivation in other estuaries is now strictly controlled (Holliday and Nell 1987).

The New Zealand oyster Ostrea lutaria

Two distinct species of oyster, *Ostrea angasi* and *O. lutaria*, have often been confused in the literature causing problems in interpreting the evidence for the suggested introduction of the New Zealand species *O. lutaria* into Tasmania.

Dartnall (1969) records that *O. angasi*, which is also native to Australia, was the oyster transported from New Zealand to Australia. However, Powell (1979) lists *O. angasi* as one of the species that was often referred to as *O. lutaria*. Although Sumner (1974) has suggested that relict populations of *O. lutaria* may exist in Tasmania, our enquiries have failed to substantiate this.

Other mollusc species, including the bivalves *Neilo australis* and *Paphirus largillierti* and the gastropod *Maoricolpus roseus*, may have also been introduced to Tasmania together with shipments of these oysters from New Zealand (Dartnall 1969).

The Asian mussel Musculista senhousia

The Asian mussel *Musculista senhousia* (Mytilidae), which was originally described from China, is indigenous to eastern Asia and ranges naturally from the western Pacific coasts of Siberia and the Kurile Islands south to Singapore (Slack-Smith and Brearley 1987). Its introduction to Australasian waters within the last decade has been documented by Willan (1985a, b; 1987) and Slack-Smith and Brearley (1987).

Musculista senhousia adapts to a wide variety of habitats, being reported from the intertidal zone down to depths of 20m (Slack-Smith and Brearley 1987). On soft substrates, dense colonies may be formed when individuals secrete tough hair-like byssal threads for attachment. These become interwoven and trap sediment, forming "nests" or mats (Willan 1985b; Slack-Smith and Brearley 1987). Such behaviour has led to the common name of "bag mussel" for this species. On hard substrates *M. senhousia* is an encrusting species, attaching with its byssal threads but apparently not forming dense colonies (Willan 1985b; Slack-Smith and Brearley 1987).

Recent records of *M. senhousia* in Australia date from February 1982 when juvenile specimens were collected in the Swan River estuary, Western Australia. Adult specimens were obtained in January 1983 from the same locality, and this species is now well established in this estuary. The species has now also spread into the nearby international port of Fremantle, but no other records from Australia have been substantiated (Willan 1987).

Musculista senhousia has also been reported by Willan (1985a,b, 1987) from Auckland Harbour, New Zealand, where its establishment coincided with the period of its establishment in Western Australia.

The sudden isolated nature of these first records, far removed from the species' native shores, and the fact that they are both from major port areas, suggest that its occurrence is not the result of a natural expansion of the species' range. (Willan 1985b).

Other introductions of *M. senhousia* have apparently occurred overseas. It was first reported from the west coast of the USA in 1944 and has since become established there and is extending its range (Willan 1985b). *M. senhousia* is believed to have been brought into the USA with shipments of Japanese oysters (Slack-Smith and Brearley 1987).

The type of dispersal mechanism leading to the establishment of *M. senhousia* in Australia is not known, although Slack-Smith and Brearley (1987) have suggested transport among fouling organisms on ships' hulls or in water intake pipes and ducts, or alternatively as larvae in the ballast water of bulk cargo ships.

To resolve which of these is the true disperal mechanism is perhaps not possible at present as we lack basic biological information on this species such as the length of its larval life (Slack-Smith and Brearley 1987).

Whatever the origin and mode of introduction of *M. senhousia* to Australia, its presence is cause for some anxiety. Mat building by this species has the capacity to radically alter the biota and movement of soft sediments. This "nesting" behavior is already occurring in the Swan estuary, with records of densities of individuals as high as 2,600 m^2, which exceed those reported from its native shores (Slack-Smith and Brearley 1987).

The New Zealand mussel Perna canaliculus

May (1923) noted that *Perna canaliculus* was rare in Australia and may have been introduced from New Zealand, but did not suggest a dispersal mechanism. Dartnall (1969) repeated May's record and discussed the possibility that the import of oysters from New Zealand could be the dispersal mechanism for a number of introductions, including *P. canaliculus*. It seems unlikely that this was the mechanism for its introduction, however, as specimens collected from Bridport, Tasmania, and dated 1876, are held at the Australian Museum (P. Colman, pers. comm.), while the importation of New Zealand oysters apparently did not occur until the mid 1880s (Dartnall 1969; Sumner 1972). Lucas (1980) notes that *P. canaliculus* may have been introduced, alternatively, through ships' fouling. In any event, this species does not appear to have become well established, if at all, as no specimens are held in the collections of the Tasmanian Museum (E. Turner, pers. comm.).

In recent years this species, which is cultured extensively in New Zealand, has been imported in large quantities to Australia, where it arrives for sale freshly killed by chilling. Although representations were made by New Zealand trade authorities to import these mussels alive, the risks of the species becoming established in Australian waters were judged to be too great for Australian authorities to accede to this proposal.

Algae

Dinoflagellates

Apart from the entrainment of marine organisms, including planktonic algae, in ships' ballast water itself, Williams et al. (1982, 1988) have also pointed out that such organisms can also be transported in the sediments of ships' ballast water tanks. Most recently, Hallegraeff et al. (1988a) have highlighted the serious problems caused by toxic dinoflagellates, the spores of which could be contained in these sediments.

Dinoflagellates are microscopic one-celled algae which form an important component of the planktonic diet of shellfish, some species of which produce potent neurological toxins which can find their way through fish and shellfish to humans. Sometimes, these toxins can cause paralytic shellfish poisoning which, in extreme cases, can lead to death through respiratory paralysis.

With the exception of the organism causing ciguatera fish poisoning (Gillespie 1980), such toxic dinoflagellates were virtually unknown from Australian waters until recently. Hallegraeff and Sumner (1986), following a general plankton survey of Tasmanian coastal waters in 1985-86, reported "dense blooms (10,000 to 100,000 cells per liter) of the toxic dinoflagellate *Gymnodinium catenatum*, which has caused human illnesses in Mexico and Spain." This dinoflagellate appeared to be confined to the Huon and Derwent estuary systems, where a number of shellfish farms were in various stages of development. Unacceptably high toxin concentrations were detected in commercial mussels *(Mytilus edulis planulatus)* and oysters *(Crassostrea gigas)*, and also in three species of scallops (Hallegraeff and Sumner 1986). Toxic shellfish were confined to the Huon estuary during March 1986, where five shellfish farms had to be temporarily closed, but then spread to the d'Entrecasteaux Channel region in May-June, where a further nine farms had to be closed (Hallegraeff and Summer 1986). Shellfish toxicity problems were also later documented for the first time from inshore waters near Melbourne and Adelaide (Hallegraeff et al. 1988b).

Hallegraeff et al. (1988a) noted that: "On a global scale, both the number and intensity of toxic dinoflagellate blooms affecting fish and shellfish farms seem to be on the rise and their geographic extent seems to be spreading. To some degree, this may be simply attributed to our increased awareness of toxic species and increased utilization of coastal waters for aquaculture, but transport of these organisms by humans may also be contributing. Possible methods of spreading include the carry-over of cyst stages with the transport of shellfish stocks from one area to another, or the transport of dinoflagellates or their benthic resting spores (cysts) in the ballast holds of large cargo ships."

Gymnodinium catenatum, which was first noticed in southern Tasmania waters in 1980, produces a resistant resting spore which under favorable conditions can germinate and seed new dinoflagellate blooms in the water column. "Extensive surveys of Tasmanian waters and sediments have indicated that *G. catenatum* is confined to the Derwent and Huon estuaries near the main shipping port of Hobart as well as the adjacent woodchip harbor of Triabunna. Neither *G. catenatum* nor its resting spore has ever been seen in surveys of other Tasmanian or Australian waters. Previously this micro-algal species was known only from Mexico, Argentina, Spain and Japan (including Yatshusiro, which is a major port of origin of Japanese woodchip carriers)" (Hallegraeff et al. 1988a). It is difficult to prove conclusively that this dinoflagellate has been introduced by ballast water, as so far examination of the ballast water and sediments from Japanese woodchip vessels at Triabunna has not revealed any *G. catenatum* cysts. However, the sediments sampled from three of six ships tested were found to contain viable dinoflagellate spores, including those of another toxic species (Hallegraeff et al. 1988a).

Macroalgae

Although Williams et al. (1982) and Carlton (1985) made mention of the entrainment of planktonic algae in ships' ballast tanks, until very recently (e.g., Sanderson 1988) no consideration appears to have been given to the possibility of free floating macroalgae being introduced in ballast water. At this stage we do not know if ballast water is an important vector for such algae or not, though future studies should consider this possibility. In any case, macroalgal spores are known to survive for very long periods in total darkness (up to 120 days) before germinating (Moss and Sheader 1973) and could potentially be transported via ballast water.

As in the case of some of the animals discussed above, transfer by shipping has long been used to explain the disjunct distributions of algae once an "alien" species was found. Slow, wooden-hulled sailing ships may have dispersed many fouling species before adequate recording of indigenous species began. Modern antifouling technology has probably decreased the chances of dispersal of such fouling species, though the occurrence of fouling macroalgae, in particular *Enteromorpha* and *Ectocarpus,* on conventional antifouling paints has been well documented (see Callow 1986). Evans (1981) has observed that marine algal cells possess a great plasticity and remarkable capacity to exploit any deficiencies, however small, in increasingly sophisticated antifouling technology.

Another method by which macroalgae and other marine organisms could be introduced is via "barges and oil platforms which are towed across the oceans at low speed, their submerged parts are not coated with antifouling paints, and they are moored for long periods in different parts of the world" (Foster and Willan 1979). Drilling rigs have been used to explain new records of marine organisms in South Africa (Joska and Branch 1986) and New Zealand (Foster and Willan 1979), and they could also be responsible for the transfer of such organisms around parts of the Australian coastline.

In Australia, three species of Rhodophyta (red algae) have been introduced into southern waters, namely *Antithamnionella spirographidis*, *Polysiphonia brodiaei* and *P. pungens*, all of "which may well have come on ships' hulls" (Womersley 1981). These were followed by the first records of three northern hemisphere Phaeophyta (brown algae) species, namely *Striaria attenuata*, *Strictyosiphon soriferus* and *Arthrocladia villosa*, in the same area (Skinner and Womersley 1983). In both papers, the introductions were explained by ships' fouling, "since the known Australian localities are near harbours" (Skinner and Womersley 1983). The authors do not discuss whether these algae are "pest" species or have any nuisance value, only that they occur.

Recently another species of Phaeophyta has been reported as occurring in Tasmania (Sanderson 1988). This is the Japanese laminarian kelp *Undaria pinnatifida*, which has become established along about 4 km of rocky coastline near Rheban, about 10 km to the south of Triabunna on the east coast of Tasmania. Clumps of plants up to 80 cm tall had colonized previously bare rocks in this area from near low water mark down to depths of 8 m. The numbers of these plants present were estimated to be in the tens of thousands.

In Japan, *Undaria* (known there as "wakame") is an important edible seaweed crop, and is also cultivated extensively to feed juvenile cultured abalone (Sanderson 1988). This species has also been introduced into Wellington Harbour, New Zealand (Hay and Lucken 1987), probably by Korean and Japanese squid fishing boats.

With regard to its introduction to Tasmania, Sanderson (1988) speculates that "fragments of plants or spores may have been released with ballast waters" from ships arriving to carry woodchips from Triabunna to Japan. As these plants form a thick canopy, Sanderson (1988) suggests that there could be competition for space and light with the native brown seaweeds *Phyllospora, Sargassum* and *Ecklonia,* which in turn could affect local fisheries for sea urchins and abalone which feed on these algae. More recently, Sanderson and Barrett (1989) have speculated that this alga "could infect the Australian coastline from Cape Leeuwin (WA) in the south west to Woolongong (NSW) in the south east", and that it "is set to become a conspicuous part of the subtidal marine flora of southern Australian waters".

Discussion

In Australia, the Australian National Parks and Wildlife Service regulates and controls the importation of all living marine organisms through the Wildlife Protection (Regulation of Exports and Imports) Act 1982.

Apart from deliberate introductions, and accidental ones known or thought to be associated with them (e.g., Dartnall 1969), many other marine organisms have apparently disjunct distributions which are difficult to explain naturally. Marine organisms often have a pelagic larval stage which may be dispersed naturally by ocean currents, resulting in some species occurring over a wide area. But some species, according to the literature, have disjunct distributions which cannot be explained in this way, and other explanations have been put forward to explain these distributions. For example, several species of invertebrate animals and some plants have apparently been transported as fouling organisms on the bottoms of ships, including the New Zealand barnacle *Elminius modestus* (Bishop 1951), the isopod crustacean *Cymodoce tuberculata* (Chilton 1910), and the alga *Arthrocladia villosia* (Skinner and Womersley 1983).

Certain processes of interchange, however, may have operated over longer periods than that during which the identification and documentation of the flora and fauna of a region may have occurred. Some organisms are such "seasoned travellers" (Woods 1974) that it is now very difficult to be sure of their country of origin. Rumors of deliberate "plantings" and other quarantine improprieties also abound in the literature, e.g., in Dartnall (1969, p. 53), Sumner (1974, p. 4), Medcof and Wolf (1975, p. 36) and Carlton (1985, p. 315).

In a previous paper (Pollard and Hutchings, this vol.), we noted that ballast water has frequently been suggested as a vector of introduced marine organisms, although it is difficult to prove. The hypothesis is not new. Carlton (1985) gives examples dating from 1908 where this mode of transport was invoked to explain the distributions of marine organisms. Carlton (1987) also suggests that transport via ballast water across the Pacific may be far more prevalent than across other oceans. However, it should be pointed out that the marine invertebrate fauna of much of the Pacific is poorly known and that the occurrence of species with apparently disjunct distributions may be simply a reflection of limited collecting.

The first examination of ballast water itself was recorded by Medcof (1975) and carried out in Australia (Carlton 1985). This study showed that living marine organisms were present in the ballast water examined and could survive oceanic transport.

Williams et al. (1982, 1988) reported on follow-up studies which confirmed and reinforced Medcof's findings. They also showed that sediment which accumulates in ships' ballast tanks and is disposed of overboard could act as an additional dispersal mechanism and this was confirmed by Hutchings et al. (1986a, b).

Overseas studies of ballast water have also been conducted in the USA and Canada (Carlton 1985). Together these studies show that an extremely wide variety of organisms are to be found in ships' ballast tanks, including larval and juvenile stages and small adults.

Medcof (1975) and Williams et al. (1982, 1988) addressed the question of whether these animals survived their discharge. Overall, their data did indicate that it would be possible for marine animals to withstand the physical and chemical rigors associated with this mode of transport, but were not conclusive. However, as Williams et al. (1982) stated, "the amount and frequency with which water is discharged makes it a prime candidate for the successful invasion of introduced species."

Williams et al. (1982) concluded that none of the animals identified from ballast water or sediment in their studies appeared very likely to be a threat as either a competitor, commensal, predator or parasite of Australian marine species. However, they did qualify this statement by making the point that the problem of nominating which particular species, when introduced into a new locality, could pose such a threat was a very difficult one. Furthermore, they indicated that many of the organisms not identified in their survey (such as juvenile polychaete worms and molluscs) did have the potential to become pests in Australia.

This study by Williams et al. (1982) increased awareness in the Australian scientific community of the potential problems associated with the discharge of ballast water into Australian ports and also recommended the future treatment of ballast water to reduce the likelihood of introducing further exotic species. Paxton and Hoese (1985) subsequently echoed this call for sterilization of ballast waters to ensure that harmful introductions do not occur. Willan (1987) has also suggested the need for more appropriate quarantine measures at ports.

In late 1989, the Bureau of Rural Resources (Federal Department of Primary Industries and Energy) initiated a Scientific Working Group on Ballast Water which has developed an extensive research program for which it is currently seeking funds. It is hoped that a series of research projects on the feasibility of treating ballast water and the distribution of toxic dinoflagellates within Australian ports, together with investigations of the effects of particular introductions on the marine environment, will be initiated shortly.

In addition, the Australian Quarantine and Inspection Service, in February 1990, introduced voluntary guidelines to shipping for the discharge of ballast water into Australian ports. At this stage these guidelines are designed to prevent the entry and spread of exotic organisms such as toxic dinoflagellates which can contaminate shellfish. Ships' masters are being asked to minimize sediment discharge when ballast water is being released, and to avoid taking on ballast water in ports where toxic dinoflagellate blooms are occurring. More details are available from the Australian Quarantine Service. The Australian Federal Department of Transport has also recently presented a paper on "Controls on Discharge of Ballast Water" at the meeting of the Marine Environment Protection

Committee of the International Maritime Organisation held in March 1990 in London.

These events indicate an increasing awareness by Australian authorities of the problems posed by the introduction of exotic marine organisms into Australia, and the need to investigate these introductions and to develop the necessary technology to minimize such introductions in the future.

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References

Allan, J.K. 1932. Australian nudibranchs. Aust. Zool. 7(2): 87-105.

Allan, J.K. 1957. Some Opisthobranchia (Class Gastropoda) new to Australia or otherwise of interest. J. Malacol. Soc. Aust. 1(1): 3-7.

Allen, F.E. 1953. Distribution of marine invertebrates by ships. Aust. J. Mar. Freshw. Res. 4(2): 307-316.

Allen, F.E. and E.J. Ferguson Wood. 1950. Investigations on underwater fouling. II. The biology of fouling in Australia: results of a year's research. Aust. J. Mar. Freshw. Res. 1(1): 92-105.

Banta, W.C. 1969a. *Watersipora arcuata*, a new species in the *subovoidea-cucullata-nigra* complex (Bryozoa, Cheilostomata). Bull. Southern Calif. Acad. Sci. 68(2): 96-102.

Banta, W.C. 1969b. The recent introduction of *Watersipora arcuata* Banta (Bryozoa, Cheilostomata) as a fouling pest in southern California. Bull. Southern Calif. Acad. Sci. 68(4): 248-251.

Bishop, W.H. 1951. Distribution of barnacles by ships. Nature (London) 167: 531.

Blake, J.A. and J.D. Kudenov. 1978. The Spionidae (Polychaeta) from southeastern Australia and adjacent areas with a revision of the genera. Mem. Nat. Mus. Vic. 39: 171 - 280.

Bowman, T. E., N.L. Bruce and J.D. Standing. 1981. Recent introduction of the cirolanid isopod crustacean *Cirolana arcuata* into San Francisco Bay. J. Crust. Biol. 1(4): 545-557.

Briggs, E. A. 1931. Notes on Australian athecate hydroids. Rec. Aust. Mus. 18(5): 279-282.

Brock, B. J. 1985. South Australian fouling Bryozoa, p. 45-49. *In* C. Nielsen and G. P. Larwood (eds.) Bryozoa: ordovician to recent. Papers presented at the 6th International Conference on Bryozoa, Vienna, 1982. Olsen and Olsen, Fredensborg.

Bruce, N. L. 1986. Cirolanidae (Crustacea: Isopoda) of Australia. Rec. Aust. Mus. Supplement No.6, 239 p.

Buckworth, R. 1979. Aspects of the population dynamics of *Palaemon macrodactylus* (Decapoda: Palaemonidae) in Lake Mannering, N.S.W., and in the laboratory. University of New South Wales, Sydney. M.Sc. Qual. thesis. 65 p.

Burn, N. L. 1978. A new record of *Thecacera pennigera* (Montagu, 1815) (Opisthobranchia: Polyceridae) from New South Wales. J. Malacol. Soc. Aust. 4(1-2): 22.

Burn, R. 1958. Further Victorian Opisthobranchia. J. Malacol. Soc. Aust. 2: 20-36.

Callow, M. E. 1986. Fouling algae from 'in-service' ships. Bot. Mar. 29: 351-357.

Carlton, J. T. 1985. Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. Ann. Rev. Oceanogr. Mar. Biol. 23: 313-371.

Carlton, J. T. 1987. Patterns of transoceanic marine biological invasions in the Pacific Ocean. Bull. Mar. Sci. 41 (2): 452-465.

Carlton, J. T. and E.W. Iverson. 1981. Biogeography and natural history of *Sphaeroma walkeri* Stebbing (Crustacea: Isopoda) and its introduction to San Diego Bay, California. J. Nat. Hist. 15: 31-95.

Castles, I. C. 1986. Year Book of Australia 1986, No. 70. Australian Bureau of Statistics, Canberra. p. 470-473.

Chalmer, P. N., E.P. Hodgkin and G.W. Kendrick. 1976. Benthic faunal changes in a seasonal estuary of south-western Australia. Rec. Western Aust. Mus. 4(4): 383-410.

Chilton, C. 1910. Note on the dispersal of marine Crustacea by means of ships. Trans. N.Z. Inst. 43: 131-133.

Coleman, N. 1986. A review of introductions of the Pacific oyster *Crassostrea gigas* around the world and a discussion of the possible ecological consequences of introducing the species into Victoria, Australia. Marine Science Laboratories, Queenscliff, Victoria, Tech. Rep. No. 56, 39 p.

Coleman, N. and N. Hickman. 1986. Pacific oyster found in Victoria. Aust. Fish. 45(6): 8, 10.

Dartnall, A. J. 1969. New Zealand sea stars in Tasmania. Pap. Proc. R. Soc. Tasmania 103: 53-55.

Day, J. H. 1975. On a collection of Polychaeta from intertidal and shallow reefs near Perth, Western Australia. Rec. Western Aust. Mus. 3(3): 167-208.

Dorsey, J.H. 1982. Intertidal community offshore from the Werribee Sewage Treatment Farm: an opportunistic infaunal assemblage. Aust. J. Mar. Freshw. Res. 33: 45-54

Evans, L.V. 1981. Marine algae and fouling. A review, with particular reference to ship-fouling. Bot. Mar. 24: 167-171.

Ferguson Wood, E.J. 1948. Japanese seed oysters brought to Australia. Fish. Newsl. 7(1): 6-7, 23.

Ferguson Wood, E.J. and F.E. Allen. 1958. Common marine fouling organisms of Australian waters. Department of the Navy, Melbourne. 23 p.

Finlay, H.J. 1927. A further commentary on New Zealand molluscan systematics. Trans. Proc. N.Z. Inst. 57: 320-340.

Foster, B.A. and R.C. Willan. 1979. Foreign barnacles transported to New Zealand on an oil platform. N.Z. J. Mar. Freshw. Res. 13(1): 143-149.

Fulton, S.W. and F.E. Grant. 1900. Note on the occurrence of the European crab, *Carcinus maenas* Leach, in Port Phillip. Victorian Naturalist 17(8): 147-148.

Fulton, S.W. and F.E. Grant. 1901. Some little known Victorian decapod Crustacea with description of a new species. Proc. R. Soc. Victoria 14(2): 55-64.

Galtsoff, P.S. 1964. The American oyster, *Crassostrea virginica* Gmelin. US Fish. Bull. 64. US Dept. of the Interior, Washington. 399 p.

Gillespie, N. 1980. Fish poisoning causes concern in Queensland. Aust. Fish. 39: 28-32.

Greenhill, J.F. 1965. New records of marine mollusca from Tasmania. Pap. Proc. R. Soc. Tasmania 99: 67-70.

Hallegraeff, G., C. Bolch, B. Koerbin and J. Bryan. 1988a. Ballast water a danger to aquaculture. Aust. Fish. 47(7): 32-34.

Hallegraeff, G., D.A. Steffensen and R. Wetherbee. 1988b. Three estuarine Australian dinoflagellates that can produce paralytic shellfish toxins. J. Plankton Res. 10: 533-541.

Hallegraeff, G. and C. Sumner. 1986. Toxic plankton blooms affect shellfish farms. Aust. Fish. 45(12): 15-18.

Harrison, K. and D.M. Holdich. 1982a. Revision of the genera *Dynamenella, Ischromene, Dynamenopsis* and *Cymodocella* (Crustacea: Isopoda), including a new genus and five new species of eubranchiate sphaeromatids from Queensland waters. J. Crust. Biol. 2(1): 84-119.

Harrison, K. and D.M. Holdich. 1982b. New eubranchiate sphaeromatid isopods from Queensland waters. Mem. Qd. Mus. 20(3): 421-446.

Harrison, K. and D.M. Holdich. 1984. Hemibranchiate sphaeromatids (Crustacea: Isopoda) from Queensland, Australia, with a world- wide review of the genera discussed. Zool. J. Linn. Soc. 81: 275-387.

Hartmann-Schröder, G. 1981. Zur Kenntnis des Eulitorals der australischen Küsten unter besonderer Berücksichtigung der Polychaeten und Ostracoden. Teil 6. Die Polychaeten der tropisch-subtropischen Westküste Australiens (zwischen Exmouth im Norden und Cervantes im Süden). Mitt. Hamb. zool. Mus. Inst. 78: 19-96.

Haswell, W.A. 1884. The marine annelids of the order Serpulea. Some observations on their anatomy, with the characteristics of the Australian species. Proc. Linn. Soc. N.S.W. 9(3): 649-75.

Haswell, W.A. 1885. Jottings from the biological laboratory of Sydney University. Proc. Linn. Soc. N.S.W. 10: 273-275.

Hay, C.H. and P.A. Lucken. 1987. The Asian kelp *Undaria pinnatifida* (Phaeophyta, Laminariales) found in a New Zealand harbour. N.Z. J. Bot. 25: 329-332.

Holdich, D.M. and K. Harrison. 1983. Sphaeromatid isopods (Crustacea) from brackish waters in Queensland, Australia. Zool. Scr. 12(2): 127-140.

Holliday, J.E. and J.A. Nell. 1985. Concern over Pacific oyster in Port Stephens. Aust. Fish. 44(11): 29-31.

Holliday, J.E. and J.A. Nell. 1987. The Pacific oyster in New South Wales. Agfact No. F2.1.3., N.S.W. Department of Agriculture, Sydney. 4 p.

Holmes, N. 1976. Occurrence of the ascidian *Stylela clava* Herdman in Hobsons Bay, Victoria: a new record for the Southern Hemisphere. Proc. R. Soc. Victoria 88(1-2): 115-116.

Holthuis, L.B. 1980. FAO Species Catalogue, Volume 1 - Shrimps and Prawns of the World. An Annotated Catalogue of Species of Interest to Fisheries. FAO Fisheries Synopsis No. 125. 270 p.

Hove, H.A. ten, and J.C.A. Weerdenburg. 1978. A generic revision of the brackish-water serpulid *Ficopomatus* Southern 1921 (Polychaeta: Serpulinae), including *Mercierella* Fauvel 1923, *Sphaeropomatus* Treadwell 1934, *Mercierellopsis* Rioja 1945 and *Neopomatus* Pillai 1960. Biol. Bull. 154: 96-120.

Hutchings, P.A. 1983. The wetlands of Fullerton Cove, Hunter River, New South Wales. Wetlands (Australia) 3(1): 12-21.

Hutchings, P.A. and S.P. Turvey. 1984. The Spionidae of South Australia (Annelida, Polychaeta). Trans. R. Soc. S. Aust. 108(1): 1-20.

Hutchings, P.A., J.T. van der Velde and S.J. Keable. 1986a. Colonisation of New South Wales by non-indigenous marine species. Baseline studies at Twofold Bay, New South Wales. Unpublished report to the Fisheries Industry Research Committee. FIRTA 84/49. 71 p.

Hutchings, P.A., J.T. van der Velde and S.J. Keable. 1986b. Colonisation of N.S.W. by foreign marine species. Aust. Fish. 45(4): 40-42.

Hutchings, P.A., J.T. van der Velde and S.J. Keable. 1987. Guidelines for the conduct of surveys for detecting introductions of non-indigenous marine species by ballast water and other vectors, and a review of marine introductions to Australia. Occ. Rep. Aust. Mus. Sydney No. 3. 147 p.

Hutchings, P.A., J.T. van der Velde and S.J. Keable. 1988. Baseline survey of the benthic macrofauna of Twofold Bay, N.S.W., with a discussion of the marine species introduced into the Bay. Proc. Linn. Soc. N.S.W. 110(4): 339-367.

Iredale, T. 1936. Australian Molluscan Notes, No. 2. Rec. Aust. Mus. 19(5): 267-353.

Jones, D. 1987. Systematics and biogeography of Western Australian Cirrepedia (Thoracica-Lepadomorpha, Balanomorpha). University of Western Australia, Perth. M.Sc. thesis.

Joska, M.A. and G. Branch. 1986. The European shore-crab - another alien invader? Afr. Wildl. 40(2): 63-65.

King, R.J. and M.D. Wheeler. 1985. Composition and geographic distribution of mangrove macroalgal communities in New South Wales. Proc. Linn. Soc. N.S.W. 108(2): 97-117.

Korringa, P. 1976. Farming the Pacific oyster *Crassostrea gigas* in Hiroshima Bay, Japan, p. 153-182. *In* Farming the Cupped Oyster of the Genus *Crassostrea*. Elsevier, Amsterdam.

Kott, P. 1976. Introduction of the north Atlantic ascidian *Molgula mahattensis* (de Kay) to two Australian river estuaries. Mem. Qd. Mus. 17(3): 449-455.

Kott, P. 1985. The Australian Ascidiacea, Part I, Phlebobranchia and Stolidobranchia. Mem. Qd. Mus. 23: 1-440.

Lodder, M. 1902. The Recent Mollusca of Tasmania, p. 89-93. *In* Australian Association for the Advancement of Science Handbook. Ninth meeting, Hobart.

Lucas, J.S. 1980. Spider crabs of the family Hymenosomatidae (Crustacea: Brachyura) with particular reference to Australian species: systematics and biology. Rec. Aust. Mus. 33(4-5): 148-247.

May, W.L. 1923. An Illustrated Index of Tasmanian Shells. Revised by J. H. MacPherson (1958). Tasmanian Government Printer, Hobart. 54 p.

McNeil, F.A. and M. Ward. 1930. Carcinological Notes, No. 1. Rec. Aust. Mus. 17: 357-383.

Medcof, J.C. 1975. Living marine animals in ship's ballast water. Proc. Natl. Shellfish. Assoc. 65: 11-12.

Medcof, J.C. and P.H. Wolf. 1975. Spread of Pacific oyster worries N.S.W. culturists. Aust. Fish. 34(7): 32-38.

Miller, M.C. and R.C. Willan. 1986. A review of New Zealand arminacean nudibranchs (Opisthobranchia: Arminacea). N.Z. J. Zool. 13(3): 377-408.

Monro, C.C.A. 1938. On a small collection of Polychaeta from Swan River, Western Australia. Ann. Mag. Nat. Hist. 11(2): 614-624.

Moss, B. and A. Sheader. 1973. The effect of light and temperature upon the germination and growth of *Halidrys siliquosa* (L). Lyngb. (Phaeophyceae, Fucales). Phycologia 12(1-2): 63-68.

Newman, W.A. 1963. On the introduction of an edible oriental shrimp (Caridea, Palaemonidae) to San Francisco Bay. Crustaceana 5(2): 119-132.

Paxton, J.R. and D.F. Hoese. 1985. The Japanese sea bass, *Lateolabrax japonicus* (Pisces, Percichthyidae), an apparent marine introduction into eastern Australia. Jap. J. Ichthyol. 31(4): 369-372.

Powell, A.W.B. 1979. New Zealand Mollusca - marine, land and freshwater shells. Collins, Auckland. 500 p.

Rosenzweig, P.A. 1984. A range extension for the European shore crab *Carcinus maenas* (Linn. 1758) in South Australia. S. Aust. Nat. 59(1): 18-19.

Sanderson, J.C. 1988. Letter to the Editor. Aust. Mar. Sci. Bull. No. 102, p. 13.

Sanderson, J.C. and N. Barrett. 1989. A survey of the distribution of the introduced Japanese macroalga *Undaria pinnatifida* (Harvey) Suringer in Tasmania, December 1988. Department of Sea Fisheries, Tasmania, Marine Laboratories Technical Report No. 38. 35 p.

Skinner, S. and H.B.S. Womersley. 1983. New records (possibly introductions) of *Striaria, Stictyosiphon* and *Arthrocladia* (Phaeophyta) for southern Australia. Trans. R. Soc. S. Aust. 107(1): 59-68.

Slack-Smith, S.M. and A. Brearley. 1987. *Musculista senhousia* (Benson, 1842): a mussel recently introduced into the Swan estuary, Western Australia (Mollusca: Mytilidae). Rec. W. Aust. Mus. 13(2): 225-230.

Stephenson, W. 1972. An annotated check list and key to the Indo- West-Pacific swimming crabs (Crustacea: Decapoda: Portunidae). R. Soc. N.Z. Bull. No. 10. 64 p.

Sumner, C.E. 1972. Oysters and Tasmania, part 1. Tasm. Fish. Res. 6(2): 1-15.

Sumner, C.E. 1974. Oysters and Tasmania, part 2. Tasm. Fish. Res. 8(2): 1-12.

Tate, R. and W.L. May. 1901. A revised census of the marine Mollusca of Tasmania. Proc. Linn. Soc. N.S.W. 26(3): 344-411.

Thompson, T.E. 1975. Dorid nudibranchs from eastern Australia (Gastropoda: Opisthobranchia). J. Zool. (London) 176: 477-517.

Thomson, J.M. 1952. The acclimatization and growth of the Pacific oyster (*Gryphaea gigas*) in Australia. Aust. J. Mar. Freshw. Res. 3(1): 64-73.

Thomson, J.M. 1959. The naturalization of the Pacific oyster in Australia. Aust. J. Mar. Freshw. Res. 10(2): 144-149.

Turner, E. 1983. Turnaround by the rosey screw shell. The Mercury (Hobart, Tasmania), 16 March, p. 21.

Turner, E. 1986. Tough little star of the Hobart waterfront. The Mercury (Hobart, Tasmania), 30 April, p. 24.

Vermeij, G.J. 1981. Environmental change and evolutionary history of the periwinkle (*Littorina littorea*) in North America. Evolution 36(3): 561-580.

Willan, R.C. 1976. The Opisthobranch *Thecacera pennigera* (Montagu) in New Zealand, with a discussion of the genus. Veliger 18(4): 347-352.

Willan, R.C. 1985a. Preliminary report on the arrival of a new mussel at Auckland, New Zealand. Poirieria (Auckland Museum Conchology Section) 14(1): 2.

Willan, R.C. 1985b. Successful establishment of the Asian mussel *Musculista senhousia* (Benson in Cantor, 1842) in New Zealand. Rec. Auckland Inst. Mus. 22: 85-96.

Willan, R.C. 1987. The mussel *Musculista senhousia* in Australasia: another aggressive alien highlights the need for quarantine at ports. Bull. Mar. Sci. 41(2): 475-489.

Willan, R.C. and N. Coleman. 1984. Nudibranchs of Australasia. Australian Marine Photographic Index, Sydney. 56 p.

Williams, R.J., E.J. van der Wal and J. Kelly. 1982. Ballast water as a dispersal vector for non-indigenous marine animals. Unpublished report to the Fishing Industry Research Committee. FIRTA 76/18, 58 p.

Williams, R.J., E.J. van der Wal and J. Story. 1978. Draft inventory of introduced marine organisms. Aust. Mar. Sci. Bull. No. 61. p. 12.

Williams, R.J., F.B. Griffiths, E.J. van der Wal and J. Kelly. 1988. Cargo vessel ballast water as a vector for the transport of non-indigenous marine species. Estuar. Coast. Mar. Sci. 26: 409-420.

Wilson, B.R. and G.W. Kendrick. 1968. The recent appearance of *Notospisula trigonella* (Lamarck) (Mollusca: Bivalvia: Mactridae) in the Swan Estuary. J. Malacol. Soc. Aust. 11: 25-31.

Wisely, B. 1958. The settling and some experimental reactions of a bryozoan larva, *Watersipora cucullata* (Busk). Aust. J. Mar. Freshw. Res. 9: 362-371.

Wolf, P.H. and J.C. Medcof. 1974. Be on your guard against the Pacific oyster. Fisherman 4(10): 3-5, 24-25.

Wollaston, E.M. 1968. Morphology and taxonomy of southern Australian genera of Crouanieae Schmitz. Aust. J. Bot. 16: 217-417.

Womersley, H.B.S. 1979. Southern Australian species of *Polysiphonia* Greville (Rhodophyta). Aust. J. Bot. 27: 459- 528.

Womersley, H.B.S. 1981. Biogeography of Australasian marine macroalgae, p. 292-307. *In* M.N. Clayton and R.J. King (eds.) Marine Botany, an Australian Perspective. Longman Cheshire, Melbourne.

Woods, A. 1974. Pest Control, a Survey. McGraw Hill, London. 407 p.

Zeidler, W. 1978. Note on the occurrence of the European shore crab *Carcinus maenas* (Linn., 1758) in Australia. S. Aust. Nat. 53(1): 11-12.

Zeidler, W. 1988. The European shore crab, *Carcinus maenas* in the Coorong - a potential threat to local fisheries. Trans. R. Soc. S. Aust. 112(4): 181-182.

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