Port of Eden
Introduced Marine Pest Species Study

D.A. Pollard and B.K. Rankin

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Report to Coasts & Clean Seas Program

May 2003

NSW Fisheries Final Report Series
No. 46
ISSN 1440-3544

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PREFACE

A prerequisite for any attempt to control the introduction and spread by shipping of exotic marine pest species in Australian waters is a sound knowledge of the current distribution and abundance of introduced species in Australian ports. However, until recently this information base had been lacking for a majority of Australian ports. The then Australian Ballast Water Management Advisory Council (ABWMAC)∗, the Standing Committee on Agriculture and Resource Management (SCARM), and the Australia and New Zealand Environment and Conservation Council (ANZECC) State of the Environment (SoE) Reporting Task Force all recognised the need for baseline studies to determine the extent to which introduced species have become established in Australian waters. In response to these needs, the CSIRO's Centre for Research on Introduced Marine Pests (CRIMP) and various state agencies initiated a national port survey program designed to define the occurrence of non-indigenous marine species in Australian ports.

Given the number of agencies and research organisations that may potentially participate in such a national port survey program, a high priority was given to developing a standardised set of survey methods that would provide a consistent basis on which to assess the introduced species status of individual ports. Surveys designed to identify all non-indigenous species in a port will inevitably be subject to scientific, logistic and cost constraints that will limit both their taxonomic and spatial scope. Recognition of these constraints led to the adoption of a targeted approach, which concentrates on a known group of introduced and potentially invasive species and provides a cost-effective approach to the collection of baseline data for all ports studied. While these surveys specifically target designated pest species, they are also designed to determine the distributions and abundances of other introduced species in each port. These known introduced marine species are listed in Appendix 1. The surveys also identify species of uncertain status (i.e. cryptogenic species, or those for which it is not known if they are endemic or introduced) that are abundant in a port and/or are likely to become major pest species in the future.

The current study, the results of which are outlined in this report, followed on from such an initial introduced marine species survey of the Port of Eden, New South Wales, which was carried out in November 1996. This survey was the first such port survey undertaken in New South Wales as part of the national port survey program (CSIRO 1997).

This present report details the results in relation to post survey monitoring of several ABWMAC listed target marine pest species previously detected during the 1996 port survey. These results are based on surveys carried out at the Port of Eden between July 1999 and June 2002. The project was jointly funded by NSW Fisheries (NSWF), the NSW Department of Transport (DoT) and the Commonwealth's Coasts and Clean Seas Program (C&CS), through the NSW Department of Land and Water Conservation (DLWC).

The various stages of the project, as agreed with the funding body at its commencement, are summarised in Appendix 2.

∗ Now known as the Australian Introduced Marine Pest Advisory Council (AIMPAC)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

Numerous NSW Fisheries (NSWF) and CSIRO Centre for Research on Introduced Marine Pests (CRIMP) divers and other staff are thanked for their assistance with both the biological field sampling and *Sabella* fanworm eradication. The latter was supervised by David Pollard of NSW Fisheries (NSWF) and co-ordinated by Peter Waterman from the University of Western Australia. Divers and staff from NSWF involved in the fieldwork included Brett Rankin, Robyn Pethebridge, Marcus Miller, John Matthews, Philip Gibbs, Igor Pirozzi and Craig Brand. Divers from CSIRO involved in the initial *Sabella* eradication exercise included Chad Hewitt, Britta Schaffelke, Alice Morris, Nicole Murphy and Jeff Ross. Michael Mulligan from Geraldton Port Corporation (WA) and volunteer divers from the Merimbula Divers Lodge and the University of Canberra are also thanked for their assistance during this *Sabella* eradication exercise.

Several people at the Port of Eden provided helpful assistance over the course of this project, including: Mr Max Saunders (Eden Harbourmaster), who provided valuable information in relation to shipping movements and port operations; Mr Paul O'Dowd (NSW Waterways Authority), who provided information on local vessel movements; the staff from Broadwater Engineering, for their advice in relation to vessel hull fouling; and also various local NSW Fisheries Officers. Mr Peter Boddis, owner/skipper of the vessel *Michael Maree*, is particularly acknowledged for his valuable assistance during the on-water field operations.

The authors wish to thank Dr S. Brett and Dr D. Hill of Microalgal Services, Melbourne, for their identification of the dinoflagellates and other microalgae in the plankton net and benthic core samples. Dr Pat Hutchings of the Australian Museum is also thanked for confirming the identification of the introduced European fan worms collected during the study. John Matthews of NSW Fisheries is thanked for his help in preparing the site locality maps. Dr Bob Creese and Dr Philip Gibbs of NSW Fisheries are thanked for their constructive criticisms of the draft manuscript.

The Project Steering Committee, whose members comprised Dr D. Pollard (NSWF), Dr P. Gibbs (NSWF), Dr C. Hewitt (CSIRO) and Mr Robert Lea (Office of Marine Administration, NSW Department of Transport), provided oversight during the project.

EXECUTIVE SUMMARY

The port of Eden is located in Twofold Bay (at approx. 37º 04’ S, 149º 56’ E), on the far southern coast of New South Wales (Figure 1). The port’s principal export commodity is wood products (woodchips), with the main import commodities being petroleum products.

An initial survey for introduced marine species was carried out in the port area and around the adjacent coastline of Twofold Bay in November 1996. That survey focused on habitats that were likely to be colonised by introduced species, and used a variety of targeted and general sampling techniques following the sampling protocols developed for the National Australian Ports Surveys by the CSIRO’s Centre for Research on Introduced Marine Pests (CRIMP) (Hewitt & Martin 1996; see also Hewitt & Martin 2001).

The 1996 survey detected three Australian Ballast Water Management Advisory Council (ABWMAC) listed introduced target pest species as occurring in the port, confirming the presence of the European shore crab *Carcinus maenas*, and identifying the Mediterranean fanworm *Sabella spallanzanii* and the toxic dinoflagellate *Alexandrium* “*catenella* type” as also being present. No other ABWMAC listed pest species were recorded from the port or adjacent coastal regions. Other introduced marine species recorded from the port and adjacent waters included the bryozoans *Bugula neritina*, *Cryptosula pallasiana* and *Membranipora membranacea*, the crab *Cancer noveazelandiae*, the Pacific oyster *Crassostrea gigas*, and three other mollusc species *Maoricolpus roseus*, *Polycera capensis* and *Theora fragilis* (CSIRO 1997).

This present monitoring project followed on from the initial 1996 port survey and was undertaken between July 1999 and June 2002. The three ABWMAC listed target pest species detected in 1996 were targeted throughout the three year duration of this project, with changes in their abundances and distributions being monitored. These monitoring surveys confirmed the ongoing presence of all three of these ABWMAC listed pests (the Mediterranean fanworm *Sabella spallanzanii*, the European shore crab *Carcinus maenas*, and various species of the toxic dinoflagellate genus *Alexandrium*) throughout this period. A fourth introduced species, the New Zealand rosy screw shell *Maoricolpus roseus*, previously detected during the 1996 survey, was found to be extremely abundant in seagrass beds in East Boyd Bay, and was also monitored throughout the study. No additional ABWMAC listed target pest species were detected in the port during the survey period.

A total of 36 specimens of the Mediterranean fanworm *Sabella spallanzanii* were identified and removed from the Port of Eden over this period, in addition to the four specimens which had been found during the initial 1996 port survey. Due to the small numbers of *S. spallanzanii* detected within the port when compared to the vast numbers of this species observed to occur in other Australian ports further to the south and west, it would appear to be possible to limit and control the current distribution of *S. spallanzanii* in the Port of Eden by manual removal of individual specimens during intermittent targeted diver searches of harbour structures, bottom debris and vessel moorings, etc., within the port.

A total of 1,486 specimens of the European shore crab *Carcinus maenas* were captured and removed from tributaries entering Twofold Bay during the present study. In view of the abundance of *C. maenas* on more southerly coastlines and this species’ spread over a broad range within southern Australia, the physical removal of the species from Twofold Bay by trapping was considered to be ineffective. Research is currently being undertaken by CSIRO on biological controls for this species in Australian waters.

Six species of the ABWMAC listed dinoflagellate genus *Alexandrium* and six species of the dinoflagellate genus *Dinophysis* were detected during this current study, although all were found at only low concentrations in Twofold Bay. Due to the location of a mussel aquaculture lease within Twofold Bay, however, it is recommended that an expanded regular dinoflagellate monitoring program be established and incorporated into the current sampling regime undertaken by the mussel farm management (Eden Shellfish) as part of the NSW Shellfish Quality Assurance Program (NSW SQAP), in order to detect the presence and abundance of any future harmful toxic dinoflagellate blooms in this area.

Documented during the 1996 survey as occurring in Snug Cove, the introduced gastropod mollusc *Maoricolpus roseus* was recognised at the time as being a common species offshore and outside of Twofold Bay (CSIRO 1997). During this present study, however, it was found on a variety of seafloor substrates throughout the bay, including in large quantities (~1,000 to 4,000 per square metre) on Zosteraceae beds at the dredge site for the proposed Multi-Purpose Naval Ammunitioning Wharf within Edrom Bay, and was also found in smaller concentrations at several other benthic sites examined. This mollusc species has become a dominant member of the offshore benthic community in south-eastern Australia (Hewitt *et al*. 1999), and as such its eradication or control is not a realistic option.

A single specimen of the introduced alga *Codium fragile tomentosoides* was tentatively identified from East Boyd Bay in May 2000. However, additional thorough searches of this area failed to locate any further specimens of this macroalga. No other introduced species was specifically searched for or encountered in Twofold Bay during this study.

Overall, the patterns of distribution and abundance of the main introduced species (except for *M. roseus*) monitored in the Port of Eden during the present study have shown no obvious signs of increase during the past six years since the initial port survey, including the period of this study. With the exception of *Sabella spallanzanii*, the distributions and abundances of the other three species present make it unlikely that they could be eradicated from the Port of Eden/Twofold Bay.

All of the other introduced species identified during the initial 1996 survey were documented at the time as already being well established in the port. In the CSIRO's (1997) Port Survey Report it is stated that for any of these species eradication from the port by physical removal was not a realistic option. Many of these species are now widespread in south-eastern Australian waters and any measures aimed at limiting their spread are likely to be ineffective.

It is recommended that regular phytoplankton netting and annual sediment core sampling be undertaken to monitor dinoflagellate abundances within Twofold Bay, along with periodic diver surveys to detect and remove any additional *Sabella spallanzanii* found from Snug Cove. Any new underwater structures in Twofold Bay (e.g. wharves under construction in Edrom Bay, and those proposed for the Heinz Cannery site) should also be monitored for the settlement of *Sabella* and other introduced marine pest species.

A joint industry and community-based marine pest education and monitoring program involving local boat owners, fishers and harbour users should also be undertaken, incorporating informative signage located at Snug Cove. This would assist in the identification within Twofold Bay of any newly translocated ABWMAC listed pest species. Locally based opportunistic monitoring for changes in the distributions and abundances of introduced marine pest species would also assist in the accumulation of up-to-date biological information, and may thereby support the general recommendation that such ports should be re-surveyed every three to five years (Hewitt & Martin 2001).

1. DESCRIPTION OF THE PORT OF EDEN

1.1. General Features

The Port of Eden is located in Twofold Bay (at approx. 37º 04’ S, 149º 56’ E), on the far southern coast of New South Wales. Twofold Bay is a natural deepwater harbour and consists of three smaller bays, Calle Calle, Nullica and East Boyd Bays, with freshwater inputs forming several brackish lagoons around its shores. Twofold Bay has an average depth of ~14 m in the approach channel and a maximum tidal range of ~1.7 m. The primary port areas are on the northern and southern shores of Twofold Bay, in Snug Cove and East Boyd Bay, respectively (Figure 1).

The first wooden jetty (Main Jetty) was constructed in Snug Cove in 1860. A slipway capable of handling large fishing vessels is located adjacent to the existing Main Jetty in Snug Cove. Small vessel and commercial fishing moorings are also located in Snug Cove, and additional small vessel moorings are located in Quarantine Bay. The construction and facilities associated with the development of the port are detailed in Table 1 and Appendix 3.

There are a number of additional developments currently in progress and proposed for the future in Twofold Bay. These include the current construction by the Royal Australian Navy of a Multi-Purpose Naval Ammunitioning Wharf at Edrom Bay, inshore of the Harris-Daishowa Woodchip Wharf facility in East Boyd Bay. This multi-purpose wharf facility is also designated to be used for the export of wood and paper products during non-ammunitioning periods. This construction in Edrom Bay will require dredging and land-filling in this area.

Further development of the mussel aquaculture industry in Twofold Bay is also currently underway. A leased area of 14 hectares is currently under production (NSWEMF), with smaller experimental plots in Nullica Bay presently being evaluated. The current leased area within Twofold Bay is 17 hectares. Potential mussel aquaculture lease sites are likely to include further areas in Nullica Bay.

Another proposed development is a recreational marina at Boydtown, which would involve the establishment of a 400 m breakwater and boat mooring facilities.

Originally settled in the early 1880s, the township of Eden is presently host to one of the largest fishing fleets in New South Wales and, until its closure in 1999, was home to one of the largest fish canneries in Australia, the Heinz Greenseas cannery. The present Heinz Greenseas cannery wharf may also be developed as a recreational boating marina.

Table 1. Summary of wharf developments at the Port of Eden.

Jetty/Wharf	Site Code	Date Built	Subsequent Modifications
Main Jetty	NSWEWHB	1860	Lengthened in 1911, rebuilt in 1984
Heinz Cannery Jetty	NSWESCC	1945	Rebuilt in 1984
Oil Berth	NSWELPG	1960	
Harris-Daishowa Woodchip Berth	NSWEWB	1969	
Breakwater Wharf	NSWEWHC	1974	
Mooring Jetty	NSWEWHA	1981	
RAN Multi-Purpose Wharf	NSWEEB	2002/3	Presently under construction

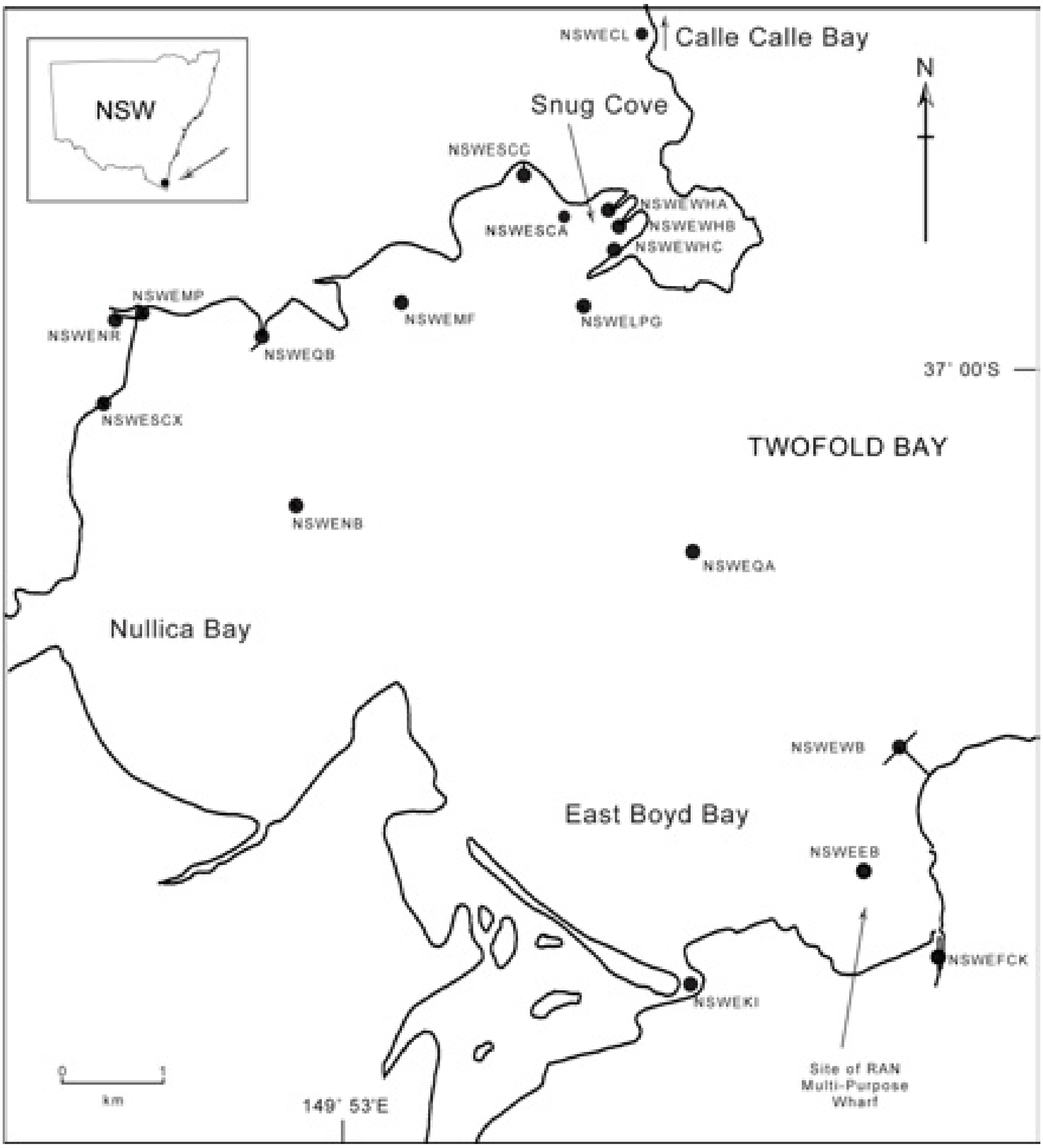

Figure 1. Twofold Bay showing sampling sites mentioned in the text.

1.2. Shipping Movements

The Port of Eden and Twofold Bay received 87 visits by large commercial ships between June 1999 and March 2002. The major export commodity from the port was woodchips, with the commodities landed at the port comprising mainly petroleum and some fish products. Shipping movements in the port are summarised in Appendix 4.

Shipping activity in the port, in terms of frequency of ship visits, is dominated by bulk cargo vessels loading woodchips (46 visits) and other fishing and trading vessels either discharging fish or petroleum products, offloading or re-supplying (23 visits). Between June 1999 and March 2002, 15 international woodchip vessels visited Eden, berthing at the Harris-Daishowa Woodchip wharf (EWB) and arriving from ports in Japan, Taiwan, Singapore, Borneo, China and Korea (see Appendix 4). Most international woodchip vessels that visit the port arrive several times each year, and are dedicated to this route. These include the *Eden Maru* from Shimizu (21 visits) and the *Daishowa Maru* from Muroran and Shimizu, Japan (7 visits). Six oil tankers visited Eden a total of 18 times between June 1999 and March 2002, originating from the Australian domestic ports of Brisbane, Botany Bay, Port Stanvac and Port Phillip Bay, with the *Tasman* (11 visits) and the *Royal Arrow* (3 visits) being the most frequent visitors. International and domestic trading and fishing vessels berthed 23 times at the Breakwater Wharf (EWHC) in Snug Cove between June 1999 and March 2002. Four of these vessels originated from overseas ports in Tonga, Noumea, Majuro, New Zealand and Singapore. Domestic trading and fishing vessels that berthed in the port arrived from Hobart, Launceston, Port Lincoln, Darwin, Portland, Westernport, Jervis Bay, Botany Bay and Bass Strait.

1.3. Port Development and Port Maintenance Activities

The chronology of major berth development in the port is summarised in Table 1. All of the existing wharves were initially built prior to 1982. Construction of a Multi-Purpose Wharf / Naval Ammunitioning Facility by the Royal Australian Navy in the Fisheries Beach area to the southwest of the existing Harris-Daishowa Jetty (see Figure 1) is currently being undertaken. Future development possibilities within Twofold Bay include plans for a recreational boating marina at Boydtown on the western shore.

Vessels permanently stationed in the port of Eden include two tugs and a number of pilot and work boats. These generally occupy anchorage points in Snug Cove (ESCA) or berths at the Main Jetty (EWHB) in Snug Cove. Most pleasure and recreational fishing vessels are kept either on swinging moorings in Snug Cove (ESCA), tied at the dock along either the Main Jetty or the Mooring Jetty (EWHA) in Snug Cove, or on moorings in Quarantine Bay (EQB) (see Figure 1).

1.4. Port Environment

Twofold Bay is a natural, cool temperate, deepwater port with strong oceanic influence. Circulation within Twofold Bay is predominantly clockwise.

Examination of the wharf pile communities during the initial 1996 survey indicated little influence of freshwater runoff in either the commercial areas of the port or around the marina moorings. The majority of wharf piles examined carried well developed marine communities, dominated intertidally by barnacles, mussels and bryozoans. Below the tidal range, these communities were dominated by sponges, ascidians, algae and bryozoans, to within about a metre of the bottom. Thinning of these communities near the bases of the piles is likely to be associated with wind and storm generated scour and siltation (CSIRO 1997). The maximum tidal range in the port is ~1.7 m, with a maximum high tide of 2.0 m and a minimum low tide of 0.3 m.

Surface sediments adjacent to the wharf piles at most berths are a combination of fine mud and silt. In some parts of the bay this fine material is replaced by coarse sand, generally indicative of greater water movement in those areas.

2. REVIEW OF EXISTING BIOLOGICAL INFORMATION ON THE PORT

2.1. Introduction

The Twofold Bay region has been the subject of a number of scientific surveys and studies undertaken over the past 20 years. Previously surveyed during a baseline study of non-indigenous marine species by Hutchings *et al.* (1986), an Environmental Impact Study (EIS) was also undertaken for the potential development of additional mussel leases in Twofold Bay in 1996 (Pacific Seafood Management Consulting Group Pty Ltd 1996). Again in 1996, as part of the national port survey program, a detailed introduced marine species survey of the Port of Eden was carried out by CSIRO (CRIMP) and NSW Fisheries (CSIRO 1997). In 1999 an EIS was prepared for the Department of Defence on the development of the Twofold Bay Multi-Purpose Wharf and Naval Munitions Storage Facility (Woodward & Clyde 1999).

From these studies and reports we have an indication of those introduced marine species which have so far been collected in or near the Port of Eden. These include the polychaete worm *Sabella spallanzanii*, the dinoflagellate *Alexandrium catenella*, the crab *Carcinus maenas*, the bryozoan *Bugula flabellata*, the ascidian *Styela plicata*, the molluscs *Maoricolpus roseus*, *Theba pisana*, *Polycera capensis* and *Crassostrea gigas*, the barnacle *Notomegabalanus algicola*, and the isopod *Eurylana arcuata*.

The introduced giant European fanworm *Sabella spallanzanii* is found in temperate Australian waters from Eden in NSW to Port Phillip Bay in Victoria, at Devonport in Tasmania, in South Australia, and in numerous ports in south-western Western Australia (Hewitt *et al*. 1999). Cysts and motile cells of toxic dinoflagellates belonging to the genus *Alexandrium* have been detected from Newcastle (CSIRO 1998) to Eden in NSW, and are also known from Victoria, Tasmania and Western Australia (Hallegraef & Bolch 1992; CSIRO 1997). The European shore crab *Carcinus maenas* is common to abundant from Eden in NSW, south and westwards through Victoria and Western Tasmania to South Australia (Zeidler 1978; Rosenzweig 1984; Furlani 1996; CSIRO 1997). The mollusc *Maoricolpus roseus* was detected in Twofold Bay in 1996 (CSIRO 1997) and currently is a dominant member of the coastal benthic community off south-eastern Australia (Hewitt *et al*. 1999).

The Australian distribution of *Bugula flabellata* includes the Gulf of St Vincent in SA and from Eden to Jervis Bay in NSW. The nudibranch *Polycera capensis* was first recorded from Sydney Harbour by Allan (1931) and subsequently throughout various areas of the New South Wales coast by Allan (1957), Thompson (1975) and Willan and Coleman (1984), including in Twofold Bay. The Pacific oyster *Crassostrea gigas* was intentionally introduced to various regions of southern Australia for mariculture purposes (Thomson 1959). A breeding population is known to exist in Port Stephens (Holliday & Nell 1985), but this species has also been found in many other NSW estuaries, and Hutchings *et al.* (1986) were the first to record it from Twofold Bay. This oyster is distributed throughout the bay on intertidal and subtidal rocks.

A number of other introduced species had been previously identified and collected from the Twofold Bay region during past surveys. However, these were not detected in the 1996 survey, or during the present study. The barnacle *Notomegabalanus algicola* was first recognised as occurring in Australia in the 1940s (Allen 1953) and has since been recorded from Eden to Port Stephens in NSW. Hutchings *et al*. (1986 & 1988) found this barnacle on rocks and piles at

Munganno Point near the Harris-Daishowa Woodchip Wharf. The isopod *Eurylana arcuata* was found to occur on intertidal rock platforms at Murrumbulga and over deep-water sediments in Twofold Bay (Hutchings *et al*. 1986 & 1988). The ascidian *Styela plicata* has a wide distribution in Australian waters (Kott 1985), and was recorded from Twofold Bay within subtidal seagrass beds in Quarantine Bay (Hutchings *et al*. 1986 & 1988). *Theba pisana* is a salt tolerant gastropod found throughout southern temperate Australia (Baker 1986), and was found in the salt marsh at the back of Curalo Lagoon in Calle Calle (Hutchings *et al*. 1986 & 1988).

2.2. Results of 1996 Port Survey

Three ABWMAC target pest species were recorded from Twofold Bay during the 1996 baseline port survey. This survey confirmed the presence of the European shore crab *Carcinus maenas*, and also identified the European fanworm *Sabella spallanzanii* and the toxic dinoflagellate *Alexandrium* "*catenella* type" as being present. The sites where ABWMAC listed pest species were found during the 1996 survey (CSIRO 1997) are summarised in Appendix 6.

Previous studies indicated that *Carcinus maenas* had been present within Twofold Bay for at least 10 years. Hutchings *et al*. (1986 & 1988) stated that this crab was commonly found around Twofold Bay, mainly amongst intertidal rocks and mud. *Carcinus maenas* appeared, at the time of the 1996 survey, to be confined to the estuarine or brackish water tributaries of the bay. This species was found in sampling sites at Nullica River and Mungora Point, Shadrack Creek, Kiah Inlet, Fisheries Beach, and Curalo Lagoon in Calle Calle Bay during the 1996 survey (CSIRO 1997).

Four specimens of *Sabella spallanzanii* were detected for the first time in New South Wales waters during the 1996 survey at the Snug Cove Berths, with one specimen being collected at the Breakwater Wharf (EWHC) and three at the Main Jetty (EWHB). However, this species was not found at any other location within Twofold Bay at that time. The specimens collected were mature worms and were found at between 1 and 5 m depth, attached to pilings and debris under the wharf structures (CSIRO 1997).

The toxic dinoflagellate *Alexandrium* "*catenella* type" was found at low concentrations in the sediments at several of the sites sampled during the 1996 survey. Attempts to isolate live cysts were unsuccessful due to the low concentration of these cysts in the sediments (CSIRO 1997). *Alexandrium catenella* was also known at the time to be present in many other coastal estuaries and embayments from the Hawkesbury River in NSW southwards to Port Phillip Bay in Victoria (Hallegraeff *et al.* 1991).

The New Zealand rosy screw shell, *Maoricolpus roseus*, was collected in only small numbers from Snug Cove during the 1996 survey, but was known to occur in high densities offshore from Twofold Bay (CSIRO 1997). Found in large numbers to depths of 50 m, it is a common bycatch in offshore trawls.

No other ABWMAC listed pest species were recorded from the port or adjacent regions during any of the previous baseline studies.

Other introduced species collected during the 1996 port survey of Twofold Bay and identified at that time included the bryozoans *Bugula flabellata*, *Bugula neritina*, *Cryptosula pallasiana*, *Membranipora membranacea* and *Watersipora subtorquata* (=*subovoidea*), the crab *Cancer noveazelandiae*, the Pacific oyster *Crassostrea gigas*, and three other molluscs *Maoricolpus roseus*, *Polycera capensis* and *Theora fragilis* (CSIRO 1997).

Bugula flabellata is an erect anascan bryozoan native to European Atlantic and Mediterranean waters. This species was found at the Harris-Daishowa Woodchip Berth. A second erect anascan bryozoan, *Bugula neritina*, also native to European waters, was found in the main port area at the Breakwater Wharf (CSIRO 1997).

The remaining bryozoans, *Cryptosula pallasiana*, *Membranipora membranacea* and *Watersipora subtorquata* (=*subovoidea*), are all considered to be of unknown or questionable origin, or cryptogenic (*sensu* Carlton 1985). These species have extensive worldwide distributions, generally being associated with ports and harbours. In Twofold Bay, specimens were collected at the Snug Cove Main Jetty, Mooring Jetty and Breakwater Wharf sites, the Heinz Cannery Jetty, and at Lookout Point (CSIRO 1997).

The New Zealand piecrust crab, *Cancer novaezelandiae*, is generally found in subtidal habitats to 60 m depth, commonly in areas of silty sand. Native to New Zealand, this crab is also known from Tasmania and Port Phillip Bay in Victoria. *Cancer novaezelandiae* feeds predominantly on bivalves, gastropods and other crustaceans, and may have a significant impact on native infaunal communities. In Twofold Bay this species was collected throughout the Snug Cove area during the initial port survey (CSIRO 1997).

The Pacific oyster, *Crassostrea gigas*, which originated from the North-West Pacific, and more particularly around Japan, occurs in the intertidal zone throughout the bay (CSIRO 1997). This species is abundant on hard and soft substrates in many areas and tends to dominate rocky intertidal and subtidal areas. It forms shoals on mud in some regions.

The presence of the nudibranch *Polycera capensis* in Twofold Bay was confirmed during the 1996 survey. Previous reports of its occurrence in New South Wales included those of Allan (1957), Willan *et al*. (1984) and Hutchings *et al*. (1988). Specimens were collected at low densities at the Harris-Daishowa Woodchip Wharf (CSIRO 1997).

The bivalve *Theora fragilis* is known from Port Phillip Bay in Victoria and Western Australia, and also (since the 1970s) has been found in many estuaries in New South Wales. This species was found in Twofold Bay in 1996, in large infaunal cores taken from near the Heinz Cannery Jetty, both close to the jetty and 50m out, indicating a probable broad distribution in this cove (CSIRO 1997).

A number of introduced species which had been previously identified and collected from the Twofold Bay region during past surveys were not detected during the 1996 survey, either due to survey constraints or species localisation/reduction (CSIRO 1997). The barnacle *Notomegabalanus algicola* was first recognised in Australia in the 1940s and is recorded as extending from Eden to Port Stephens in NSW (Allen 1953). Hutchings *et al*. (1986 & 1988) found this barnacle on the rocks and wharf piles at Munganno Point near the Harris-Daishowa Woodchip Wharf. The isopod *Eurylana arcuata* occurred on both intertidal rock platforms and deep-water sediments in Twofold Bay (Hutchings *et al.* 1986 & 1988). The ascidian *Styela plicata* has a wide distribution in Australian waters (Kott 1985) and was recorded within subtidal seagrass beds in Quarantine Bay (Hutchings *et al*. 1986 & 1988). *Theba pisana*, a salt tolerant gastropod found throughout southern temperate Australia (Baker 1986), was found in the salt marsh at the back of Curalo Lagoon in Twofold Bay (Hutchings *et al*. 1986 & 1988).

3. MONITORING SURVEY METHODS

3.1. Sampling Strategy

The 1996 port survey followed the protocol developed by Hewitt & Martin (1996) which was designed to determine:

- the distribution and relative abundance of a limited number of ABWMAC target pest species;
- a baseline assessment of introduced and cryptogenic species; and
- a baseline assessment of native species.

In Australia, these target species (see Appendix 1) comprise:

- those species listed on the ABWMAC schedule of target introduced marine pest species;
- a group of species which are major pests in overseas ports and which, on the basis of their invasive history and projected shipping movements, might be expected to colonise and pose a threat to Australian ports; and
- those known exotic species present in Australian waters that currently are not assigned pest status.

The sampling strategy in the initial port survey protocol was concentrated on habitats and sites in the port and adjacent areas that were most likely to have been colonised by the target species. The areas sampled during the 1996 survey of the Port of Eden (CSIRO 1997) comprised:

- active wharves;
- disused or inactive wharves;
- slipways;
- known deballasting areas;
- mariculture facilities;
- breakwaters and jetties;
- estuarine areas; and
- representative habitats on the adjacent coast.

The strategy used during this current study was designed to target and monitor those ABWMAC listed pest species previously detected during the 1996 survey and other past scientific surveys in the port. Where a target species had been originally detected in the port at low densities (such as with *Sabella spallanzanii* in the 1996 survey), during the current study the distribution and population abundance of that species were determined. If densities were still found to be low, eradication of the population was attempted, and subsequent monitoring undertaken to determine the eradication success (Hewitt & Martin 2001).

Where target species were detected at higher densities (such as with the crab *Carcinus maenas*), monitoring of the population's distribution and abundance was again undertaken, though eradication was not attempted.

Detailed descriptions of the sampling procedures are given in Appendix 5, and the sampling methods used, habitats sampled and target taxa studied are summarised in Appendix 6.

The main sites of the *Sabella spallanzanii* surveys and subsequent eradication exercise were wharves and structures in the Snug Cove Harbour area, where specimens of this worm were first found during the 1996 survey of the port. Sites surveyed here included the Mooring Jetty (EWHA), Main Jetty (EWHB) and Breakwater Wharf (EWHC), as well as the harbour floor.

Additional sites surveyed for the presence of introduced marine pest species were based on those used in the 1996 survey (CSIRO 1997), and included the Oman Point Mariculture Lease (EMF), Harris-Daishowa Woodchip Berth (EWB), Edrom Bay (EEB), Quarantine Bay (EQB), Cannery Jetty (ESCC), Fisheries Creek (EFCK) and several other sites within Twofold Bay (see Figure 1 and Appendix 6).

3.2. Sampling Methods

The sampling methods used during the 1996 survey were selected to ensure a comprehensive coverage of habitats, and were intended to provide presence/absence information and/or semi-quantitative indices of abundance only (see Hewitt & Martin 1996 and Appendix 5).

The sampling methods employed during this current 1999-2002 study were designed to monitor the abundances and distributions of those introduced marine pest species previously detected in Twofold Bay. The sampling was distributed at a number of sites throughout the bay (see Figure 1). The main methods used included visual surveys, still photography, sediment coring, plankton net sampling and crab trapping (Hewitt & Martin 2001).

Qualitative diver searches were undertaken to investigate the presence of *Sabella spallanzanii* on wharf and port structures and the harbour floor in the Snug Cove area and at other targeted sites throughout Twofold Bay. Visual surveys were carried out and supplemented with still photographs and sample collection where appropriate. Divers swam the length of each wharf, searching structures between the surface and the bottom as well as the substratum, to provide a complete visual survey of the wharf structure and its surrounds. Surveys were also carried out on the open harbour floor, with divers searching along underwater transects following compass bearings. Vessel hulls and moorings were also inspected by divers. A total of 42 survey dives was undertaken between July 1999 and June 2002 to specifically search for *Sabella spallanzanii* in Twofold Bay. Incorporating an in-water dive team of two or sometimes three divers, a total of 93 diver hours was spent during these underwater searches (see Appendix 7). Sites examined specifically for this purpose included Snug Cove Harbour, Harris-Daishowa Woodchip Wharf, Cannery Wharf, Quarantine Anchorage and Mussel Lease sites.

A total of 86 hull fouling surveys to look for the presence of *Sabella spallanzanii* was undertaken by divers at various berths and moorings within the Port of Eden (Appendix 8). These inspections were classified into two vessel/mooring categories: commercial (23) and recreational (63). The types and uses of the vessels inspected included commercial fishing vessels, barges, charter fishing boats, motor cruisers and yachts (see Figures 2 and 3). These vessels were either temporarily moored at the Snug Cove wharves or attached to permanent swinging moorings within the Quarantine and Snug Cove Anchorages. Photography and qualitative surveys of hull fouling were undertaken using horizontal transects along the vessel's hull from the bow to the stern, including a visual check of the keel, propeller and rudder of each vessel. A check of these vessels' mooring lines and anchor chains was also undertaken where possible. The degree of fouling and the primary type of fouling communities present on both the vessels' hulls and mooring lines were recorded.

Sampling of dinoflagellates to assess the occurrence and concentration of ABWMAC listed pest species of the genus *Alexandrium* and other toxic dinoflagellates in Twofold Bay was undertaken at a number of sites (refer to Figure 1 & Appendix 6). Two sampling methods were used to test for the presence of these toxic dinoflagellate species. Benthic sediment cores targeting the resting cysts of *Alexandrium* species were taken by SCUBA diving at a number of locations in Twofold Bay on an annual basis. A 20 micron phytoplankton net was also used (via vertical tows of the water column) to sample for the occurrence and concentration of any motile *A. catenella* and other dinoflagellates at the same sites throughout the bay on an approximately quarterly basis.

Crab traps were used to sample the distribution and abundance of *Carcinus maenas* in tributaries around the shoreline of Twofold Bay. Five sampling sites were selected, representing likely habitats for *C. maenas*. These tributaries were Fisheries Creek (EFCK), Kiah Inlet (EKI), Nullica River (ENR), Shadracks Creek (ESCX) and Curalo Lagoon (ECL). Whenever possible, traps were deployed in the late afternoon and recovered early the next morning (see Figure 4). Any *C. maenas* captured were preserved in 10% formalin and returned to the laboratory for sex and size frequency analysis. Visual searches for any introduced crabs were also made at selected wharves in the port area, and other likely habitats in and around Twofold Bay.

The New Zealand rosy screw shell, *Maoricolpus roseus*, was sampled at random sites in Zosteraceae seagrass beds within Edrom Bay (EEB) on an approximately quarterly basis using a 0.10 m^2 quadrat (33x33 cm). Three replicates were collected on each sampling occasion, with any gastropods, seagrass (*Zostera muelleri* and/or *Heterozostera tasmanica*) and sediment present being removed to a depth of 10 cm (see Figure 5). These samples were then sieved through a fine (1 mm) mesh bag to remove the sediment whilst retaining any invertebrates and other benthic organisms present within the sample. Photographs of the sampling sites were often taken prior to sampling. All material collected was preserved in 10% formalin. In the laboratory, the sample was sorted and any *M. roseus* present were measured for length frequency analysis.

Figure 2. Recreational yacht *Safari* moored at the NSWESCA sampling site in Snug Cove.

Figure 3. Commercial fishing vessels berthed at the NSWEWHB sampling site in Snug Cove.

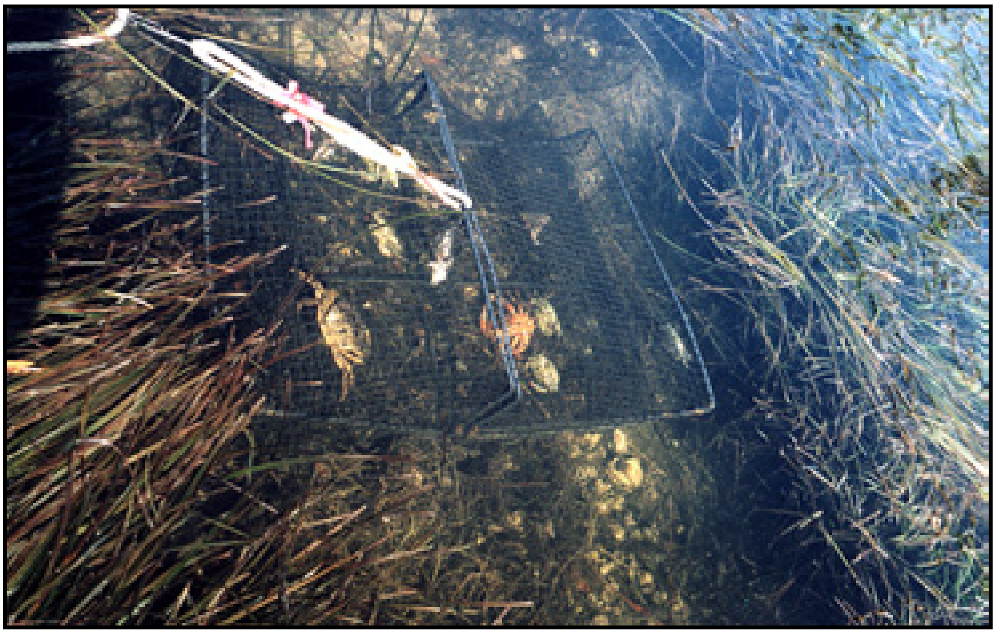

Figure 4. *Carcinus maenas* captured at the NSWEFCK sampling site in Twofold Bay.

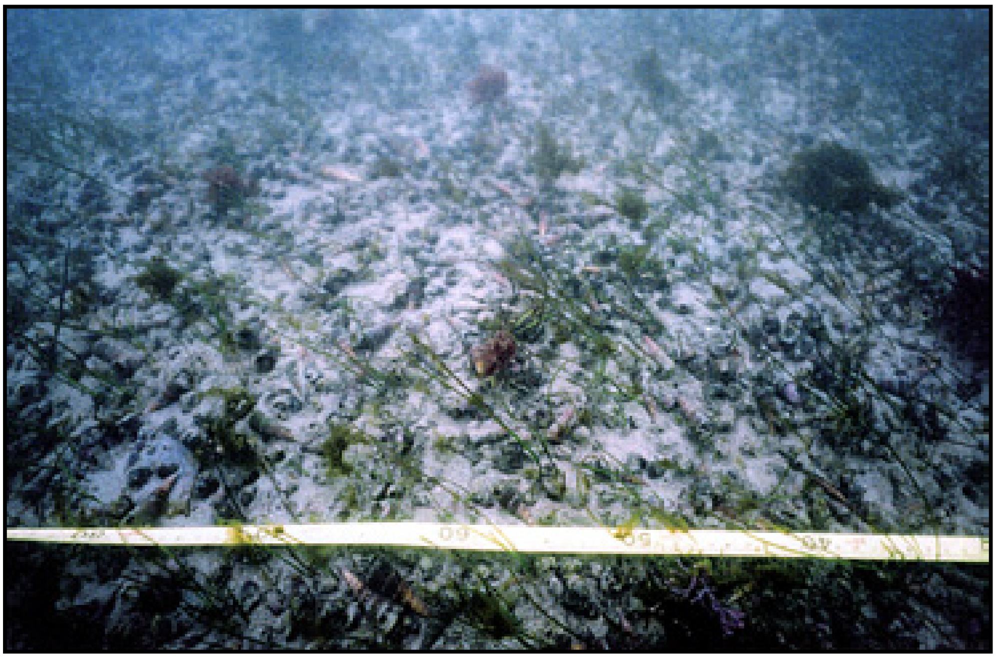

Figure 5. *Maoricolpus roseus* within Zosteraceae beds at the NSWEEB sampling site in Twofold Bay (photo source: Woodward & Clyde 1999).

4. SURVEY RESULTS

4.1. *Sabella spallanzanii*

Sabella spallanzanii was found at a number of sites within the Snug Cove Harbour area, although at very low densities compared to its occurrence in other more southerly Australian ports (Hewitt *et al.* 1999). A total of 36 specimens was located and removed from a variety of substrata, including wharf pilings, bottom debris, vessel mooring lines and the harbour floor. The specimens collected were of a broad size range, from juvenile individuals of ~ 1 cm tube length to mature specimens of ~30 cm. These worms were collected from areas ranging between 1 and 10 metres in depth. *Sabella spallanzanii* was not found at any other location within Twofold Bay outside the Snug Cove and Snug Cove Anchorage (ESCA) areas. A total number of 40 *Sabella spallanzanii* have now been removed from the Snug Cove harbour area at Eden, when the four *Sabella* specimens identified and removed by CRIMP and NSW Fisheries divers during the initial November 1996 survey of the Port of Eden are included. These four specimens were the first documented records of *Sabella spallanzanii* in the Eden area, or for that matter in NSW waters in general.

Of the 36 *Sabella* specimens identified and removed during the present project (see Figure 6 and Appendix 7), twelve were located on or adjacent to the Breakwater Wharf, eight were removed from wharf pilings (four) and the under-wharf substratum (four) at the Mooring Jetty Wharf, twelve were found on the open harbour floor areas, and two on the harbour floor underneath and adjacent to the Main Jetty. No *Sabella* were detected on the hulls of vessels during the 86 hull fouling inspections carried out in Snug Cove. However, two specimens were identified and removed from a mooring in the anchorage area (ESCA) to the west of Snug Cove. These latter are the only two fanworms to be found outside of the nearby Snug Cove wharf area (see Appendix 7).

4.2. *Carcinus maenas*

Carcinus maenas was detected in a number of the estuarine or brackish water tributaries to the bay. This species was captured in tributaries at Fisheries Creek, Nullica River, and Curalo Lagoon off Calle Calle Bay. A total of 1,486 specimens was collected from these areas during this study. *Carcinus maenas* were most abundant at the Fisheries Creek (EFCK) site, with 1,398 specimens being captured there. Smaller catches of *C. maenas* were taken at the Curalo Lagoon (55 specimens) and Nullica River (33 specimens) sampling sites. No specimens were captured from the Kiah Inlet (EKI) or Shadracks Creek (ESCX) sampling sites. All sites were intertidal, generally seagrass dominated tributaries, with the crabs being commonly captured around areas offering shelter in the form of seagrass and rocks (see Figure 4). No specimens were collected from fully marine habitats.

Length frequency analysis of the eleven approximately quarterly samples collected over the study period indicated that the sizes of *Carcinus maenas* taken ranged from approximately 19 to 62 mm (male) and 20 to 51 mm (female) in carapace length (CL), with the males generally being larger than the females (see Figures 7, 8, 9 and 10). Breakdowns of these length frequency distributions by sex indicated the occurrence of possibly several cohorts in the EFCK population over the duration of the study. A total of 9 berried females ranging in size from 32 to 51 mm CL were captured in 2001 from the EFCK site, 7 in August and 1 each in April and September.

The estimated growth rate of the main cohort of male crabs appeared to be around 1 mm per month over the two year period from around May 2000 to April 2002, and possibly slower for the females. Overall, the sex ratio of the male to female crabs collected at all sites was 5.3:4.7.

The peak in crab numbers recorded in April 2001 may have been due to immigration of larger crabs (i.e. those >30 mm CL) from either upstream or downstream to the sampling area, and or recruitment of juveniles (i.e. individuals around 20-30 mm CL) to the sampled population.

The samples from those sites other than Fisheries Creek were generally too small to show any significant patterns, though the sizes of these specimens ranged from approximately 24 to 63 mm CL, with the males again being larger and more numerous (see Figure 11).

A conversion graph for carapace length to carapace width (based on the April 2002 samples) is given in Figure 12 for comparison with carapace width data described in other studies of this species (see Discussion).

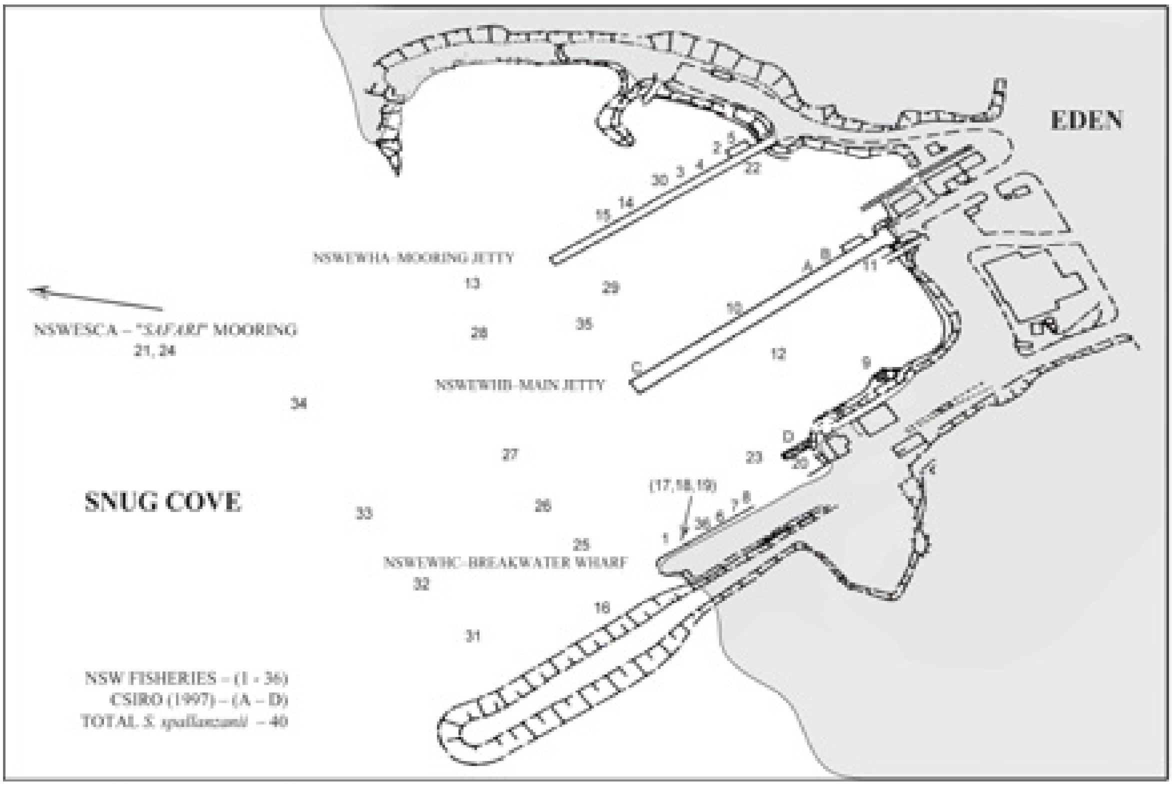

Figure 6. Locations of *Sabella spallanzanii* specimens collected in and around Snug Cove.

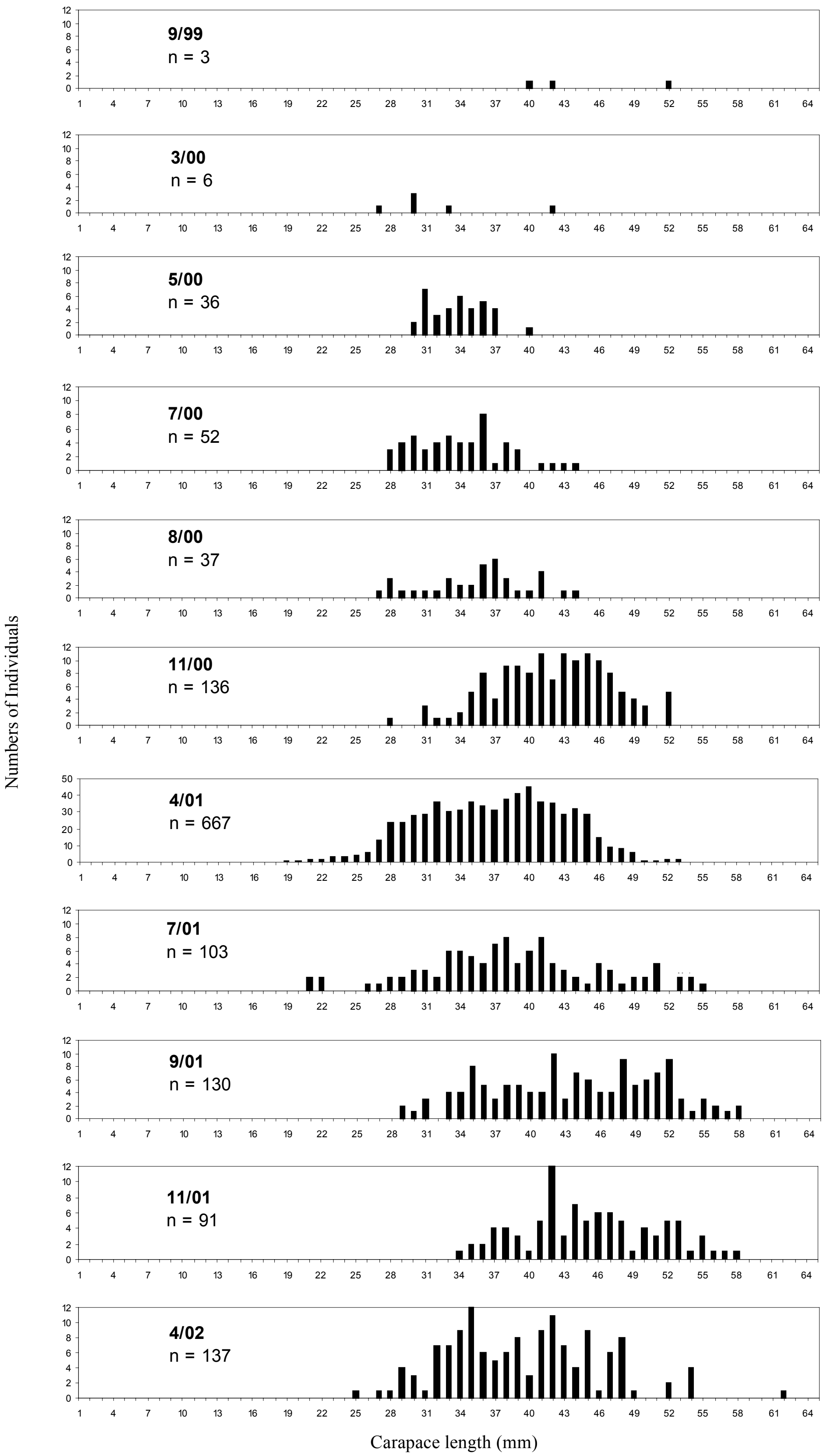

Figure 7. Length frequency distributions for combined male and female *Carcinus maenas* captured at the NSWEFCK sampling site in Twofold Bay.

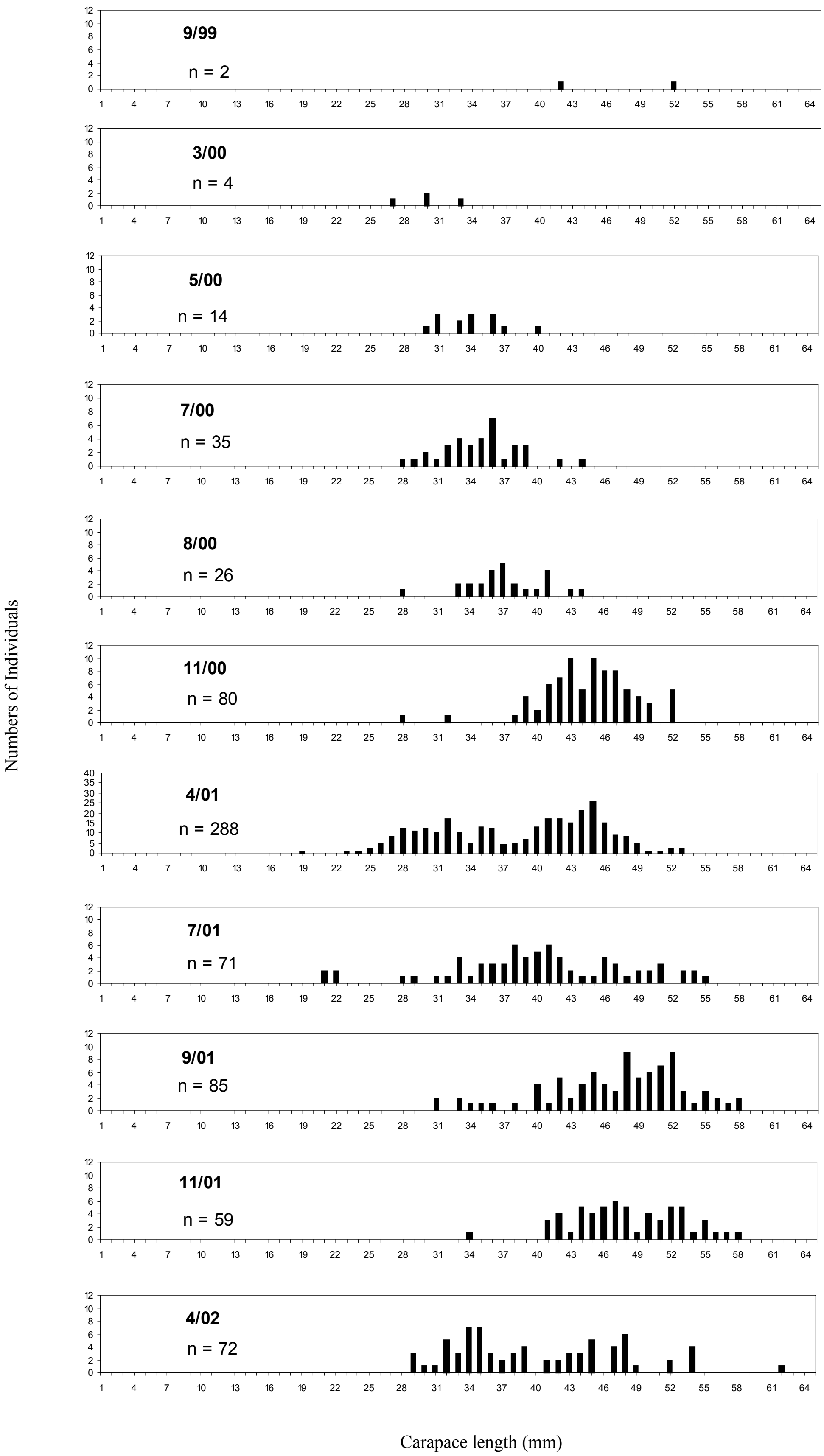

Figure 8. Length frequency distributions for male *Carcinus maenas* captured at the NSWEFCK sampling site in Twofold Bay.

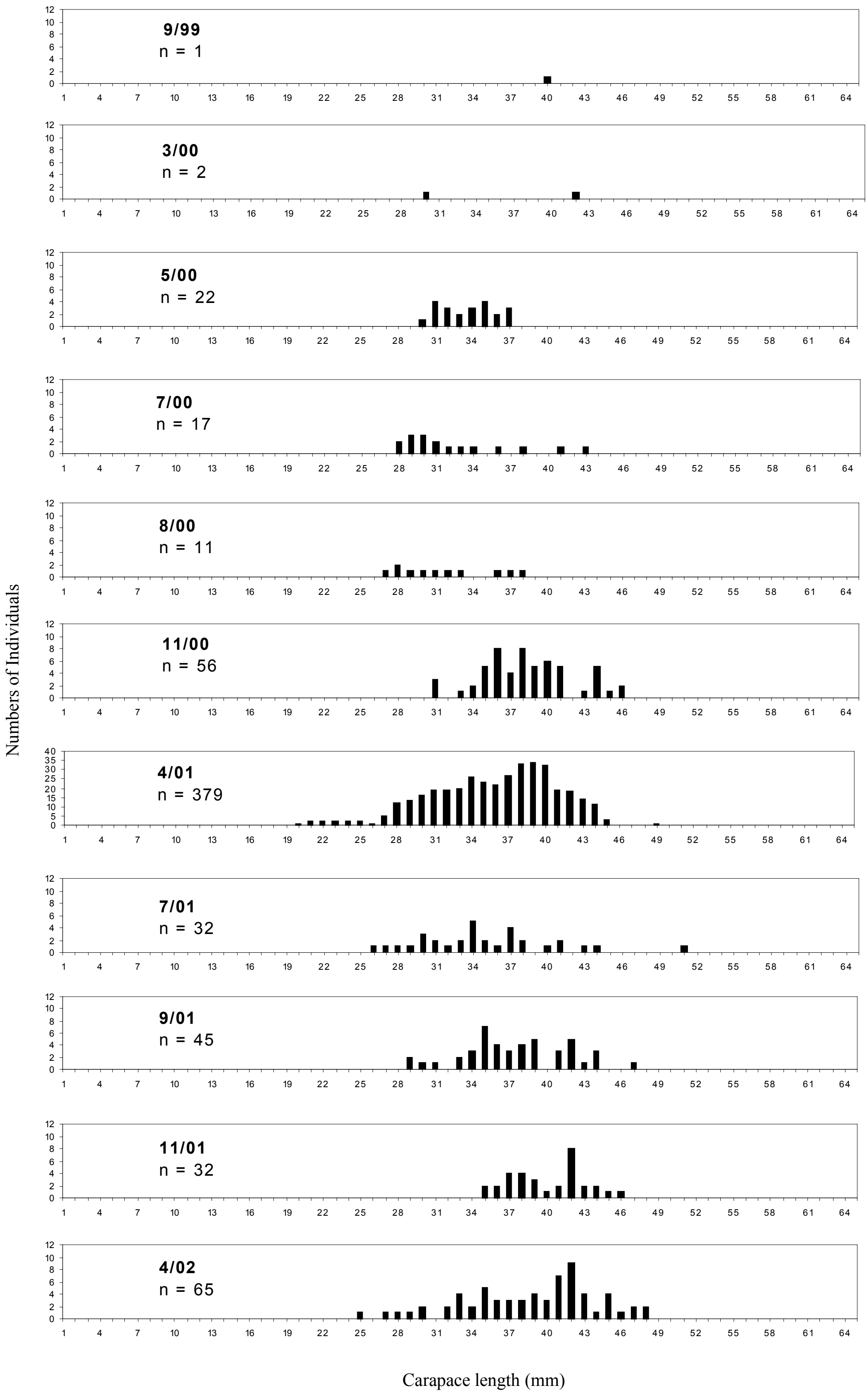

Figure 9. Length frequency distributions for female *Carcinus maenas* captured at the NSWEFCK sampling site in Twofold Bay.

4.3. *Alexandrium* and *Dinophysis* Species

A number of potentially toxic dinoflagellate species were detected at low concentrations at a number of the sites by the two sampling methods (benthic cores and phytoplankton nets) which were employed (see Appendix 5). Three species of the potentially toxic (i.e. Paralytic Shellfish Poisoning or PSP producing) dinoflagellate genus *Alexandrium* were detected as dormant cysts in sediment cores taken at various sites over the three annual sampling periods (see Table 2). One species commonly detected during each of the annual benthic core samplings was unable to be positively identified as *A. catenella*, but was identified as being of the *A*. "*catenella* type". Another species of the *Alexandrium* genus, *A. cf. minutum*, was also identified from the November 2001 samples. A third species which was unable to be positively identified was labelled as *Alexandrium* sp. (similar to *A. ostenfeldii*).

Five species of the potentially toxic (i.e. PSP producing) genus *Alexandrium* (*A. catenella*/*fundyense*, *A. margalefi*, *A. minutum*, *A. ostenfeldii*/*peruvianum* and *A. tamarense*) were identified in low concentrations as motile cells at a number of sites during the seasonal phytoplankton net sampling carried out within Twofold Bay (see Table 3).

Six species of the potentially toxic (i.e. Diarrhetic Shellfish Poisoning or DSP producing) dinoflagellate genus *Dinophysis* (*D. acuminata*, *D. acuta*, *D. caudata*, *D. diagensis*, *D. fortii* and *D. tripos*) were also identified in low numbers from samples collected at a number of sites using vertical phytoplankton net tows (see Table 3). No species of the genus *Dinophysis* were found in the sediment core samples (see Table 2)

4.4. *Maoricolpus roseus*

The gastropod *Maoricolpus roseus* was identified at a number of sites on a variety of benthic substrata throughout Twofold Bay. Previously detected only in Snug Cove, *M. roseus* was found in very high densities (up to 4,000 per square metre) in Edrom Bay (EEB), and was also identified in smaller concentrations at other benthic sites examined within Twofold Bay. The Edrom Bay sampling site contained Zosteraceae seagrass beds located inshore of the Harris-Daishowa woodchip facility (see Figure 5). These seagrass beds are the dredging site for the Multi-Purpose Naval Ammunitioning Wharf within Edrom Bay. Periodic (approximately quarterly) representative samples of the gastropods and flora present were collected at this site, with length frequency analysis being undertaken on the *Maoricolpus roseus* samples (see Figure 13).

The *Maoricolpus roseus* collected during the study ranged in length from around 30 to 70 mm, and at each of the sampling occasions only one broadly identifiable cohort was present in the population. The variation in modal length over time, however, proved to be very confusing in terms of determining any patterns of incremental growth. In this regard, over the first ~3.5 months of the sampling period (late winter to late spring 2000), the modal length of the specimens measured (n = 140 and 172, respectively) increased by around 12 mm, whereas over the ~2 month period between mid winter and early spring 2001 (n = 362 and 391, respectively) the modal length decreased by around 4 mm. The first cohort of screw shells appeared to disappear from the sampled population after the early April 2001 (mid autumn) sampling, and be replaced by a different cohort with a modal length approximately 10 mm shorter by early July 2001 (mid winter). The only ready explanation of this anomaly may be that screw shells of different sizes (i.e. from different recruitments) were present in different parts of these Zosteraceae beds, sampling in which was carried out in a spatially random manner.

Maoricolpus roseus numbers present in the Zosteraceae beds during the period from late winter 2000 to mid autumn 2001 ranged from 107 to 172 individuals per 0.1 square metre, and during the period from mid winter 2001 to mid autumn 2002 from 207 to 391 individuals per 0.1 square metre.

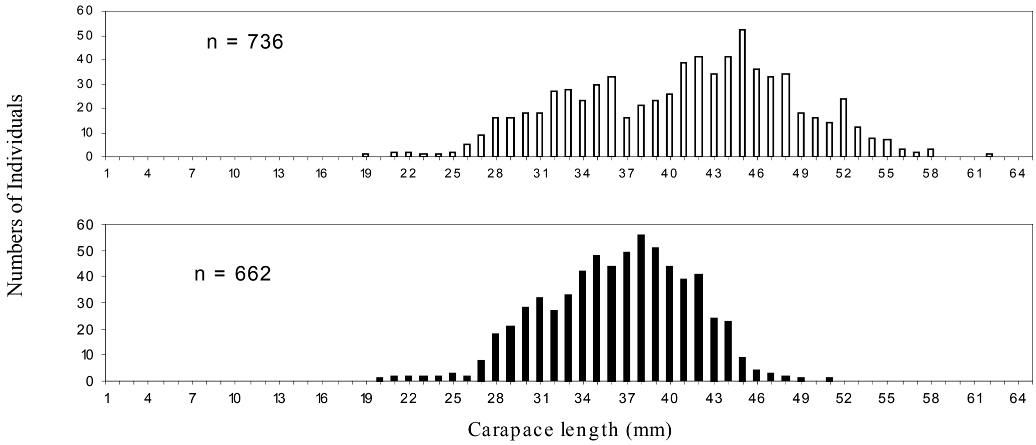

Figure 10. Overall length frequency distributions for male and female *Carcinus maenas* catches at the NSWEFCK sampling site in Twofold Bay over the entire study period. Key: male = white, female = black.

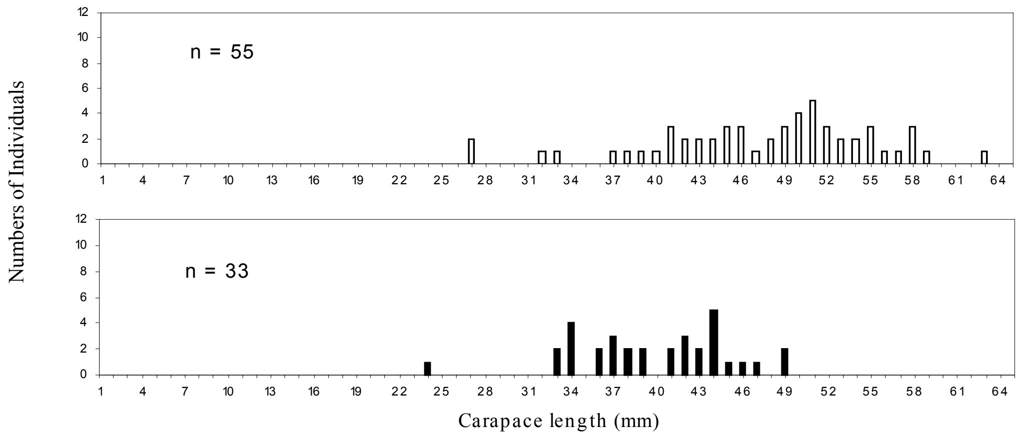

Figure 11. Overall length frequency distributions for male and female *Carcinus maenas* catches at all other sampling sites in Twofold Bay over the entire study period. Key: male = white, female = black.

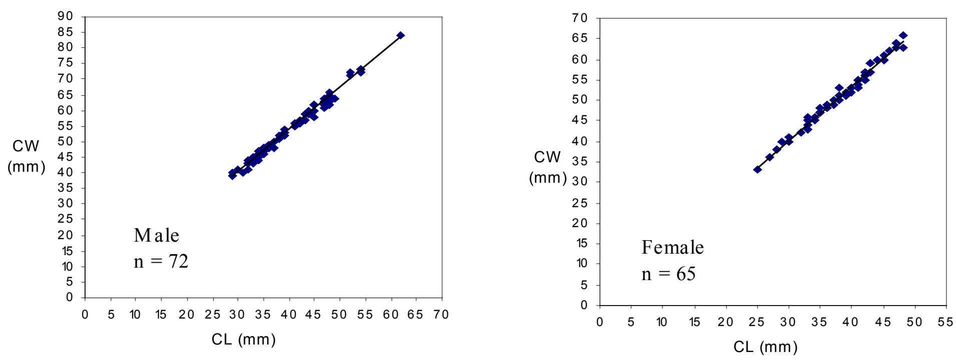

Figure 12. Comparisons of carapace length (CL) and carapace width (CW) for male and female *Carcinus maenas* captured in April 2002 at the NSWEFCK sampling site in Twofold Bay.

Table 2. *Alexandrium* cysts collected from sampling sites in Twofold Bay (benthic core samples).

Date	Dinoflagellate species present	EQA	EWB	EEB	ENB	EMF	WHB
September-99	*Alexandrium sp. ("catenella* type" cyst)	0.9		4.3	0.9		
November-00	*Alexandrium sp. ("catenella* type" cyst)			1.9			
	Alexandrium sp. - similar to *A. ostenfeldii*					0.9	
November-01	*Alexandrium sp. ("catenella* type" cyst)		1	2.9		1	1
	Alexandrium cf. minutum		2	1		3	
Key: Figures shown are % numbers of *Alexandrium* cysts among dinoflagellate cysts present in core samples							

Table 3. Motile dinoflagellates collected from sampling sites in Twofold Bay (phytoplankton net samples).

Date	Dinoflagellate species present	EQA	EWB	EEB	ENB	EMF	WHB
November-99	*Alexandrium sp.*	X		X	X		
	Dinophysis acuminata	X	X	X	X	X	X
	Dinophysis caudata	X					
March-00	*Alexandrium minutum*					X	
	Alexandrium tamarense	X	X		X	X	X
	Alexandrium ostenfeldii/peruvianum		X				
	Dinophysis acuminata	X	XX	XX	XX	X	
	Dinophysis caudata	XX	X	X		X	
	Dinophysis tripos		XX	X			X
May-00	*Alexandrium catenella/fundyense*						X
	Alexandrium minutum				X		X
	Alexandrium ostenfeldii/peruvianum	X		X		X	X
	Dinophysis acuminata	XX	X	XX	XX	XX	XX
	Dinophysis caudata	XX	XX	X			X
	Dinophysis tripos	X	X	X		X	X
August-00	*Alexandrium ostenfeldii/peruvianum*	X	X	X			X
	Dinophysis acuminata	XX	X	X	XX	XX	XX
	Dinophysis fortii	XX			X		
	Dinophysis tripos	XX			X	X	
November-00	*Alexandrium ostenfeldii/peruvianum*		X				
	Dinophysis acuminata	X	XX	X	X		X
	Dinophysis acuta		XX				X
	Dinophysis tripos		X				
April-01	*Alexandrium ostenfeldii/peruvianum*			X			X
	Dinophysis acuminata	XXX	XX	XXX	XXX	XX	XX
	Dinophysis acuta	X	X	XX	X		
	Dinophysis tripos	XX	X	X	X	X	
July-01	*Alexandrium margalefi*			X			X
	Alexandrium ostenfeldii/peruvianum	X	X			X	
	Dinophysis acuminata	X	X	X	X	X	X
	Dinophysis caudata	X	X	X	X		
	Dinophysis diagensis	X					
	Dinophysis tripos	X				X	
November-01	*Alexandrium catenella/fundyense*	X	X	X	X	X	
	Alexandrium margalefi	X			X	X	X
	Alexandrium minutum	X					
	Dinophysis acuminata	XXX	XX	XX	XX	XX	XX
April-02	*Dinophysis acuminata*	X	X	X			X
	Dinophysis caudata	X	X	X	X		X
	Dinophysis diagensis				X		XX
	Dinophysis tripos	XXX	X	X	X	X	XX
Key: x = rarely observed species, xx = common species, xxx = dominant species in replicate net samples							

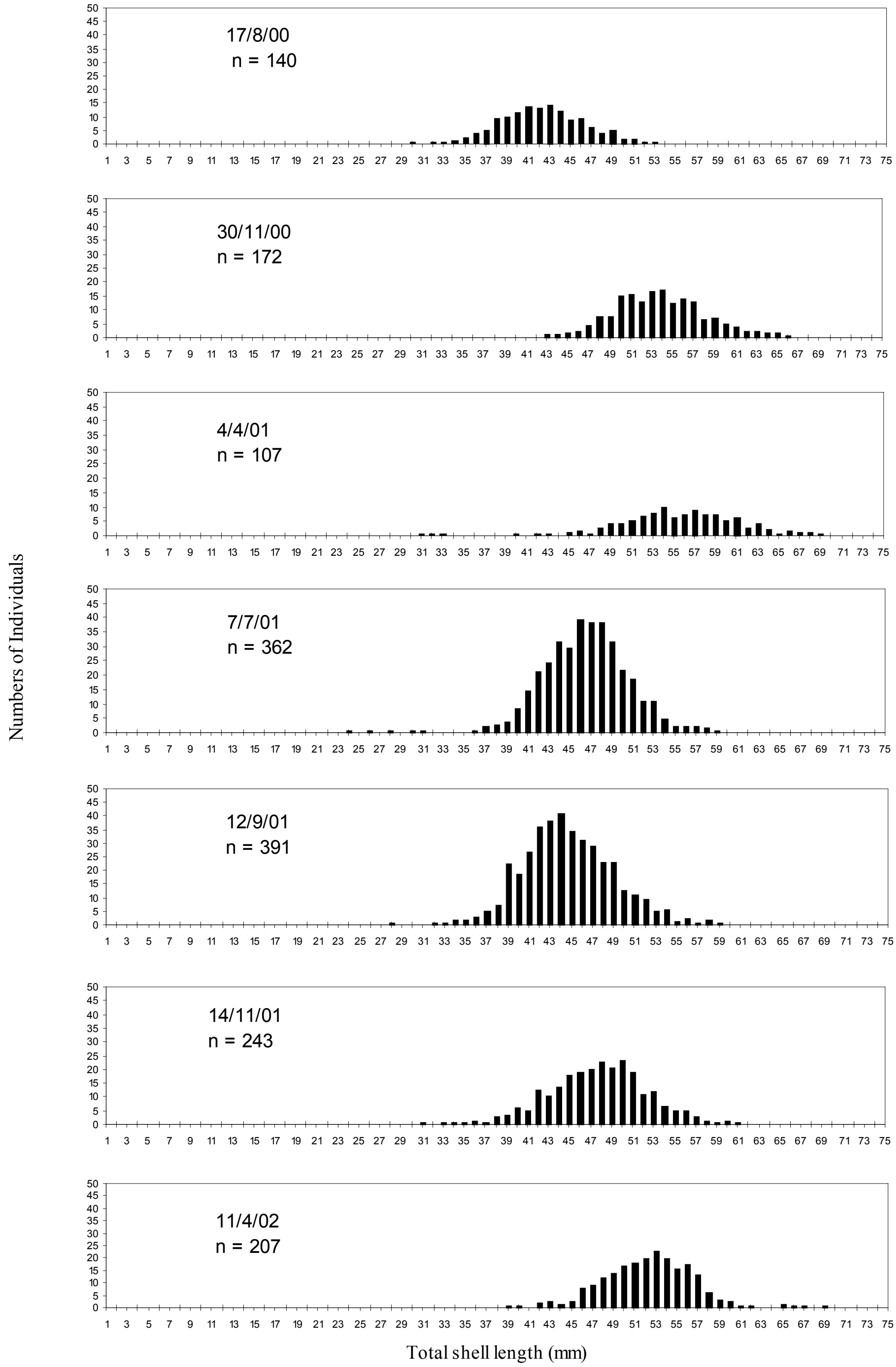

Figure 13. Length frequency distributions for *Maoricolpus roseus* collected from the NSWEEB sampling site in Twofold Bay (mean numbers per 0.1 square metre quadrat).

4.5. Other Introduced Species

Species of the potentially toxic diatom genus *Pseudo-nitzschia* were also frequently detected at very low concentrations in the net tow samples. Hewitt *et al*. (1999) and SafeFood (2001) have stated that species of the *Pseudo-nitzschia* genus are known to cause Amnesic Shellfish Poisoning (ASP) in humans.

A single specimen of the introduced alga *Codium fragile tomentosoides* was tentatively identified from a rocky reef area off the shoreline of Edrom Bay in May 2000. McEnnulty *et al*. (2001) stated that this species is identified as being of worldwide concern as a potential pest species. Additional thorough searches of this area, however, failed to locate any other specimens of this macroalga.

Other introduced non-pest species identified during previous studies were not specifically searched for nor collected, as this was not within the scope of this current study. CSIRO (1997) stated that all of the introduced species detected during the 1996 survey, with the exception of *Sabella spallanzanii*, were well established in the port. For these species eradication from the port by physical removal was thus not considered to be a realistic option. Many of these species are widespread in south-eastern Australian waters and any controls aimed at limiting their spread are likely to be ineffective.

5. DISCUSSION OF THE FOUR MAIN SPECIES STUDIED

5.1. *Sabella spallanzanii*

Sabella spallanzanii appears to have a distribution within Twofold Bay which is limited to the Snug Cove area. Of the 40 *Sabella* detected during both surveys, 38 were located in the immediate Snug Cove wharf area, with only two specimens being collected from a mooring line at the Snug Cove Anchorage (ESCA) site some 500 metres to the west of the Mooring Wharf. No *Sabella* were detected in any of the other bays or around other wharf developments, such as the Harris-Daishowa Woodchip Wharf, within Twofold Bay.

The recreational vessel anchorage at Quarantine Bay (EQB), around 1 kilometre to the west of Snug Cove, was regularly searched for *S. spallanzanii*, with no specimens being detected. This was originally thought to be a possible site for *Sabella* translocation into the Twofold Bay area via recreational vessel movements between Port Phillip Bay and Eden. Every boat hull here was inspected and the area of sea floor beneath this anchorage area searched. However, all of the vessels moored at the Quarantine Bay anchorage are locally owned and apparently very few travel between Port Phillip Bay and Twofold Bay.

The four *Sabella spallanzanii* specimens initially detected within Twofold Bay during the 1996 survey were found attached to debris underneath two separate Snug Cove wharves during qualitative underwater searches of the pilings and the under-wharf harbour floor (CSIRO 1997). These were the first targeted underwater surveys for the presence of *S. spallanzanii* undertaken by scientific researchers within the Snug Cove wharf area. A previous baseline study of Twofold Bay by Hutchings *et al.* (1986) did not include underwater diver surveys of the Snug Cove wharf area. Although only four specimens were detected during the 1996 survey, it is highly likely that there were more *S. spallanzanii* present at that time. Survey dives undertaken during this present study detected large well established *Sabella* specimens in areas that were not searched during the 1996 survey, primarily the Snug Cove harbour floor and Breakwater Wharf harbour floor areas. Often smaller *Sabella* specimens were difficult to identify when attached to vertical structures, unless their easily distinguished crown of orange radioles was visible. If the radioles were not visible, the similarity in colour of the individual tubes to some of the other wharf fouling organisms present made their positive identification difficult. Any disturbance to the surrounding water or any light shone on an open *Sabella* by a diver often resulted in the specimen retracting its crown, usually rendering the tube indistinguishable from its surroundings. During this present study multiple dives were conducted on all of the Snug Cove wharves and harbour floor areas, as a single survey dive on a wharf was deemed inadequate for a thorough search for *S. spallanzanii*. It is thus possible that additional *Sabella* may have been present on the wharves surveyed during these 1996 dives, but that they remained undetected at that time. Alternatively, new individuals could have been introduced to the port between 1996 and 2000. *Sabella* located on the harbour floor and wharf floor areas were much easier to identify due to the lack of any other similar organisms being present on these substrates.

The *Sabella* detected within Snug Cove during this present survey were of varying tube lengths and in a number of cases were located together in small groups of two or three individuals. The documented capacity of this worm to regenerate itself was observed with new smaller crowns of radioles occasionally seen protruding from the sides of the tubes of larger individuals. The tube length range of ~1 to ~30 centimetres in the 36 specimens collected indicates the possible establishment of some of these specimens over the past 5 or more years. However, Currie *et al.*

(2000) stated that growth can at times be rapid, and a study of *S. spallanzanii* in a laboratory aquarium indicated tube length growth of > 5 centimetres in 6 months (B. Rankin, pers. obs.).

Considering tube length as an approximate indicator of age, and thus reproductive maturity, in *Sabella spallanzanii*, the life history characteristics of this species in Australia can differ markedly from those in its native Mediterranean habitat, where the minimum size at maturity is 15 cm (Giangrande and Petraroli 1994; Giangrande *et al*. 2000). This can be compared with Port Phillip Bay, where the species may apparently reach maturity at a tube length of 5 cm (Currie *et al.* 2000). Based on these observations in Australian temperate waters, it must be assumed that nearly all of the *Sabella* detected during this current survey within Twofold Bay could have been of a mature reproductive age.

Previous studies on the dispersal and expansion of *Sabella spallanzanii* populations in Port Phillip Bay over the past 10 years or so indicate that the spread of these populations has been in a general clockwise direction, consistent with known water circulation patterns within this bay. External fertilisation, with large numbers of mature gametes being released, occurs over an extended autumn/winter period (Currie *et al*. 2000), following seasonal changes in seawater temperature and photoperiod. This species is a broadcast spawner, and estimates of mature oocyte densities of >50,000 eggs being produced and released by large *S. spallanzanii* (~40 cm body length) are documented. The size of the two immature *Sabella* specimens (<2 cm) detected on the mooring chain of the recreational vessel *Safari* at the Snug Cove anchorage in April and September 2001 (which were unlikely to have been translocated via hull fouling due to the vessel's clean hull and absence of any other *Sabella* specimens), suggests that larval dispersal may have originated from a spawning of mature individuals during winter 1999 within the close vicinity of Snug Cove. Checks of all other moorings in the Snug Cove anchorage and its vicinity, however, failed to detect any other recently settled *Sabella* which may have originated from this presumed spawning. Thus it appears that there may have been a reproductive population of *Sabella spallanzanii* present within the Snug Cove area.

Currently, it seems that the population of *Sabella* within this area of Twofold Bay is still very small, with increases in this population number through natural reproduction considered to be slow, especially when coupled with the removal of all specimens detected during the current survey program. With the entire known *Sabella spallanzanii* population of Twofold Bay being located in the Snug Cove area and within a ~500 metre radius, any further spread of *Sabella* within Twofold Bay would hopefully be limited to the Snug Cove region, as Currie *et al*. (2000) have indicated that larvae produced during each annual spawning only appear to be carried short distances from their parent stock prior to settlement. Due to the low numbers present and this apparent single aggregation of the *S. spallanzanii* population within Twofold Bay, it would thus appear that a single entry or very low number of translocation events by *Sabella* infested vessels berthing at the Snug Cove wharf area may have been the cause of the introduction of the *S. spallanzanii* to Twofold Bay. There appears to be little immediate likelihood of *Sabella* being translocated throughout the remainder of Twofold Bay, due to the lack of vessels with *Sabella* infested hulls which might move from the Snug Cove wharves, and possibly poor larval exchange between Snug Cove and other areas within Twofold Bay.

5.2. *Carcinus maenas*

Previous studies indicate that *Carcinus maenas* has been present within Twofold Bay for at least 10 years. Hutchings *et al*. (1986 & 1988) stated that this crab was commonly found around the shores of Twofold Bay, generally amongst intertidal rocks and over mud. The 1996 survey detected *C. maenas* in nearly all of the main tributaries surrounding Twofold Bay, namely Fisheries Creek, Shadrack Creek, Kiah Inlet, Curalo Lagoon and Nullica River/Mungora Point (CSIRO 1997). The current study targeted all five of these 1996 sampling sites within Twofold Bay, with *C. maenas* populations being detected at three of the above tributaries. *Carcinus maenas* is currently only well established in Fisheries Creek on the southern side of Twofold Bay, with a large number (1,398) of specimens being captured there during this 1999-2002 study. Smaller densities of *C. maenas* were found in the other two tributaries (Nullica River and Curalo Lagoon), but no specimens were captured at the Kiah Inlet or Shadrack Creek sites. The larger population abundance at the Fisheries Creek site compared to the other four sites sampled may be due to a number of beneficial factors found at this site, such as the remoteness of the location, a lack of predators or human interference, and the abundance of shelter and suitable habitat.

The capture of berried females and juvenile specimens (~20 mm CL), along with the broad size range of both sexes found, indicates a well established breeding population of *C. maenas* at the Fisheries Creek site within Twofold Bay. Large males of >60 mm CL (measuring >80 mm CW - refer to Figure 12) were also captured at this site. This can be compared to the results of Proctor & Thresher (1997), who stated that the maximum size of *C. maenas* found in Tasmanian waters surpasses that of most, if not all, other native and introduced populations of *C. maenas* worldwide. The largest known European *C. maenas* specimen was 90.5 mm CW, from Valentia Harbour in Ireland (Minchin 1997). Proctor & Thresher (1997) stated that the largest *C. maenas* captured in Tasmania up to that time was a male of 96 mm CW.

Carcinus maenas has a broad introduced distribution throughout south-eastern Australia, with Twofold Bay in southern NSW thought to be towards the northerly extent of its range. In this regard, sampling was undertaken on a single occasion during April 2002 to check for the presence of *C. maenas* to the north of Eden. Traps were set in Pambula Lake, the closest estuary to the north of Eden, with no *C. maenas* being captured. Tentative records from Merimbula and Narooma have, however, been noted in the past (Day and Hutchings, 1984). This species has also been documented to spread via natural processes over hundreds of kilometres in the United States (Grolsholz and Ruiz 1995; Ruiz *et al*. 1998).

Control methods involving the physical removal of *C. maenas* by trapping were considered to be inefficient and temporary, and there may be few predators within the tributaries of Twofold Bay which feed on the adult stages of this species. McEnnulty *et al*. (2001) stated that in areas of such high abundance, physical removal may only have a minor effect on recruitment and do little to reduce any impacts due to the large numbers of crabs present and their high fecundity. Chemical control of crabs in localised areas using poisoned baits are also likely to be ineffective. Biological options for control, such as parasites, parasitic castration or genetic and molecular techniques, have not yet been adequately assessed (McEnnulty *et al*. 2001).

5.3. ***Alexandrium* and *Dinophysis* Species**

Many species of dinoflagellates occur in Australian waters. These species can be present as motile free swimming forms, as well as sedentary cysts in marine sediments. Under certain favourable environmental conditions some dinoflagellate species can multiply rapidly in numbers to produce extensive blooms, which may often appear red in colour due to the intense concentration of motile cells in the water column. Some of these dinoflagellate species produce toxins which, when concentrated in filter-feeding invertebrates (e.g. molluscs) during these blooms, and then subsequently consumed by humans, can cause gastrointestinal and neurological illnesses which potentially can be fatal. Numerous species of the dinoflagellate genera *Gymnodinium*, *Alexandrium* and *Dinophysis*, and the diatom genus *Pseudo-nitzschia*, are documented to pose a threat to human health when in high concentrations due to their potential toxicity (Edgar 2000, SafeFood 2001).

Several species of the potentially toxic dinoflagellate genus *Alexandrium* have been previously documented as occurring in Twofold Bay (Hallegraef & Bolch 1992; CSIRO 1997). Specimens of

Alexandrium of the "*catenella* type" were found at low concentrations at a number of sites throughout Twofold Bay in 1996. Hallegraef *et al*. (1991) have stated that *A. catenella* is known from coastal estuaries and embayments from Port Phillip Bay in Victoria northwards to the Hawkesbury River in NSW. CSIRO (1998) confirmed that Newcastle was the most recently documented northerly extent of the known Australian distribution of *A. catenella* at that time. This species is only one of several known toxic dinoflagellates which have been found in Australian waters.

During this current study, a number of different species of the potentially toxic (PSP producing) dinoflagellate genus *Alexandrium* were detected in Twofold Bay. Five species (*A. catenella*/*fundyense*, *A. margalefi*, *A. minutum*, *A. ostenfeldii*/*peruvianum* and *A. tamarense*) were identified as motile cells at a number of sites in the seasonal phytoplankton net samples; and three species, *A.* "*catenella* type", *A. cf. minutum* and *Alexandrium* sp. (similar to *A. ostenfeldii*), were identified as resting cysts in benthic core sediment samples from various sites. All of these *Alexandrium* species were detected at only low concentrations at the sites sampled in Twofold Bay. The presence in Twofold Bay of numerous species of this ABWMAC target pest genus, even though detected at only low concentrations, has potential significance for the mussel mariculture facility (EMF site) in the bay. Edgar (2000) stated that the impacts of these toxic dinoflagellates are likely to be greatest on such shellfish mariculture activities. Any concentration of these potentially toxic dinoflagellate species in the vicinity of such shellfish production areas can pose a health threat to humans through the consumption of contaminated shellfish following the occurrence of toxic blooms. The detection of three *Alexandrium* species (see Table 2) as dormant cysts at the EMF site, although in very low concentrations, is thus of note.

The occurrence of at least six species of the potentially toxic (DSP producing) dinoflagellate genus *Dinophysis* as motile cells may also have significance to aquaculture within Twofold Bay. *Dinophysis acuminata* was the most commonly detected species, with *D. acuta*, *D. caudata*, *D. diagensis*, *D. fortii* and *D. tripos* also being identified. Motile cells of *Dinophysis* were collected at all sites sampled during phytoplankton net sampling. *Dinophysis acuminata* was identified as a common dinoflagellate species at the EMF site on a number of occasions.

5.4. ***Maoricolpus roseus***

First identified from Twofold Bay during the 1996 survey, *Maoricolpus roseus* was then only found at Snug Cove (CSIRO 1997). Hewitt *et al*. (1999) stated that, after first being recorded in Tasmania in the 1950s, this species has now spread around the coasts of most of south-eastern Australia, becoming a dominant member of the coastal and shelf benthic communities.

The present study detected *M. roseus* at all of the more marine benthic sites sampled throughout Twofold Bay, often at high densities over a variety of benthic habitat types, including mud, rocky reef, clean sand and Zosteraceae seagrass beds. The *M. roseus* present at the Edrom Bay (EEB) sampling site comprised the most concentrated population detected within Twofold Bay, with densities at the EEB site ranging from ~1000 to 4000 per square metre in the Zosteraceae beds there. Much lower densities were found at other benthic sites in Twofold Bay. This concentration of *M. roseus* at the EEB site may approach that occurring on parts of the coastal and shelf benthic habitats off south-eastern Australia as described by CSIRO (1997). The relatively sheltered nature of this site (due to the presence of the Harris-Daishowa Woodchip Berth, nearby headlands and a north facing bay), along with the presence of the Zosteraceae seagrass beds (acting as a benthic sediment trap), makes this low wave impact site a relatively favourable habitat for *M. roseus* within Twofold Bay. Shallow, high energy sites may not be such suitable habitats for *M. roseus*, as large numbers of this species were observed having been washed ashore from such sites onto the shoreline of Twofold Bay after heavy sea conditions (B. Rankin, pers. obs.).

Due to the wide distribution and very large abundances of *Maoricolpus roseus* offshore across the south-eastern Australian seafloor (Hewitt *et al*. 1999), including off Twofold Bay (CSIRO 1997), any attempt at control of the *M. roseus* population found within Twofold Bay was considered to be futile.

6. DISTRIBUTION AND POTENTIAL IMPACTS OF INTRODUCED SPECIES FOUND IN THE PORT

This present study has confirmed the continued presence in Twofold Bay of three currently listed ABWMAC target pest species, the European shore crab *Carcinus maenas*, the European fanworm *Sabella spallanzanii* and the toxic dinoflagellate *Alexandrium* "*catenella* type", as well as the New Zealand rosy screw shell *Maoricolpus roseus*. No other target introduced pest species currently listed on the ABWMAC Schedule 1 were detected during the study.

Analysis of the specimens collected during the initial 1996 port survey of Twofold Bay had previously detected the presence of these three ABWMAC listed pest species (*Carcinus maenas*, *Sabella spallanzanii* and *Alexandrium* "*catenella* type"), and *Maoricolpus roseus* was also identified and documented during the 1996 survey.

Additional introduced species found during the 1996 survey that were not searched for or studied during the current survey were the bryozoans *Bugula flabellata*, *B. neritina*, *Cryptosula pallasiana*, *Membranipora membranacea* and *Watersipora subtorquata* (=*subovoidea*); the crab *Cancer noveazelandiae*; the Pacific oyster *Crassostrea gigas*; and two other molluscs, *Polycera capensis* and *Theora fragilis*. Other introduced species that had been identified in previous biological studies of Twofold Bay, and which were not collected or identified in either the 1996 survey or this current study, included the ascidian *Styela plicata*, the snail *Theba pisana*, the barnacle *Notomegabalanus algicola* and the isopod *Eurylana arcuata* (CSIRO 1997).

The European green crab, *Carcinus maenas*, is a native of European Atlantic coastlines. First recorded in Australia from Port Phillip Bay in the late 1890s (Fulton & Grant 1900), the current known distribution of *C. maenas* in Australia is from the south coast of NSW to South Australia, and the north and east coasts of Tasmania (Proctor & Thresher 1997). It was introduced to the North American east coast in the early 19th century and now extends along the eastern coastlines of the USA and Canada. After being found in San Francisco Bay in 1989, it has since invaded most of the western coastline of the USA (Grolsholz & Ruiz 1995). It has also been recorded from Brazil and the Bay of Panama (Rathburn 1930), South Africa (Le Roux *et al*. 1990) and Japan (McEnnulty *et al*. 2001).

Carcinus maenas is capable of colonising a wide variety of inshore habitats from estuaries and salt marshes through to protected marine areas, with populations reaching high densities. As a voracious predatory species, *C. maenas* has considerable potential to alter and damage the fisheries, aquaculture and native faunal communities it invades (Thresher 1997). The impact of *C. maenas* on shellfish aquaculture facilities in its native Europe and in invaded regions of the USA is well documented (Ruiz *et al.* 1998).

Thresher (1997) stated that the impacts of *Carcinus maenas* on coastal invertebrate communities in Australia differ between Tasmania and the mainland. With the introduction of this species into Tasmanian waters being believed to have occurred only recently (within the past 10 years) (Proctor & Thresher 1997), the highly dense and pervasive populations of *C. maenas* presently found in well suited Tasmanian environments may have a very large impact on bivalve and native crab populations. However, with *C. maenas* having been detected along the southern coasts of the Australian mainland for over 100 years (Proctor & Thresher 1997), by comparison, the pattern of impacts of *C. maenas* on Australian mainland coastal habitats and biota appears to be slight, due to the generally smaller population densities. At present, *C. maenas* does not appear to be having any large impact on Australian fisheries or mariculture, partly due for instance to current management practices such as suspending grow-out racks off the bottom to protect aquaculture grown shellfish from benthic predators (McEnnulty *et al.* 2001). Currently, the mussel mariculture facility located in Twofold Bay is not impacted by the *C. maenas* populations present within the bay due to a number of factors including the lease's deep-water position within the bay, the remoteness of the lease from the shorelines and tributaries where *C. maenas* is currently located, and production practices limiting access by *C. maenas* to the mussels.

The giant European fanworm, *Sabella spallanzanii*, is native to the Mediterranean and North East Atlantic coasts, as far north as the English Channel. Surveys have established that this fanworm has been present in Australian waters since the 1960s (McEnnulty *et al*. 2001), and it is currently found at Eden in New South Wales; Port Phillip Bay in Victoria; West Lakes, North Haven, Kangaroo Island and the Port River in South Australia; Esperance, Albany, Bunbury, Cockburn Sound and Fremantle in Western Australia; and Devonport in Tasmania. In most of these areas it causes major fouling on man-made structures (wharf piles, breakwalls, buoys, pontoons, etc.) and is able to form dense 'meadows' on soft sediments. When present at high densities, *S. spallanzanii* can impact on wild scallop fisheries such as those in Port Phillip Bay, through increased fanworm catches clogging the dredges and greatly increasing sorting times. This species can also adversely affect shellfish (oyster, mussel and scallop) aquaculture operations that rely on the settlement of wild spat, either by reducing recruitment success by fouling lines and collection areas, or by reducing the availability of planktonic food. *Sabella spallanzanii* is dispersed as a planktonic larval form, and in its adult stage can spread as a fouling organism, from either fragments or whole worms discarded as fishing bait (McEnnulty *et al.* 2001).

Numerous species of the ABWMAC listed dinoflagellate genus *Alexandrium,* in the forms of cysts and motile cells, along with various species of the potentially toxic dinoflagellate genus *Dinophysis* and diatom genus *Pseudo-nitzschia*, were identified during this current study. However, all of these potentially toxic dinoflagellate and diatom species detected in the Port of Eden were only found in low concentrations.

Numerous species of potentially toxic dinoflagellates have previously been identified from Australian estuarine and marine waters and sediments. The toxic dinoflagellate *Alexandrium catenella* has been commonly recorded in coastal bays and estuaries from Port Phillip Bay in Victoria (Hallegraeff *et al*. 1991), and northwards along the Victorian and NSW coasts to the Hunter River at Newcastle (CSIRO 1998).

Several species of toxic dinoflagellates (including those from the genera *Alexandrium* and *Dinophysis*) can form extensive blooms which concentrate potent neurotoxins. These neurotoxins are concentrated by shellfish and, when eaten by humans, can cause Paralytic Shellfish Poisoning (PSP) or Diarrhetic Shellfish Poisoning (DSP). Toxicity may develop in both wild and cultured shellfish. This impact is likely to be greatest on shellfish mariculture activities (SafeFood 2001). Extensive mussel leases are located within Twofold Bay, although to date they do not appear to have been affected.

The New Zealand rosy screw shell, *Maoricolpus roseus*, was first recorded in Tasmania in 1950, and now forms extensive aggregations in a wide range of coastal and shelf habitats to depths of 150 m around the coasts of south-eastern Australia (Hewitt *et al.* 1999). The impacts of this gastropod on soft bottom infaunal and epifaunal communities are not certain, although documented concentrations of *M. roseus* in the vicinity of >10,000 per square metre off the south-eastern Australian coast (CSIRO 1997) are likely to result in a very significant competitive impact by *M. roseus* in a range of benthic habitats on any native gastropod species found within them.

The vast majority of the remaining introduced and cryptogenic species previously detected in the Port of Eden are not known to have any significant impacts on native aquatic animal and plant communities (CSIRO 1997). These known introduced species are generally recognised as having been transferred to Australia in both historic and modern times, most probably via ships' ballast water discharge and/or hull fouling, but are not listed as 'pest species' which are known to pose any significant economic or environmental threats in this area.

7. ORIGINS OF AND POSSIBLE VECTORS FOR THE INTRODUCTION OF NON-INDIGENOUS SPECIES FOUND IN THE PORT

Exotic species in the Port of Eden and Twofold Bay are likely to have been introduced by one of three main mechanisms:
(i) natural range expansion of species previously introduced to other parts of the south-eastern coastline of the Australian mainland;
(ii) directly to the bay by shipping using the port, either in ballast water or by hull fouling; or
(iii) by domestic translocation via fishing and recreational vessels.

The single ABWMAC target pest species likely to have become established in Twofold Bay as a result of natural range expansion is the European shore crab, *Carcinus maenas*.

Carcinus maenas was first discovered in Australia in the 1890s and was most likely introduced amongst semi-ballast used in English ships visiting Port Phillip Bay (Fulton & Grant 1900). This species is likely to have been introduced during multiple invasion events. In the 100 years or so since, *C. maenas* has attained a broad distribution throughout south-eastern Australia from southern New South Wales to South Australia. The *C. maenas* population in Twofold Bay is hypothesised to be a northern extension of the species' Victorian distribution (Zeidler, 1978), especially considering that *C. maenas* has been documented to have spread via natural processes over hundreds of kilometers in the United States (Grolsholz & Ruiz 1995).

Several of the other known introduced species previously identified within Twofold Bay are likely to have been introduced either directly via international shipping or indirectly from other first-entry ports via commercial, recreational and fishing vessels or slower moving vessels (e.g. dredges). Extensive hull fouling can develop on these vessels due to longer port residence times and the relative infrequency of dry-docking and brush-cart service (in-water hull cleaning). Slower moving vessels are likely to increase the chances of survival of species encrusting their hulls, leading to the entry and potential colonisation of the port by a diverse and often adult marine fouling community.

Domestic translocations within Australia are likely to contribute significantly to the spread of introduced marine organisms via the ballast water and hull fouling of larger commercial vessels, and hull fouling on smaller coastwise fishing and recreational craft.

The European fanworm, *Sabella spallanzanii*, is a known hull-fouling organism (Clapin and Evans 1995; Furlani 1996), and its occurrence around the Snug Cove Berths at Eden is consistent with its introduction via hull fouling rather than ballast water. The most likely source for this species is transport from Port Phillip Bay (where it is abundant, Hewitt *et al.* 1999) on the hulls of visiting fishing vessels. The proximity of the Snug Cove boat slipping facility to this point of invasion at Eden lends additional support to the hypothesis of a hull fouling origin.

The New Zealand rosy screw shell, *Maoricolpus roseus*, is present in high densities off the New South Wales south coast on the continental shelf, where these gastropods can be found at densities exceeding 10,000 per square meter (CSIRO 1997). A large number of vessels from Eden are active in the offshore trawl fishery, and are very likely to be the cause of the transport of live individuals in their nets from the shelf to the inshore waters of Twofold Bay. The localised distribution of *M. roseus* around the Snug Cove wharves, and particularly in East Boyd Bay where fishing vessels clean their nets while sheltering from bad weather, indicates that this is probably the primary cause of the invasion of this species in the sheltered waters of Twofold Bay.

The origin of the various species of the toxic dinoflagellate genus *Alexandrium* found in Twofold Bay is problematic. On the basis of existing information, it is not possible to determine if the *Alexandrium* spp. were introduced to the port via shipping or another vector. The resting cysts of *Alexandrium* spp. survive for 5-10 years in sediments, but fossilisation of cysts is not known to occur. The origin of any recently found cysts therefore cannot be inferred from fossil records. *Alexandrium catenella* is known from coastal estuaries and embayments from the Hawkesbury River in NSW southwards to Port Phillip Bay in Victoria (Hallegraeff *et al*. 1991), and may thus most likely have been transported via coastwise ballast water movements. The broad distribution of both *Alexandrium* and *Dinophysis* within Twofold Bay could indicate multiple inoculations over time.

8. EFFECTS OF THE PORT ENVIRONMENT AND PORT PRACTICES ON COLONISATION AND SURVIVAL OF INTRODUCED SPECIES

The resident marine fauna of the Port of Eden and Twofold Bay is indicative of a sheltered open coastal community with little exposure to variations in salinity typically associated with estuarine systems. Of the introduced species detected in the port, the majority are not generally restricted to such sheltered environments and may be capable of extending their ranges beyond the Twofold Bay locale (CSIRO 1997).

The European fanworm, *Sabella spallanzanii*, was first recorded in New South Wales at Eden during the 1996 baseline port survey (CSIRO 1997). Those individuals collected were found underneath or attached to wharf structures. In protected areas of other Australian ports where *S. spallanzanii* has established reproductive populations, it is a major coloniser of recently cleared or new structures such as wharf piles, beacons and buoys, and vessels that are not regularly cleaned and antifouled are likely to be rapidly colonised. The sheltered environment of Snug Cove with its wharves, harbour floor areas and moored vessels provides ideal habitats for the settlement and colonisation of *S. spallanzanii*.

During this 1999-2002 study, 42 underwater surveys were carried out, totalling 93 diver hours spent searching for the presence of *S. spallanzanii*, with only 36 specimens being detected. When compared to other southern Australian ports with known infestations of this species, e.g. Port Phillip Bay and Cockburn Sound (Hewitt *et al*. 1999), *S. spallanzanii* appears to be not at all well established in the Port of Eden.

Numerous hull fouling surveys undertaken during this current project failed to detect the presence of *S. spallanzanii* on the hulls of any commercial or recreational vessels. Regular checks of local and visiting commercial fishing vessels on the Snug Cove slipway also failed to detect the presence of *S. spallanzanii*.

It is thus likely that *S. spallanzanii* may be periodically introduced to Twofold Bay through domestic boat movements from Port Phillip Bay, or other ports with known fanworm infestations.

The continued practice of the cleaning of trawl nets and similar activities by the offshore fishing fleet within Twofold Bay may contribute to the range expansion of the introduced gastropod *Maoricolpus roseus* within Twofold Bay, as was evident from its likely introduction by fishing boats at the Edrom Bay (EEB) sampling site.

9. ASSESSMENT OF THE RISK OF NEW INTRODUCTIONS TO THE PORT

The successful introduction of an exotic species to a port through hull fouling or ballast water discharge requires some level of environmental matching between the donor and receiving ports; the degree of matching required and important environmental characteristics will depend on the environmental (e.g. temperature) tolerances of the individual species (CSIRO 1997). In the absence of this information, however, some general observations can still be made on the risks of new introductions to the Port of Eden and Twofold Bay based on current activity in the port.

Given the current level of international ship visits to the Port of Eden and Twofold Bay, the risk of new introductions from overseas would appear to be greatest at the Harris-Daishowa Woodchip Wharf and the Breakwater Berth. Vessels using these berths are likely to carry at least some hull fouling organisms compatible with the environment present in Twofold Bay. The Japanese vessels visiting the Harris-Daishowa Woodchip Wharf have previously been documented as carrying toxic dinoflagellate cysts in their ballast sediments (Hallegraef & Bolch 1992) and can also carry, and discharge, significant numbers of invertebrate larvae entrained in their ballast water. The two woodchip vessels which most frequently visit Twofold Bay, the *Eden Maru* and the *Daishowa Maru*, primarily trade between the ports of Shimizu and Muroran in Japan, and Eden. However, the woodchip bulk carriers that take on cargo at the Port of Eden now routinely exchange their ballast water at sea, and hence are recorded as discharging it in 'mid ocean' before taking on their woodchip cargo in Twofold Bay. These open ocean waters are considered to present a very low risk in terms of the introduction of marine pests to inshore coastal waters via ballast water infection.

The small bulk fuel tankers that call into the Port of Eden on a regular basis to discharge petroleum products may take on some ballast water depending on the volume of liquid cargo discharged. These tankers operate a consistent route between Eden and Brisbane, Botany Bay, Port Melbourne or Port Stanvac in Victoria. The frequency and year-round operation of this service may increase the risk of any marine pest organisms living on their hulls being introduced to Twofold Bay.

The periodic presence of slow-moving, long residence vessels such as drilling platforms or dredges in the port may present an opportunity for significant fouling communities to establish themselves in port waters. Previous work in the North Pacific has demonstrated the ability for these slow-moving vessels to transport complete assemblages over long distances. The long residence times allow for reproductive populations to establish themselves (CSIRO 1997). Checks of such vessels within Twofold Bay during this current study, however, failed to detect any targeted introduced marine species present as hull fouling. Any dredging vessels used during the future construction of the RAN Multi-Purpose Wharf at Edrom Bay should also be inspected.

The occurrence of *Sabella spallanzanii* in the Snug Cove area of the port indicates that domestic traffic is also likely to play a significant role in the translocation of introduced marine species (Clapin & Evans 1995) to the Port of Eden. *Sabella* is likely to have arrived via hull fouling from Port Phillip Bay, Victoria. Such hull fouling organisms may have either spawned and their offspring settled in Snug Cove, been accidentally scraped or knocked off vessels adjacent to the berth, or have been scraped off due to in-water cleaning or during slipping. Those vessels most likely to be implicated include the coastal fishing fleet of trawlers, and a variety of recreational vessels periodically visiting or located at Eden.

In CSIRO (1997) it is stated that those introduced species most likely to be translocated from Port Phillip Bay would include the polychaete *Sabella spallanzanii*, the algae *Undaria pinnatifida* and *Codium fragile tomentosoides*, the bivalves *Corbula gibba* and *Musculista senhousia*, and potentially also the seastar *Asterias amurensis*. Marine pest education programs initiated by the Victorian Environment Protection Authority (EPA) and the Department of Natural Resources and Environment (NRE) have been undertaken in Victorian ports in an attempt to limit the translocation of these introduced marine pest species, along with the dissemination of guidelines for hull fouling management developed to prohibit the disposal of hull fouling wastes into marine waters.

10. ASSESSMENT OF THE RISK OF TRANSLOCATION OF INTRODUCED SPECIES FOUND IN THE PORT

An assessment of the risks of translocation of introduced species from the Port of Eden and Twofold Bay to other ports by shipping involves similar considerations to those discussed in assessing the risks of new introductions to the port. Few vessels load ballast water in Twofold Bay, and it is thus unlikely that water from Eden would be discharged in other Australian ports. The visiting oil tankers rarely take on ballast in Twofold Bay and are thus unlikely to transport planktonic organisms between Twofold Bay and other domestic ports.

A number of vessels could, however, be involved in the translocation of introduced organisms to other ports via hull fouling. Numerous smaller recreational and commercial (mainly fishing) vessels located within Twofold Bay were surveyed for hull fouling during this current study, with no *Sabella spallanzanii* being detected on any of these vessels' hulls. Given the low abundance of this species in the port, however, it is unlikely that Eden would be the source of any significant domestic translocations of *S. spallanzanii* to other domestic ports.

11. MANAGEMENT OPTIONS AND RECOMMENDATIONS

11.1. Management and Monitoring of Existing Introduced Species in the Port

All of the introduced species detected during this project, with the exception *of Sabella spallanzanii*, are already well established in the Port of Eden. For these species, eradication from the port by physical removal is not a realistic option. Many of these species are already widespread in south-eastern Australian waters and any controls aimed at limiting their movements are likely to be ineffective.

Sabella spallanzanii, however, is not yet well established in the port, and is highly localised there. Nevertheless, the small numbers of specimens collected at the Snug Cove wharves indicate that Twofold Bay is susceptible to invasion by this species, and it is thought that the most likely source area is Port Phillip Bay. Control of *S. spallanzanii* is possible if individuals are detected and removed within 12 months of settlement, i.e. before they have begun to spawn in the port. There are currently no specific control methods for *S. spallanzanii* available (McEnnulty *et al*. 2001), thus highlighting the importance of continued manual removal whilst densities are low in the Port of Eden. It is therefore recommended that biannual monitoring and eradication (during spring and autumn) around the Snug Cove jetties and Breakwater Wharf areas be undertaken by divers to locate and where possible remove any recently settled worms. These surveys should involve qualitative searches, and could be carried out by commercial and/or volunteer divers who could be trained to recognise *Sabella* in the field. Such surveys would also facilitate the early detection of other pest species such as the northern Pacific seastar, *Asterias amurensis*, or the Japanese kelp, *Undaria pinnatifida*, should they become introduced to the port. The early detection of such introduced marine pest species could also be facilitated by the educational/awareness program aimed at local fishers and commercial vessel operators undertaken as part of the Victorian Local Ports Introduced Marine Pest Project, which also covers the Port of Eden, which is not far from the Victorian border.

Observations in Port Phillip Bay and other mainland ports indicate that *Sabella spallanzanii* readily colonises both fixed and floating man-made structures (Hewitt *et al.* 1999). Any new developments in the port, such as the Multi-Purpose Naval Ammunitioning Berth presently being constructed in East Boyd Bay, should be included in these proposed biannual surveys and examined by divers. These surveys should be continued at least until the submerged surfaces have developed well established native fouling communities. In the event that *Sabella spallanzanii* does become well established in the port, physical removal of infestations extending over large areas by divers may not be logistically possible; nor would dredging or similar mechanical techniques that could fragment these fanworms. It should thus be imperative to attempt to prevent the spread of this species to other New South Wales ports, with a key component of this strategy being an education program aimed at the owners of all vessels that regularly use the port to ensure that inspection and cleaning of hulls takes place on a regular basis. This is particularly important in the case of vessels laid up in the port for extended periods; these should be inspected and cleaned prior to their departing for other ports to minimise any translocation risks.

Dinoflagellates of the *Alexandrium* "*catenella* type" were not found to be abundant in the Port of Eden. However, other species of the potentially toxic dinoflagellate genus *Alexandrium* and various species of the potentially toxic dinoflagellate genus *Dinophysis* were detected within Twofold Bay. The toxic status and seasonal abundance of *Alexandrium* "*catenella* type" and other potentially toxic dinoflagellate species needs to be further clarified, and their potential for bloom formation needs to be assessed. The siting of any future aquaculture facilities should take into account studies on the bay's hydrodynamics, water quality and the prevalence of algal cysts in the sediments (McEnnulty *et al.* 2001).

Currently, the mussel mariculture facility (NSWEMF) located in Twofold Bay conducts regular microbiological, chemical and biotoxin analysis (M. Bamford, pers. comm.) as part of the NSW Shellfish Quality Assurance Program (NSW SQAP), in accordance with the requirements of the Food Production (Seafood Safety Scheme) Regulation 2001 (SafeFood 2001). This includes regular water sampling surrounding the lease area to detect dinoflagellate abundances. Benchmark concentration levels for phytoplankton species have been developed (see Appendix 10) along with a Marine Algal Biotoxin Contingency Management Plan (SafeFood 2001).

It is recommended that an expanded and on-going phytoplankton net monitoring program be incorporated into this regular NSW SQAP monitoring exercise at the EMF site to determine the presence and seasonality of toxic dinoflagellates in the water column within Twofold Bay. Core sampling to detect the presence of sedentary dinoflagellate cysts in the benthic sediments beneath the lease sites is also recommended.

Carcinus maenas is relatively abundant within several tributaries to Twofold Bay (and especially Fisheries Creek), but only limited surveys have been carried out on the distribution of this species on the NSW coastline north of Eden. Current research by CSIRO Marine Laboratories has used trapping to gather morphometric, demographic and parasite information, and to promote understanding of this species' impacts and vulnerabilities in Australia (McEnnulty *et al*. 2001). An international workshop held in Tasmania in 1997 (Thresher 1997) on managing *C. maenas* numbers suggested that two options could be effective out of the many potential longer-term control options considered. The first was a large-scale program of physical removal, possibly in the form of a subsidised fishery, which may reduce impacts temporarily or in small areas where the crab is causing localised problems. The second was biological control. There are several potential biological control options available, including parasites, parasitic castrators, enhancement of native predators and genetic or molecular techniques. However, none of these biological control options has yet been adequately assessed (McEnnulty *et al*. 2001).

The gastropod mollusc *Maoricolus roseus* was found to be abundant within parts of Twofold Bay, and is a dominant member of the south-eastern Australian coastal benthic community (Hewitt *et al*. 1999). The eradication of *M. roseus* from Twofold Bay, however, is also not a realistic option, and with an apparent lack of predators in Australian waters, the continued spread and increased abundance of this species seems likely. Currently there are few control options available for this species.

11.2. Prevention of New Introductions to the Port

There is currently no information available on which to base an estimate of the risks of further introductions to the port via hull fouling, though this should not be a serious problem in view of more modern hull cleaning management approaches (see ANZECC 1997 and Appendix 11).

New mandatory arrangements for managing international ballast water have been introduced by the Australian Quarantine and Inspection Service (AQIS), which have been in operation since July 2001. These require exchange of ballast water in mid-ocean, and the individual assessment of ballast water loads as low-risk or high-risk for introducing toxic organisms to Australian waters. Contingency deballasting zones, where high risk ballast water can be safely discharged, are to be established following research to map suitable areas. These measures should reduce the likelihood of future marine pest species introductions into and between Australian ports, including Twofold Bay, through this vector (AQIS 2001, Geeves 2001).

In relation to future shipping activities in the port, current activity by AQIS should also result in additional database development concerning both vessel movements and ballast water origins and discharges on a per tank basis. In order to facilitate consistency between databases, it would also be useful to incorporate an agreed upon set of port names of the world. This list should be available in the near future and would provide for accurate naming and identification of last and next ports of call.

The operations of the slipway at Eden could contribute to the introduction of hull fouling organisms. Standard procedure is to wash the scraped material back into the port waters rather than into a holding bin. The disposal to the port of these organisms may provide ample opportunity for any introduced species present to establish viable populations in the port (see Appendix 11).

12. REFERENCES

Allan, J.K., 1931. Australian nudibranchs. Aust. Zool., 7: 87-100.

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

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

ANZECC, 1997. Code of practice for antifouling and in-water hull cleaning and maintenance. Australian and New Zealand Environment and Conservation Council, Canberra, 12 pp.

AQIS, 2001. Ballast water brochure. Australian Quarantine and Inspection Service, Canberra, 4 pp.

Baker, G.H., 1986. The biology and control of white snails (Mollusca: Helicidae), introduced pests in Australia. CSIRO Division of Entomology Technical Paper No. 25. CSIRO, Australia, 31pp.

Bolch, C.J. & Hallegraeff, G.M., 1990. Dinoflagellate cysts in recent marine sediments from Tasmania, Australia. Bot. Marr, 33: 1736-192.

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

Clapin, G. & Evans, D.R., 1995. The status of the introduced marine fanworm *Sabella spallanzanii* in Western Australia: a preliminary investigation. CRIMP Technical Report No. 2. CSIRO Marine Research, Hobart, Tasmania.

CSIRO Marine Research, 1997. Introduced species survey, Eden and Twofold Bay, New South Wales. CSIRO Marine Research, Hobart, Tasmania, 50 pp.

CSIRO Marine Research, 1998. Introduced species survey, Newcastle, New South Wales. CSIRO Marine Research, Hobart, Tasmania, 53 pp.

Currie, D.R., McArthur, M.A. & Cohen, B.F., 2000. Reproduction and distribution of the invasive European fanworm *Sabella spallanzanii* (Polychaeta: Sabellidae) in Port Phillip Bay, Victoria, Australia. Mar. Biol., 136: 645-656.

Day, J.H. & Hutchings, P.A., 1984. Descriptive notes on the fauna and flora of Merimbula, Pambula and Back Lakes, New South Wales. Aust. Zool., 21 (3): 269-289.

Edgar, G.J., 2000. Australian Marine Life – the Plants and Animals of Temperate Waters. Reed Books, Kew, Victoria, 544 pp.

Furlani, D.M., 1996. A guide to the introduced marine species in Australian Waters. CRIMP Technical Report No. 5. CSIRO Marine Research, Hobart, Tasmania.

Fulton, S.W. & Grant, F.E., 1900. Notes on the occurrence of the European shore crab, *Carcinus maenas* Leach, in Port Phillip Bay. Vic. Nat., 17: 147-148.

Geeves, W., 2001. The latest news on the battle against introduced marine pests. Waves (Marine and Coastal Community Network, Sydney), 8(2): 13.

Giangrande, A., Licciano, M., Pagliara, P. & Gambi, M.C., 2000. Gametogenesis and larval development in *Sabella spallanzanii* (Polychaeta: Sabellidae) from the Mediterranean Sea. Mar. Biol., 136: 847-861.

Giangrande, A. & Petraroli, A., 1994. Observations on reproduction and growth of *Sabella spallanzanii* (Polychaeta: Sabellidae) in the Mediterranean Sea. In Dauvin, J.C., Laubier, L. & Reish, D.J. (eds). Actes de la 4eme Conference Internationale des Polychaetes / Proceedings of the 4th International Polychaete Conference. Memoires du Museum National d'Histoire Naturelle, 162: 51-56.

Grolsholz, E.D. & Ruiz, G.M., 1995. Spread and potential impacts of the recently introduced European green crab, *Carcinus maenas*, in central California. Mar. Biol., 122: 239-247.

Hallegraeff, G.M. & Bolch, C.J., 1992. Transport of diatom and dinoflagellate resting spores in ships' ballast water: implications for plankton biogeography and aquaculture. J. Plankt. Res., 14(8): 1067-1084.

Hallegraeff, G.M., Bolch, C.J., Blackburn, S.I. & Oshima, Y., 1991. Species of the toxic dinoflagellate genus *Alexandrium* in south eastern Australian waters. Bot. Mar., 34: 575-587.

Hewitt, C.L. & Martin, R.B., 1996. Port surveys for introduced marine species – background considerations and sampling protocols. CRIMP Technical Report No. 4. CSIRO Marine Research, Hobart, Tasmania, 40 pp.

Hewitt, C.L. & Martin, R.B., 2001. Revised protocols for baseline port surveys for introduced marine species – survey design, sampling protocols and specimen handling. CRIMP Technical Report No. 22. CSIRO Marine Research, Hobart, Tasmania, 46 pp.

Hewitt, C.L., Campbell, M.L., Thresher, R.E. & Martin, R.B., 1999. Marine Biological Invasions of Port Phillip Bay, Victoria. CRIMP Technical Report No. 20. CSIRO Marine Research, Hobart, Tasmania, 344 pp.

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

Hutchings, P.A., Van der Velde, J.T. & Keable, S.J., 1986. Colonisation of NSW by non-indigenous marine species. Baseline studies at Twofold Bay, NSW (FIRTA 84-49). Final Report to the Fishing Industry Research Committee, Australian Museum, Sydney, 71pp.

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

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

Le Roux, P.J., Branch, G.M. & Joska, M.A.P., 1990. On the distribution, diet and possible impact of the invasive European shore crab *Carcinus maenas* (L.) along the South African coast. S. Afr. J. Mar. Sci., 9: 85-93.

Minchin, D., 1997. The influence of the parasitic cirrepede *Sacculina carcini* on its brachyuran host *Carcinus maenas* within its home range. Pp. 76-80, in: Thresher, R.E. (ed.), Proceedings of the First International Workshop on the Demography, Impacts and Management of Introduced Populations of the European Crab, *Carcinus maenas*. CSIRO

Marine Laboratories, Hobart, 20-21 March 1997. CRIMP Technical Report No. 11. CSIRO Marine Research, Hobart, Tasmania.

McEnnulty, F.R., Bax, N.J., Schaffelke, B. & Campbell, M.L., 2001. A review of the rapid response options for the control of ABWMAC listed introduced marine pest species and related taxa in Australian waters. CRIMP Technical Report No. 23. CSIRO Marine Research, Hobart, Tasmania.

Pacific Seafood Management Consulting Group Pty Ltd, 1996. Environmental Impact Statement (incorporating Fauna Impact Statement): evaluating mussel aquaculture in Twofold Bay. South Coast Business Enterprise Centre Ltd, Eden, NSW, 178 pp.

Pollard, D.A. & Pethebridge, R.L., 2002. Report on Port Kembla Introduced Marine Pest Species Survey. NSW Fisheries Final Report Series No. 41. NSW Fisheries, Cronulla, NSW, 73 pp.

Proctor, C. & Thresher, R.E., 1997. The invasive history, distribution and abundance of *C. maenas* in Australia. Pp. 31-33, in: Thresher, R.E. (ed.), Proceedings of the First International Workshop on the Demography, Impacts and Management of Introduced Populations of the European Crab, *Carcinus maenas*. CSIRO Marine Laboratories, Hobart, 20-21 March 1997. CRIMP Technical Report No. 11. CSIRO Marine Research, Hobart, Tasmania.

Rathburn, M., 1930. The cancroid crabs of America of the families Euryalidae, Portunidae, Atelecyclidae and Xanthidae. Bull. U.S. Nat. Mus., 152, 609 pp.

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

Ruiz, G.M., Miller, A.W. & Walton, W.C., 1998. The bi-coastal invasion of North America by the European green crab: impacts and management strategies. Aquatic Nuisance Species Task Force, Smithsonian Environmental Research Centre, Edgewater, Maryland, USA, 45 pp.

SafeFood NSW, 2001. New South Wales Shellfish Program Operations Manual. SafeFood NSW, Sydney, NSW, 109pp.

Thompson, J.M., 1959. The naturalisation of the Pacific oyster in Australia. Aust. J. Mar. Freshwat. Res., 10: 144-149.

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

Thresher, R.E., (ed.) 1997. Proceedings of the First International Workshop on the Demography, Impacts and Management of Introduced Populations of the European Crab, *Carcinus maenas*. CSIRO Marine Laboratories, Hobart, 20-21 March 1997. CRIMP Technical Report No. 11. CSIRO Marine Research, Hobart, Tasmania.

Willan, R. C. & Coleman, N., 1984. Nudibranchs of Australasia. Australasian Marine Photographic Index, Australian Museum, Sydney, 56pp.

Woodward & Clyde, 1999. Twofold Bay Multi-Purpose Wharf and Naval Munitions Storage Facility – Draft Environmental Impact Statement. Prepared for Department of Defence & NSW Waterways Authority. Volumes 1-2 & Appendices.

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

APPENDICES

APPENDIX 1. SCHEDULE OF INTRODUCED SPECIES

Schedule 1. Australian Ballast Water Management Advisory Council (ABWMAC) ∗ schedule of target introduced pest species (or taxa)

Gymnodinium & *Alexandrium* spp. (toxic dinoflagellates)
Undaria pinnatifida (Japanese seaweed)
Sabella spallanzanii (European fan worm)
Carcinus maenas (European shore crab)
Corbula gibba (European clam)
Mytilopsis sallei (Central American striped mussel)
Asterias amurensis (Northern Pacific seastar)
Vibrio cholera (cholera bacterium)
Fish pathogens (various)

Schedule 2. Marine pest species that may pose a significant threat in Australian waters

Mnemiopsis leidyi (North American comb jelly)
Philine auriformis (New Zealand sea slug)
Potamocorbula amurensis (Chinese clam)
Mytilus galloprovincialis (Mediterranean mussel)

Schedule 3. Known exotic species present in Australian waters

ANIMALS

Species	Possible Origin	Australian Distribution
Bougainvillea ramosa (hydroid)	N. Hemisphere	NSW
Hydroides elegans(serpulid)	Europe	WA, Vic, Tas, NSW
Boccardia proboscidea (spionid)	Japan/N.E. Pacific	Vic
Polydora ciliata (spionid)	Europe	WA, NSW
Pseudopolydora paucibranchiata (spionid)	Japan/N.E. Pacific/NZ	Vic
Euchone (?) sp. (fan worm)	?	Vic?
Sabella spallanzanii (fan worm)	Mediterranean	WA, SA, Vic, Tas, NSW
Balanus improvisus (barnacle)	Atlantic	SA?
Megabalanus rosa (barnacle)	Japan	WA
Megabalanus tintinnabulum (barnacle)	cosmopolitan	WA
Notomegabalanus algicola (barnacle)	S. Africa	NSW
Neomysis japonica (mysid shrimp)	Japan	NSW
Tanais dulongi (tanaid)	Europe	SA
Cirolana hardfordi (isopod)	USA	WA, Vic, NSW
Eurylana arcuata (isopod)	NZ/Chile	SA, NSW
Paracerceis sculpta (isopod)	USA/S. America	Qld
Paradella dianae (isopod)	USA/S. America	Qld
Sphaeroma serratum (isopod)	widespread	WA
Sphaeroma walkeri (isopod)	Indian Ocean	NSW, Qld

∗ Now known as the Australian Introduced Marine Pest Advisory Council (AIMPAC)

Synidotea laevidorsalis (isopod)	?	?
Cancer novaezelandiae (crab)	NZ	Vic, Tas
Carcinus maenas (crab)	Europe	WA, SA, Vic, Tas, NSW
Halicarcinus innominatus (crab)	NZ	Tas
Petrolisthes elongatus (half crab)	NZ	Tas
Pyromaia tuberculata (crab)	E. Pacific	WA
Palaemon macrodactylus (shrimp)	N. Pacific	NSW
Sergiella angra (shrimp)	?	?
Maoricolpus roseus (screw shell)	NZ	Tas, NSW
Zeacumantis subcarinatus (screw shell)	NZ	NSW
Aeolidiella indica (sea slug)	widespread	NSW
Godiva quadricolor (sea slug)	S. Africa	WA
Janolus hyalinus (sea slug)	Europe	Vic
Okenia plana (sea slug)	Japan	Vic, NSW
Polycera capensis (sea slug)	S. Africa	NSW
Polycera hedgpethi (sea slug)	California	WA, Vic, NSW
Thecacera pennigera (sea slug)	?	NSW
Crassostrea gigas (oyster)	Japan	WA, SA, Vic, Tas, NSW
Ostrea lutaria (oyster)	NZ	Vic
Corbula gibba (clam)	Europe/Mediterranean	Vic
Neilo australis (clam)	NZ	Tas
Paphirus largellierti (clam)	NZ	Tas
Musculista senhousia (mussel)	Pacific/Asia	WA, Vic, Tas
Mytilopsis sallei (striped mussel)	Central America	NT
Perna canaliculus (mussel)	NZ	Tas
Soletellina donacoides (tellinid)	NZ?	Tas?
Theora lubrica (semelid)	Pacific/Asia	WA, Vic
Amaurochiton glaucus (chiton)	NZ	Tas
Anguinella palmata (bryozoan)	Atlantic	NSW
Bugula flabellata (bryozoan)	Atlantic/Mediterranean	SA, NSW
Conopeum tubigerum (bryozoan)	Atlantic	Qld
Cryptosula pallasiana (bryozoan)	?	WA, SA, Tas, NSW
Membranipora membranacea (bryozoan)	cosmopolitan	SA, Vic?, Tas?
Schizoporella unicornis (bryozoan)	Japan	WA, SA, NSW, Qld
Watersipora arcuata (bryozoan)	Mexico	WA, SA, NSW, Qld
Asterias amurensis (seastar)	Japan	Vic, Tas
Astrostole scabra (seastar)	NZ	Tas
Patiriella regularis (seastar)	NZ	Tas
Ascidiella aspersa (ascidian)	Europe	WA, SA, Vic, Tas
Ciona intestinalis (ascidian)	Europe	WA, SA, Vic, Tas, NSW, Qld
Molgula manhattensis (ascidian)	N. Atlantic	Vic, Qld
Styela clava (ascidian)	N.W. Pacific/Europe	Vic
Styela plicata (ascidian)	widespread	WA, SA, NSW, Qld
Lateolabrax japonicus (sea bass)	Japan	NSW
Triso dermopterus (grouper)	W. Equat. Pacific	Qld
Sparidentex hasta (sea bream)	Arabian Gulf	WA
Acanthogobius flavimanus (goby)	W. Equat. Pacific	Vic, NSW
Acentrogobius pflaumi (goby)	Japan	Vic, NSW
Tridentiger trigonocephalus (goby)	W. Equat. Pacific	WA, Vic, NSW
Fosterygion varium (blenny)	NZ	Tas
Oncorhynchus mykiss (trout)	California (via NZ)	Tas
Oreochromis mossambicus (tilapia)	S.E. Asia	WA, Qld
Salmo salar (salmon)	N. America	Tas
Salmo trutta (trout)	UK	Tas

PLANTS

Species	Possible Origin	Australian Distribution
Alexandrium catenella (dinoflagellate)	Japan?	WA, SA, Vic, NSW
Alexandrium minutum (dinoflagellate)	Mediterranean?	WA, SA, Vic, NSW
Alexandrium tamarense (dinoflagellate)	Europe? Japan?	WA, SA, Vic, Tas
Gymnodinium catenatum (dinoflagellate)	Japan?	WA, Vic, Tas
Caulerpa taxifolia (green alga)	Atlantic/Indo Pacific	NSW, Qld
Codium fragile tomentosoides (green alga)	Atlantic Europe	Vic, NSW
Antithamnionella spirographidis (red alga)	N. hemisphere	?
Arthrocladia villosa (red alga)	N. hemisphere	?
Polysiphonia brodiaei (red alga)	N. hemisphere	?
Polysiphonia pungens (red alga)	N. hemisphere	?
Sperococcus compressus (red alga)	N. hemisphere	?
Discosporangium mesarthrocarpum (brown alga)	Mediterranean	SA
Spacella subtilissima (brown alga)	Mediterranean	SA
Undaria pinnatifida (brown alga)	Japan	Vic, Tas
Zosterocarpus spp. (brown alga)	Mediterranean	SA

Sourced from: Pollard & Pethebridge (2002)

APPENDIX 2. SUMMARY OF PROJECT STAGES

The brief summary outlined below provides information in relation to stages one to eight of the project as detailed in the Department of Land and Water Conservation's letter dated 3 November 1998 and the Ministry for Forests and Marine Administration's letter of acceptance dated 11 March 1999.

Stage 1. Initial payment contingent on approval by the Commonwealth and relevant NSW management agencies of a revised methodology.

A revised methodology for the project was submitted by NSW Fisheries (NSWF) to CRIMP and Environment Australia for approval in September 1998. NSWF received phase one (initial) funding of $28,600 in May 1999. Phase two (6 month) funding of $28,500 was received in January 2000, phase three (12 month) funding of $30,100 in September 2000, phase four (18 month) funding of $30,000 in May 2001, phase five (24 month) funding of $21,600 in September 2001, phase six (30 month) funding of $20,000 in early 2002, and the final payment of $20,000 was received following completion of the project report, in March 2003.

Stage 2. Recruitment of NSW Fisheries divers and recreational diving groups.

A Fisheries Technician (qualified scientific diver) was appointed to the project by NSWF in July 1999. Community diver groups and CRIMP divers were utilised in a major attempt to eradicate *Sabella spallanzanii* from the Port of Eden during May 2000. Various other qualified NSWF staff divers have assisted on regular quarterly field trips throughout the course of the project.

Stage 3. Plankton (*A. catenella*) dinoflagellate monitoring program.

Vertical phytoplankton net tow sampling for toxic dinoflagellates in the water column was carried out on an approximately quarterly basis throughout the project. Annual sampling of sediment cores for toxic dinoflagellate cysts was also conducted three times during the project, and both the resulting cores and the phytoplankton net tow samples analysed by a dinoflagellate specialist.

Six species of the ABWMAC listed toxic dinoflagellate genus *Alexandrium* and six species of the genus *Dinophysis* were identified from the collections made using the above two sampling methods during the monitoring program, all being present within Twofold Bay at only very low concentrations. The ABWMAC target species *Alexandrium catenella*, however, was not positively identified as one of those present, although *Alexandrium* cysts identified as being of the "*catenella* type" were present in the benthic core samples.

Phytoplankton samples contained five species of the dinoflagellate genus *Alexandrium*, including the exotic species *A. catenella/fundyense*, *A. minutum* and *A. tamarense* (listed under Schedule 3, known exotic species present in Australian waters - see Appendix 1). Species of the potentially toxic diatom genus *Pseudo-nitzschia* were also frequently detected in net tow samples in low concentrations. In Hewitt *et al.* (1999) it is stated that species of the genus *Pseudo-nitzschia* are known to have caused Amnesic Shellfish Poisoning (ASP) in humans.

Stage 4. Three diving trips per year to conduct visual surveys of introduced marine pests, physical removal of European fanworms (*Sabella spallanzanii*) and possibly other introduced marine pest species, and collection and analysis of scrapings from hard substrates and samples of hull fouling organisms.

A total of 42 survey dives for *Sabella spallanzanii* (each incorporating a dive team of two or sometimes three divers with an average duration of ~ 60 minutes), were carried out by NSWF staff on 14 field trips to Eden undertaken between September 1999 and April 2002. A total of 93 diver hours were accumulated during underwater searches within the Snug Cove harbour wharves and adjacent harbour floor areas and at other sites within Twofold Bay, and these resulted in a total of 36 *Sabella spallanzanii* being identified and removed over the course of the project.

Stage 5. Laboratory testing of scrapings from hard substrata and individual organisms removed during each dive.

Surveys of hard substrata for introduced marine pest species were first undertaken in August 2000, with 18 permanently moored recreational vessels present in Quarantine Harbour being searched for any identifiable pest species, along with 21 temporarily moored commercial vessels at the Snug Cove wharves. On that occasion, no *Sabella spallanzanii* or other introduced marine pest species were found. In April 2001, NSWF staff divers undertook surveys of 23 permanently moored recreational vessels in Quarantine Harbour and 13 permanently moored recreational vessels in the Snug Cove Anchorage area to assess the types and levels of hull fouling present. The vessels' hulls, and also their accompanying mooring lines, were inspected. During this April 2001 survey, one *Sabella spallanzanii* specimen was identified and removed from a heavily fouled mooring chain in the Snug Cove Anchorage. Another was detected during a thorough resurvey of that same vessel's mooring line in September 2001. Six additional fouling surveys undertaken in April 2002 of some of these vessels' hulls and moorings within the Snug Cove Anchorage site detected no *S. spallanzanii*.

Stage 6. Assessment of the impacts of ballast water organisms in the Port of Eden and development of proposed management options.

Ballast water proforma data sheets were provided to the Eden Harbourmaster to record information on any international or domestic vessels visiting the Port of Eden which may have been involved in deballasting operations there. These data sheets allow for recording of the details of shipping origin and use, international and domestic ports of call, durations of stays in port, and any ballasting and deballasting activities undertaken.

The woodchip bulk carriers that take on their bulk cargo at the Port of Eden routinely exchange ballast water at sea, and hence are recorded as discharging 'mid ocean' before taking on their cargo. Ballast water discharge into these oceanic waters is considered to present a very low risk of introducing marine pests, and as such the project did not keep records of these offshore deballasting activities (records of these ship's ballast water discharge reports are, however, maintained by AQIS). Since the start of the project, there have been no other vessels calling at Eden which have been known to discharge ballast water within the port.

Stage 7. Assessment of the impacts of toxic dinoflagellates in the Port of Eden and development of proposed management options.

Dinoflagellate sampling using phytoplankton nets was undertaken on an approximately quarterly basis throughout the duration of the project, and benthic sediment cores were sampled annually.

The ABWMAC target pest species *Alexandrium catenella* was not positively identified from net tows as one of the many dinoflagellate species present in the Port of Eden, although encysted specimens of the *Alexandrium* "*catenella* type" were identified from the sediment cores. However, five species from the dinoflagellate genus *Alexandrium* were identified from the vertical plankton net tow samples. Six species of the dinoflagellate genus *Dinophysis* were also identified from the vertical plankton net tow samples, with two of these, *D. acuminata* and *D. caudata*, being found at a number of the sites sampled. Species of the potentially toxic diatom genus *Pseudo-nitzschia* were also frequently detected in net tow samples in low concentrations. Species of the genus *Pseudo-nitzschia* are known to have caused amnesic shellfish poisoning (ASP) in humans. An annual dinoflagellate sampling program is recommended each spring to monitor toxic phytoplankton abundances within Twofold Bay.

Stage 8. <u>Assessment of the impacts of hull fouling organisms in the Port of Eden and development of proposed management options.</u>

As *Sabella spallanzanii* was most likely translocated to the Port of Eden from another infested Australian port, information was obtained from the Eden Harbourmaster and other relevant government organisations on recreational and commercial vessel movements to and from the port. From the hull fouling surveys undertaken, no additional ABWMAC listed target pest species were found on the hulls or moorings of those vessels examined. However, it is recommended that an industry/community-based marine pest education and monitoring program involving local boat owners, fishers and other harbour users should be initiated, along with informative signage being established at Snug Cove. This would assist with the identification within Twofold Bay of any newly translocated ABWMAC listed introduced pest species.

APPENDIX 3. DETAILS OF PORT FACILITIES

Snug Cove [1]

Mooring Jetty

Built in 1981, this wharf consists of a combination of wooden piles, steel beams and steel jacketed concrete piles with a reinforced concrete deck protected by cathode devices. The berth is a general wharf, and is mainly used as moorage for fishing vessels. This wharf has a nominal length of 120 m and a maximum depth of 5 m.

Main Jetty

Part of the original jetty built in 1860, the Main Jetty is used as moorage for fishing vessels, and also acts as the tug and pilot vessel berth. The jetty was lengthened in 1911 and rebuilt in 1984. It consists of steel jacketed concrete piles with a reinforced concrete deck protected by cathode devices. This wharf has a nominal length of 194 m and a maximum depth of 7 m.

Breakwater Wharf

Part of the breakwater built in 1974, this wharf is used for quarantine and customs inspection of vessels visiting Snug Cove. The wharf consists of steel facings with a reinforced concrete deck protected by cathode devices. It has a nominal length of 120 m and maximum depth of 9 m.

Oil Berth

The Oil Berth is an import only facility located 200m south of the main breakwater of Snug Cove. Established around 1960, this mooring services the shore via a submarine oil pipeline originating at a depth of 12 m.

Heinz Cannery Jetty

Originally built in 1945, this jetty was rebuilt in 1985. It is wholly owned by the H.J. Heinz Greenseas Cannery. The jetty provides offloading facilities for trawlers and factory vessels. It consists of a combination of wooden and steel piles with a wooden deck. It has a nominal length of 120 m and maximum depth of 5 m.

East Boyd Bay [1]

Harris-Daishowa Woodchip Berth

Originally built in 1969, the Harris-Daishowa Jetty presents a 'T' head with dolphins. The wharf and dolphins consist of steel beams and fiberglass-wrapped concrete piles with a reinforced concrete deck. The berth is used solely for woodchip export. The wharf face is 61 m wide with five mooring dolphins, and the jetty has a total nominal length of 274 m and a maximum depth of 12.5 m.

East Boyd Bay [2]

Multi-Purpose Wharf

At present the Royal Australian Navy is in the initial construction stage of developing a Multi-Purpose Wharf in Twofold Bay for naval ammunitioning and commercial operations. The East Boyd Bay site is located to the southwest of the Harris-Daishowa Woodchip Wharf and involves extensive shoreline reclamation and dredging activities in the Edrom Bay area. The nominal length of the proposed berth is 200 m with a maximum dredged depth of 10.5 m.

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1 Information sourced from CSIRO (1997)

2 Information sourced from Woodward & Clyde (1999)

APPENDIX 4. SHIPPING ACTIVITIES IN TWOFOLD BAY

Summary of shipping activities in Twofold Bay from June 1999 to March 2002 *.

Vessel Name	No. Visits	Last Port of Call	Site Code - Berth in Port
Eden Maru	21	Japan (Shimizu)	NSWEWB - Woodchip Wharf
Daishowa Maru	7	Japan (Muroran & Shimizu) / China	NSWEWB " "
Taiho Maru	3	Japan (Sendai & Shimizu)	NSWEWB " "
Iwanuma Maru	3	Japan / Singapore	NSWEWB " "
World Trader	2	Borneo	NSWEWB " "
Raicho II	1	Japan	NSWEWB " "
Globulus	1	Taiwan	NSWEWB " "
Forestal Esperanza	1	Japan	NSWEWB " "
Stellar Andes	1	Japan	NSWEWB " "
Craig the Pioneer	1	Japan	NSWEWB " "
Miraflores	1	Japan	NSWEWB " "
Keisho Maru	1	Japan	NSWEWB " "
Daishin Maru	1	Japan	NSWEWB " "
Dixie Monarch	1	Korea	NSWEWB " "
Forest King	1	Japan	NSWEWB " "
Tasman	11	Melbourne / Botany Bay	NSWELP - Oil Berth
Royal Arrow	3	Melbourne / Brisbane	NSWELP - " "
Captain Martin	1	Botany Bay	NSWELP - " "
Palmerston	1	Geelong	NSWELP - " "
Jag Pankhi	1	Melbourne	NSWELP - " "
Kyoto	1	Port Stanvac	NSWELP - " "
Lastrolabe	3	Hobart / Launceston / Bass Strait	NSWEWHC - Breakwater Wharf
Helen	3	Tonga / Botany Bay / Noumea	NSWEWHC - " "
Southern Salvor	2	Launceston / New Zealand	NSWEWHC - " "
Pacific Conqueror	2	Bass Strait	NSWEWHC - " "
Western Pacific	2	Majuro / Port Lincoln	NSWEWHC - " "
Mermaid Raider	2	Darwin / Bass Strait	NSWEWHC - " "
Hebe	1	Westernport	NSWEWHC - " "
Starflyte	1	Portland	NSWEWHC - " "
Seahorse Horizon	1	Jervis Bay	NSWEWHC - " "
Geco My	1	Bass Strait	NSWEWHC - " "
Southern Surveyor	1	Bass Strait	NSWEWHC - " "
Seatow 25	1	Port Kembla	NSWEWHC - " "
Minigulai	1	Portland	NSWEWHC - " "
Pacific Sentinel	1	Bass Strait	NSWEWHC - " "
Geco Beta	1	Singapore	NSWEWHC - " "

* Information supplied by NSW Waterways Authority, Eden

APPENDIX 5. SAMPLING PROCEDURES

Dinoflagellates

Sediment sampling for cyst-forming species

Sediment cores are taken from locations within the port where the deposition and undisturbed accumulation of dinoflagellate cysts is likely to occur. Selection of sites is based on depth, local hydrography and sediment characteristics of the area. At each site duplicate sediment cores are taken by divers using 20 cm long tubes with a 2.5 cm internal diameter. Tubes are forced into the sediment then capped at each end with a bung to provide an air-tight seal. Cores are stored upright in the dark at 4°C prior to size fractionation and examination for dinoflagellate cysts.

Sediment preparation and cyst identification

The top 6 cm of sediment core is carefully extruded from the coring tube and stored at 4°C in a sealed container until further examination. Subsamples (approx. 1–2 cm^3) of each core sample are mixed with filtered seawater to obtain a watery slurry. Subsamples (5–10 ml) are sonicated for 2 min (Braun Labsonic homogenizer, intermediate probe, 100 watts) to dislodge detritus particles. The sample is then screened through a 90 µm sieve and collected onto a 20 µm sieve and the remaining fraction panned to remove denser sand grains and larger detritus particles. Subsamples (1 ml) are examined and counted on wet-mount slides, using a compound light microscope. Where possible, a total of at least 100 cysts are counted in each sample. Identification of species follows Bolch and Hallegraeff (1990). Cysts of suspected toxic species are photographed with a Zeiss Axioplan light microscope using bright field or differential interference contrast illumination.

Plankton net sampling and species identification

Plankton samples are collected by vertical tows of a hand-deployed plankton net (25 cm diam. opening, 20 µm Nytal mesh). The samples are sealed in plankton jars, preserved using a 2% Lugols solution and returned to the laboratory for analysis. In the laboratory, net samples are examined by light microscopy, and single cells of suspected toxic species isolated by micro pipette for further examination and species identification.

Carcinus maenas

Trapping

The European shore crab *Carcinus maenas* is sampled using light-weight plastic-coated wire-framed traps (60 cm long, 45 cm wide and 20 cm high) covered with 1.27 cm square mesh netting. Entry to the trap is through slits at the apex of inwardly-directed V-shaped panels at each end of the trap. The internal bait bag is baited with pilchards. Traps are weighted with chain or divers weights and deployed with surface buoys. Whenever possible, traps are deployed in the late afternoon and recovered early the next morning. Any *C. maenas* captured are preserved in a 10% formalin solution and returned to the laboratory for sex and size frequency analysis.

Visual searches

Visual searches for crabs and other target species are also made at selected wharves in the port area. Divers swim the length of the wharf, searching between the surface and the bottom, to provide a complete visual survey of the wharf structure and under-wharf harbour floor.

Maoricolpus roseus

Quantitative sampling

The New Zealand rosy screw shell *Maoricolpus roseus* is sampled using a 0.10 m^2 area quadrat (33x33cm). Three replicates are collected, with any gastropods, seagrass (*Zostera muelleri* and/or *Heterozostera tasmanica*) and sediment present being removed to a depth of 10 cm by shovel. These samples are then sieved through a fine (1 mm) mesh bag to remove the sediment whilst retaining any invertebrates and other benthic organisms present within the sample. Photographs of the sampling sites are usually taken prior to sampling (see details below). All material collected is preserved in a 10% formalin solution. In the laboratory, the samples are sorted and any *M. roseus* present measured for length frequency analysis.

Sabella spallanzanii

Visual searches

Visual searches for the European fanworm *Sabella spallanzanii* are carried out by divers in rocky reef and wharf areas, and over soft bottoms. Divers are free swimming, with any *Sabella* specimens located being photographed using a Nikonos V underwater camera with a 35 mm lens and single SB-102 flash, and removed from the substrate using a divers knife. Specimens are either returned alive to the laboratory for aquarium observations, or preserved in 10% formalin.

APPENDIX 6. SAMPLING DETAILS

Locations of sampling sites, sampling methods, species targeted and sampling details for the Port of Eden Introduced Marine Pests monitoring study.

Site Code	Location	Sampling Method	Species Targeted	Sampling Details
NSWEWHA	Snug Cove - Mooring Jetty	diver survey	*Sabella spallanzanii*	pylons, wharf & harbour floor search
		diver survey	*Sabella spallanzanii*	commercial vessel hull search
NSWEWHB	Snug Cove - Main Jetty	diver survey	*Sabella spallanzanii*	pylons, wharf & harbour floor search
		diver survey	*Sabella spallanzanii*	commercial vessel hull search
		plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
NSWEWHC	Snug Cove - Breakwater Wharf	diver survey	*Sabella spallanzanii*	wharf & harbour floor search
NSWEMF	Mussel Mariculture Facility - Oman Point	diver survey	*Sabella spallanzanii*	seafloor & aquaculture lease search
		plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
NSWEWB	Harris-Daishowa Woodchip Berth	diver survey	*Sabella spallanzanii*	pylons & wharf floor search
		plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
NSWEQA	Centre of Bay	plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
NSWEQB	Quarantine Bay / Anchorage	diver survey	*Sabella spallanzanii*	recreational vessel hull search
NSWENB	Nullica Bay	plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
NSWENR	Nullica River	crab traps	*Carcinus maenas*	9 traps set
NSWECL	Curalo Lagoon	crab traps	*Carcinus maenas*	9 traps set
NSWEKI	Kiah Inlet	crab traps	*Carcinus maenas*	9 traps set
NSWEFCK	Fisheries Creek	crab traps	*Carcinus maenas*	15 traps set
NSWESCX	Shadrack Creek	crab traps	*Carcinus maenas*	3 traps set
NSWESCC	Heinz Cannery Jetty	diver survey	*Sabella spallanzanii*	pylons, wharf & harbour floor search
NSWEEB	Edrom Bay - RAN Wharf Site	plankton net	dinoflagellate cells	2 replicates x quarterly
		small cores	dinoflagellate cysts	2 replicates x annually
		quadrat survey	*Maoricolpus roseus*	3 replicates x quarterly
		diver survey	*Codium* sp.	rocky headland & seagrass bed search
NSWESCA	Snug Cove Anchorage	diver survey	*Sabella spallanzanii*	comm. & rec. vessel hull search

APPENDIX 7. FANWORM SURVEY RESULTS

Sabella spallanzanii specimen collection details (refer to Figure 6).

Specimen No.	Dive No.	D	M	Y	Site Code	Site Location	Substrate	Depth (m)
A	**CSIRO (1997)**	6	11	96	EWHB	1/3 distance from shore	Cyclone mesh roll on floor	**4.5**
B	**CSIRO (1997)**	6	"	"	"	" "	" "	**4.5**
C	**CSIRO (1997)**	7	11	96	"	Outer end of wharf	Tyre tube on harbour floor	**5**
D	**CSIRO (1997)**	8	11	96	EWHC	Wharf pylon	Wharf pylon	**3**
1	**3**	17	8	99	"	Off unloading area	Harbour floor	**7**
2	**6**	14	9	99	EWHA	West side near steps	Wharf pylon	**1**
3	**6**	14	"	"	"	Mid way on wharf floor	Harbour floor	**4**
4	**10**	16	9	99	"	" "	" "	**4**
5	**13**	21	5	0	"	West side near steps	Wharf pylon	**1**
6	**16**	"	"	"	EWHC	Off unloading area	Harbour floor	**6**
7	**16**	"	"	"	"	" "	" "	**6**
8	**16**	"	"	"	"	" "	" "	**6**
9	**16**	"	"	"	"	Off Cat Balou ramp	" "	**4**
10	**17**	"	"	"	EWHB	Midway on wharf floor	" "	**5**
11	**17**	"	"	"	"	5m from boat ramp	Abalone shell	**2**
12	**19**	22	5	0	"	Midway between EWHC & B	Harbour floor	**6**
13	**20**	24	5	0	EWHA	15m off end of wharf	" "	**7**
14	**25**	30	11	0	"	Midway on wharf floor	Glass bottle on harbour floor	**4**
15	**25**	30	"	"	"	" "	Harbour floor	**4**
16	**26**	3	4	1	EWHC	Nth end of Breakwater rocks	" "	**8**
17	**26**	"	"	"	"	Sth of Processors	Rope on tyre on harbour floor	**6**
18	**26**	"	"	"	"	" "	" "	**6**
19	**26**	"	"	"	"	" "	" "	**6**
20	**26**	"	"	"	"	Under police launch	Glass bottle on harbour floor	**6**
21	**28**	4	4	1	ESCA - *Safari*	On mooring	Heavily fouled chain	**4**
22	**29**	5	4	1	EWHA	East side 15m from shore	Wharf pylon	**2**
23	**31**	11	9	1	EWHC	Sth of Processors	Harbour floor	**8**
24	**32**	"	"	"	ESCA - *Safari*	On mooring	Heavily fouled chain	**2**
25	**33**	"	"	"	EWHC	On Harbour floor	Harbour floor	**8**
26	**33**	"	"	"	"	" "	" "	**8**
27	**33**	"	"	"	"	" "	" "	**8**
28	**34**	12	9	1	Outer Hbr	Hbr floor 25mtr out from wharf	" "	**10**
29	**34**	"	"	"	EWHA	Hbr floor east of wharf	" "	**6**
30	**35**	13	9	1	"	Midway on wharf	Wharf pylon	**4**
31	**37**	15	11	1	Outer Hbr	On Harbour floor	Harbour floor	**10**
32	**37**	"	"	"	"	" "	" "	**10**
33	**37**	"	"	"	"	" "	" "	**10**
34	**39**	11	4	2	"	" "	" "	**10**
35	**39**	"	"	"	EWHA	" "	" "	**8**
36	**42**	12	4	2	EWHC	" "	Rope	**5**

APPENDIX 8. HULL SURVEY DETAILS

Details of vessels searched for ABWMAC introduced target pest fouling organisms.

Survey No.	M	Y	Vessel Name	Vessel Type	Target Species Found	Site Code	Area
1	8	2000	*Broadwater*	Workboat	Nil	EWHB	western side
2	"	"	*Shira*	Trawler	"	"	" "
3	"	"	*Josephine Jean*	"	"	"	" "
4	"	"	*Lindasfarn*	Dropliner	"	"	" "
5	"	"	*Osprey IV*	Trawler	"	"	" "
6	"	"	*Weena*	Tug	"	EWHB	eastern side
7	"	"	*Kanimbla Star*	Trawler	"	"	" "
8	"	"	*Island Leader*	"	"	"	" "
9	"	"	*Catriona B*	"	"	"	" "
10	"	"	*Rosebud E*	"	"	"	" "
11	"	"	*Tauranga*	"	"	"	" "
12	"	"	*Michael Maree*	Charter	"	ESCA	moorings
13	"	"	*Cass II*	Trawler	"	EWHA	eastern side
14	"	"	*Little Scotch*	Dropliner	"	"	" "
15	"	"	*Buckley*	Charter	"	"	" "
16	"	"	*Roamer*	Comm. Fishing	"	"	" "
17	"	"	*Miss Mawarrie*	Dropliner	"	EWHA	western side
18	"	"	*Breeza*	"	"	"	" "
19	"	"	*Chubby M*	Comm. Fishing	"	"	" "
20	"	"	*Silver Cloud*	" "	"	"	" "
21	"	"	*Rikara Star*	" "	"	"	" "
22	"	"	*Barook*	Yacht	"	EQB	moorings
23	"	"	*Magic Dragon*	Comm. Fishing	"	"	"
24	"	"	*Triton VIII*	Yacht	"	"	"
25	"	"	*Natura*	"	"	"	"
26	"	"	*Webby*	Motorcruiser	"	"	"
27	"	"	*Kin*	Yacht	"	"	"
28	"	"	*JY53IN*	"	"	"	"
29	"	"	*Son of Lars*	"	"	"	"
30	"	"	*Thermopylae*	"	"	"	"
31	"	"	*The Scot*	"	"	"	"
32	"	"	*Skye*	"	"	"	"
33	"	"	*Capricorn*	"	"	"	"
34	"	"	*Island Sun*	"	"	"	"
35	"	"	*Adolphis*	Trimaran	"	"	"
36	"	"	*Pegasus*	Yacht	"	"	"
37	"	"	*Bobeldok*	"	"	"	"
38	"	"	*Papillion*	"	"	"	"
39	"	"	*VQ307N*	Rec. Fishing	"	"	"
40	4	2001	*Artemis*	Yacht	"	"	"
41	"	"	*Kahana*	"	"	"	"
42	"	"	*Triton VIII*	"	"	"	"
43	"	"	*Natura*	"	"	"	"
44	"	"	*Webby*	Motorcruiser	"	"	"
45	"	"	*Capricorn*	Yacht	"	"	"
46	"	"	*Griffin*	Gamefishing	"	"	"
47	"	"	*Barren Goose*	Yacht	"	"	"
48	"	"	*Kin*	"	"	"	"
49	"	"	*JY53IN*	"	"	"	"
50	"	"	*Island Sun*	"	"	"	"
51	"	"	*Adolphis*	Trimaran	"	"	"
52	"	"	*Will - Dee*	Motorcruiser	"	"	"
53	"	"	*Timeout II*	Gamefishing	"	"	"
54	"	"	*Papillion*	Yacht	"	"	"
55	"	"	*Thresher*	"	"	"	"
56	"	"	*Bobeldok*	"	"	"	"
57	"	"	*Skye*	"	"	"	"
58	"	"	*Beaujolais*	"	"	"	"
59	"	"	*The Scot*	"	"	"	"
60	"	"	*Thermopylae*	"	"	"	"
61	"	"	*Son of Lars*	"	"	"	"
62	"	"	*JY53IN*	"	"	"	"
63	"	"	*Carmen Aussie*	"	"	ESCA	moorings
64	"	"	*Double Dutch*	"	"	"	"
65	"	"	*Sapphire Dancer*	"	"	"	"
66	"	"	*Climax One*	Fishing Charter	"	"	"
67	"	"	*Ananda*	Yacht	"	"	"
68	"	"	*Red Reef*	"	"	"	"
69	"	"	*Kaiara*	"	"	"	"
70	"	"	*Safari - (*Mooring Line)	"	***Sabella spallanzanii***	"	"
71	"	"	*Reel Affair*	"	Nil	"	"
72	"	"	*Jabaruka*	"	"	"	"
73	"	"	*Fand*	"	"	"	"
74	"	"	*Vagrant*	"	"	"	"
75	"	"	*Sheena*	Fishing Charter	"	"	"
76	"	"	*Barge 1*	Comm. Barge	"	"	"
77	"	"	*Barge 2*	" "	"	"	"
78	9	2001	*Safari - (*Mooring Line)	Yacht	***Sabella spallanzanii***	"	"
79	"	"	N/A - (Mooring Line)	Mooring	Nil	"	"
80	11	2001	*Safari*	Yacht	"	"	"
81	4	2002	*Vagrant*	"	"	"	"
82	"	"	*Michael Maree*	Charter	"	"	"
83	"	"	*Reel Affair*	Yacht	"	"	"
84	"	"	*Safari*	"	"	"	"
85	"	"	*Kaiara*	"	"	"	"
86	"	"	*Sula Sula*	"	"	"	"

APPENDIX 9. 1996 PORT SURVEY RESULTS

Localities searched for ABWMAC introduced target pest species.

Site Code	Site Location	Target Species Found
NSWEWHA	Snug Cove - Mooring Jetty	Nil
NSWEWHB	Snug Cove - Main Jetty	*Sabella spallanzanii*
NSWEWHC	Snug Cove - Breakwater Wharf	*Sabella spallanzanii*
NSWEMF	Mussel Mariculture Facility - Oman Point	Nil
NSWEWB	Harris Daishowa - Woodchip Berth	Nil
NSWEQA	Centre of Bay	Nil
NSWENB	Nullica Bay	Nil
NSWENR	Nullica River	*Carcinus maenas*
NSWEMP	Mungora Point	*Carcinus maenas*
NSWECL	Curalo Lagoon	*Carcinus maenas*
NSWEKI	Kiah Inlet	*Carcinus maenas*
NSWEFCK	Fisheries Creek	*Carcinus maenas*
NSWESCX	Shadrack Creek	*Carcinus maenas*
NSWESCC	Heinz Jetty	Nil
NSWEQB	Quarantine Bay / Anchorage	*Alexandrium* cf. *catenella* cysts
NSWEYC	Yallumgo Cove	*Alexandrium* cf. *catenella* cysts
NSWUNL		*Alexandrium* cf. *catenella* cysts
NSWLPG	Oil Berth	*Alexandrium* cf. *catenella* cysts
NSWEEB	Edrom Bay	Nil

From CSIRO (1997)

APPENDIX 10. GUIDELINES FOR NSW SHELLFISH QUALITY ASSURANCE PROGRAM (NSW SQAP)

Biotoxin Risk Management Plan - Phytoplankton Action Levels.

Phytoplankton Species	Toxin	Shellfish Testing Level	Shellfish Closure Level
Alexandrium catenella	PSP	100 cells/L	500 cells/L
Alexandrium minutum	PSP	100 cells/L	500 cells/L
Alexandrium ostenfeldii	PSP	100 cells/L	500 cells/L
Alexandrium tamarense	PSP	100 cells/L	500 cells/L
Dinophysis acuminata	DSP	1,000 cells/L	2,000 cells/L
Dinophysis acuta	DSP	500 cells/L	1,000 cells/L
Gymnodium catenatum	PSP	100 cells/L	N/A
Pseudonitzschia spp. (>50% total phytoplankton)	ASP	50,000 cells/L	200,000 cells/L
Pseudonitzschia spp. (<50% total phytoplankton)	ASP	100,000 cells/L	500,000 cells/L

Source: SafeFood NSW (2001)

APPENDIX 11. CODE OF PRACTICE FOR IN-WATER HULL CLEANING AND MAINTENANCE

The following *Code of Practice for In-water Hull Cleaning and Maintenance* was prepared and adopted by the Australian and New Zealand Environment and Conservation Council (ANZECC 1997).

10.1. Background

In recent years much attention has been focussed on the introduction of exotic marine organisms via ship's ballast. Another way of transporting exotic marine organisms is via a ship's hull.

To minimise the risk of further exotic organisms establishing in marine waters, ANZECC in consultation with the Australian Quarantine Inspection Service has established the following *Code of Practice for In-water Hull Cleaning and Maintenance*.

10.2. Application

These requirements shall apply in Australian waters and are applicable to all commercial vessels.

These requirements are to be used with any relevant state environmental protection agency requirements.

10.3. Procedures

No part of a vessel's hull treated with antifoulant is to be cleaned in Australian waters without the written permission of the Harbour Master, local government or state environmental protection agency (administering authority).

In-water hull cleaning is prohibited except under extra-ordinary circumstances, and permission will not normally be granted.

The cleaning of sea chests, sea suction grids and other hull apertures may be permitted provided that any debris removed (including encrustation, barnacles, weeds) is not allowed to pass into the water column or fall to the sea bed and subject to any other conditions attached to the permit. An application seeking permission to carry out this work must be lodged with the administering authority at least five (5) working days prior to commencement of the anticipated start date. Such application will detail how encrustations, barnacles and other debris will be contained and or collected for disposal as well as the method of disposal.

The polishing of ship's propellers may be permitted subject to any conditions attached to the permit. An application seeking permission to carry out "propeller polishing" must be lodged with the administering authority at least five (5) working days prior to commencement of the work.
Applications for permits may be facsimiled to the administering authority.

Source: Pollard & Pethebridge (2002)

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