# Report on Port of Botany Bay Introduced Marine Pest Species Survey


D.A. Pollard and R.L. Pethebridge

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Cronulla Fisheries Centre
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Report to Sydney Ports Corporation
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# PREFACE

A prerequisite for any attempt to control the spread by shipping of introduced marine pest species in Australian waters is a knowledge of the current distribution and abundance of exotic species in Australian ports. However, until very recently this information base has been lacking for most Australian ports. An Australian port survey program was therefore commenced as a joint initiative of the Australian Association of Port and Marine Authorities (AAPMA), the CSIRO's Centre for Research on Introduced Marine Pests (CRIMP) and a variety of individual state and territory agencies, supported by the Australian Ballast Water Management Advisory Council (ABWMAC). This program seeks to redress the lack of knowledge about the occurrence of exotic species in Australian ports and to provide a consistent basis on which the introduced species status of individual ports can be assessed.

Port surveys designed to identify all exotic species present will inevitably be subject to scientific, logistic and cost constraints that will limit both their taxonomic and spatial scope. Recognition of these constraints has 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. These surveys are designed to determine the distributions and abundances of a range of target species in each port. These species are listed in Appendix 1, and 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.

These targeted surveys will also identify species of uncertain status (endemic or introduced) that are abundant in a port and/or are likely to become major pest species. A component of each port survey is a local public awareness program designed to collect any available information that might indicate the presence of introduced species in the port and adjacent areas, the approximate dates of any introductions, and their potential impacts on native marine communities.

This report details the results in relation to the search for targeted ABWMAC pest species from an introduced species survey of the Port of Botany Bay, New South Wales, carried out between 19 and 29 October 1998. This survey was undertaken as part of the broader AAPMA/CRIMP port survey initiative by staff of NSW Fisheries assisted by CRIMP staff, and was jointly funded by the Sydney Ports Corporation and the Maritime Assets Division of the NSW Waterways Authority, with significant in kind contributions from NSW Fisheries.

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Dinoflagellates: Dr S. Brett and Dr D. Hill (Microalgal Services, Melbourne); Macroalgae: Dr A. Millar (Royal Botanic Gardens, Sydney); Poriferans: Dr P. Bergquist (University of Auckland, New Zealand); Hydrozoans: Dr J. Watson (Hydrozoan Research Laboratory, Melbourne); Polychaetes: Dr P. O'Donnell (The Ecology Lab, Brookvale, NSW); Cirripedes: Dr D. Jones (Western Australian Museum, Perth); Malacostracans: Dr G. Poore and Dr S. Heislers (Museum of Victoria, Melbourne), and A. Murray and S. Ahyong (Australian Museum, Sydney); Molluscs: J. Pogonoski (Australian Museum, Sydney); Bryozoans: Dr R. Nair (Anmika Enterprises, Wentworthville, NSW); Echinoderms: J. Pogonoski (Australian Museum, Sydney); Ascidians: K. Moore (CSIRO Marine Research Laboratories, Hobart) and Fishes: B. Louden (NSW Fisheries).

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Shane Hobday, Kevin Davis, Roy Garth and Murray Fox (of Sydney Ports Corporation), Chad Hewitt (of CRIMP), and Philip Gibbs, Rob Williams and Darryl Grey (all of NSW Fisheries) are thanked for their constructive comments on various drafts of this report.

# EXECUTIVE SUMMARY

The Port of Botany Bay is located on the central coast of New South Wales, about 15 kilometres to the south of the Sydney central business district, at around 34º 00' S, 151º 14' E. The associated catchment of the bay is around 1100 $km^2$, and includes the drainages of the Georges, Woronora and Cooks Rivers. The principal trade of the port is in container goods, chemicals, and petroleum and petroleum products.

A survey for introduced marine species was carried out in the port area and around the adjacent bay coastline between 19 and 29 October 1998. This survey focused on habitats that were likely to be colonised by introduced species and generally followed the sampling protocols developed for the National Australian Ports Surveys by the CSIRO's Centre for Research on Introduced Marine Pests (CRIMP).

Previous known introductions to Botany Bay had included four species of crustaceans, three mollusc species, several species of worms, toxic dinoflagellates, three species of gobies and the Japanese sea bass.

The toxic dinoflagellate *Alexandrium* sp. *(catenella* type) was the only Australian Ballast Water Management Advisory Council (ABWMAC) target introduced marine pest species collected during the present survey. This dinoflagellate, which generally occurs encysted in the bottom sediments, has been commonly recorded from a number of coastal bays and estuaries, mainly ports, in southeastern Australia. Blooms of such dinoflagellates in the water column produce neurotoxins, which can not only cause fish kills, but can also accumulate in shellfish and, being toxic to humans, may therefore affect oyster growing and other aquaculture industries. These cysts, however, were not found to be abundant in Botany Bay, and no toxic dinoflagellate blooms have previously been recorded there. Although there could be a potential risk to shellfish aquaculture in Botany Bay in the future, at present this risk is considered to be low.

A number (33) of other introduced (18) and cryptogenic (i.e. of unknown origin) (15) species were also recorded from the bay during the present survey, in addition to the other dozen or so such species previously recorded there. These introduced species are 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 formally listed as "pest species" posing any significant or known economic or environmental threats in this area. The additional introduced species found included 2 species of polychaetes (*Boccardia chilensis* and *Capitella capitata*), 4 species of crustaceans *(Corophium ascherusicum, Corophium acutum, Paracerceis sculpta* and *Megabalanus rosa)*, 11 species of bryozoans *(Amathia distans, Bowerbankia* sp*., Zoobotryon verticillatum, Conopeum seurati, Bugula flabellata, Bugula neritina, Bugula stolonifera, Cryptosula pallasiana, Schizoporella unicornis, Tricellaria occidentalis* and *Watersipora subtorquata.)*, and 1 ascidian *(Botrylloides leachi).* The cryptogenic species included 2 species of algae *(Caulerpa filiformis* and *Pterosiphonia bipinnata),* 4 hydrozoans *(Clytia hemisphaerica, Obelia dichotoma, Phialella quadrata* and *Antenella secundaria)*, 1 anthozoan *(Culicia c.f. tenella),* 6 species of crustaceans *(Megabalanus tintinnabulum, Megabalanus zebra, Caprella equilibra, Paracorophium excavatum, Pseudosphaeroma campbellense* and *Palaemonella rotumana),* and 2 species of bryozoans *(Electra tenella* and *Fenestrulina* sp.).

Overall, and apart from the single toxic dinoflagellate species *(Alexandrium* sp.) identified, from the results of this survey Botany Bay would appear to be otherwise free of ABWMAC listed target introduced marine pest species. In the light of the above, it is recommended that *Alexandrium* be periodically monitored in both the water column and sediments of the bay.

The data collected during this survey fit the requirements of the Australian Quarantine Inspection Service's (AQIS) Decision Support System in relation to the need or otherwise for any future ballast water controls on shipping using this port.

# 1. DESCRIPTION OF THE PORT

## 1.1. General features

Botany Bay is a large marine-dominated estuary located on the central coast of New South Wales, just to the south of Sydney. Lieutenant James Cook first set foot on Australian shores within this bay over 200 years ago, and since that time the bay and its foreshores have undergone immense changes through industrial, residential and, in the past, agricultural activities. Its catchment now houses about one third of the population of Sydney, and includes about half of the industrial land in the Sydney metropolitan area.

In spite of its urbanisation, the bay still retains important natural areas, including several foreshore parks and natural habitat (including aquatic) reserves. The wetlands on the southern foreshores are important habitats for migratory and other aquatic birds, parks and reserves occur throughout the catchment, and the waterways and foreshores provide for many recreational activities (State Pollution Control Commission 1978). However, the ever-increasing population and associated residential developments within the catchment are gradually resulting in the degradation of many of the bay's natural features.

Ever since the early days of European colonisation, Botany Bay has continued to be one of the most important areas for the production of seafood for Sydney's growing population. This was because of the bay's extensive shallow waters, which were quickly exploited, and in 1880 it was described as being as productive as Broken Bay, which had a greater extent of netting grounds (State Pollution Control Commission 1979a).

Commercial fisheries for finfish and crustaceans (mainly prawns and crabs) have not been as significant since 1900, because the population expanded to other areas of the state. However, the fishery is still diverse, and has retained its commercial importance because of its close proximity to Sydney, the state's most important marketing and consuming area. Oyster cultivation has also been important in Botany Bay, initially for the supply of lime and later for table oysters (State Pollution Control Commission 1979a).

More recently, a major port complex has been developed on the northern side of the bay, and additional berths serve the oil industry at Kurnell on the southern side. The principal trade is currently in container goods, chemicals, and petroleum and petroleum products. Since it was first used as an oil port in 1930, Botany Bay has developed to support large storage and container terminals and bulk liquids berths. It is now one of Australia's largest ports, with most of Sydney's commercial shipping passing through it. The country's busiest international airport, Kingsford-Smith Airport, is also located on the foreshores of the bay. Together with the port structures, the airport has made a major contribution to the growth of the developed shoreline. A significant part of the original natural shoreline, however, has been successfully preserved in national parks, nature reserves and historic sites.

## 1.2. Port developments

Table 1.2 summarises the major port-related developments that have taken place in and around the Port of Botany Bay.

**Table 1.2.** Summary of foreshore and port-related developments at the Port of Botany Bay.

| Port Development | Date Built | Subsequent Modifications or Notes |
|---|---|---|
| Coal Jetty ("Long Pier") | 1880 | Built on the northern foreshore at Banksmeadow for the import of coal from Newcastle. Removed when no longer used as a coal wharf. |
| HC Sleigh Ltd Oil Terminal | 1930 | Built on the banks of Alexandria Canal for the transfer of motor fuel shipments. |
| Single Point Mooring | 1948 | Single-point mooring and submarine pipeline built at Yarra Bay to carry crude oil to the Boral Refinery at Matraville. Accommodated tanker vessels up to 80,000 dead weight tonnes. Closed in 1980. |
| Australian Oil Refining (AOR) Pty Ltd - Caltex Wharf | 1955 | Substantial berthing facilities constructed at Kurnell for the import/export of refined petroleum products. |
| AOR Submarine Pipeline Terminal | 1960 | Multi-buoy mooring and pipleline built off the southern shore to transfer imported crude oil to the Caltex Refinery at Kurnell and the Boral Refinery at Matraville |
| Port Botany | Late 1970s | Developed on the northern shore as a supplementary port to Port Jackson to handle large bulk carriers and container ships. |
| Brotherson Dock and Bulk Liquids Berth | 1979 | Port Botany container and bulk liquid facilities completed on the northern shore. |

*From SPCC 1979 and S. Hobday, unpubl.*

The first Australian settlement was based at Port Jackson rather than Botany Bay in 1788 because the latter was considered unsuitable due to its shallowness, wind exposure and other negative features. The bay was, however, still used in the early days of the colony for transportation of commodities, such as timber and lime, by sea to other areas of the colony (State Pollution Control Commission 1979b). The first major pier (known locally as the "Long Pier") was built in 1880 and utilised the naturally deeper water of the northern foreshores, as did most of the earlier built structures. This pier was used mainly for unloading coal from the Hunter Valley, which was utilised at the nearby Bunnerong Power Station. This jetty was removed many years later when these coal shipments ceased (State Pollution Control Commission 1979b).

Botany Bay first became important as a shipping port in 1930, when H.C. Sleigh Ltd established a terminal for receiving cargoes of motor fuel from ships moored in the bay. Many thousands of shipments have since entered Botany Bay for this purpose. Botany Bay is now one of the major ports in New South Wales providing facilities for the shipment of petroleum and petroleum products. Subsequent developments have provided for significant increases in bulk liquids, solid products and general cargo traffic.

The two main port areas in Botany Bay are Brotherson Dock on the northern foreshore, and the Caltex Wharf and Multi-Buoy Mooring offshore from Kurnell on the southern foreshore (see Appendix 2). Brotherson Dock and the Bulk Liquids Berth are mainly used as a container terminal, and for the transfer of bulk liquids such as LP gas, chemicals and refined petroleum, respectively. The importation of crude oil and the handling of refined petroleum products take place at the Kurnell facilities (S. Hobday, unpubl.).

## 1.3. Shipping movements

In 1998 a total of 1230 ships visited Botany Bay, including 761 ships from domestic ports and 469 ships from international ports of call. These ships were used for transporting major quantities of mainly containerised import and export goods to and from the Sydney region. The main exports included aluminium, iron and steel, chemicals, rice and other cereals, cotton, paper, meat, animal foods, wood and petroleum. Imports included petroleum, chemicals, paper, machinery, electronic equipment, food preparations, iron and steel, textile yarns, fruit and vegetables, beverages and aluminium (S. Hobday, unpubl.).

Table 1.3 summarises shipping movements (see Appendix 4) in the Port of Botany Bay for 1998. Ships entered the port from a total of 17 countries, with those from Singapore accounting for the most visits (136), and those from 7 countries accounting for only 1 or 2 visits each. Hong Kong, New Zealand, South Korea, Japan and China were all countries with 30 to 80 ship visits during this year. Domestic ship visits originated from 21 different ports around the country.

**TABLE 1.3: SHIP VISITS TO PORT BOTANY DURING 1998 (source: S. Hobday, unpubl.)**

| Last International Port of Call | | Last Australian Port of Call | | Next International Port of Call | | Next Australian Port of Call | |
|---|---|---|---|---|---|---|---|
| **Country** | **No. Visits** | **Port** | **No. Visits** | **Country** | **No. Visits** | **Port** | **No. Visits** |
| Australia | 761 | Adelaide | 27 | Chile | 2 | Adelaide | 4 |
| Singapore | 136 | Bell Bay | 1 | China | 2 | Australia (unknown) | 1 |
| Hong Kong | 73 | Botany Bay | 9 | Hong Kong | 1 | Bell Bay | 8 |
| New Zealand | 72 | Brisbane | 139 | India | 1 | Botany Bay | 16 |
| South Korea | 65 | Bundaberg | 2 | Indonesia | 16 | Brisbane | 248 |
| Japan | 38 | Burnie | 4 | Japan | 3 | Burnie | 13 |
| China | 36 | Cairns | 4 | Korea | 3 | Cairns | 1 |
| Indonesia | 14 | Eden | 1 | New Zealand | 177 | Cossack Pioneer | 1 |
| Taiwan | 11 | Fremantle | 101 | Papua New Guinea | 9 | Dampier | 5 |
| Saudi Arabia | 10 | Geelong | 8 | Philippines | 2 | Darwin | 1 |
| Philippines | 4 | Gladstone | 4 | Singapore | 56 | Eden | 7 |
| Malaysia | 2 | Hobart | 4 | Taiwan | 3 | Fremantle | 2 |
| New Caledonia | 2 | Kwinana | 1 | USA | 2 | Geelong | 7 |
| Thailand | 2 | Mackay | 1 | **Total** | **277** | Gladstone | 2 |
| Chile | 1 | Melbourne | 377 | | | Hobart | 6 |
| Pacific Island Trust | 1 | Newcastle | 4 | | | Jabiru | 1 |
| USA | 1 | Port Bonython | 5 | | | Kwinana | 3 |
| Vanuatu | 1 | Port Stanvac | 3 | | | Melbourne | 518 |
| **Total** | **1230** | Sydney Harbour | 29 | | | Newcastle | 2 |
| | | Townsville | 2 | | | Port Bonython | 5 |
| | | Westernport | 35 | | | Port Kembla | 3 |
| | | **Total** | **761** | | | Port Stanvac | 3 |
| | | | | | | Sydney Harbour | 61 |
| | | | | | | Townsville | 2 |
| | | | | | | Westernport | 34 |
| | | | | | | **Total** | **954** |

A total of 277 ships left Botany Bay destined for 13 different countries, with New Zealand being the country with the highest number (177) of visits. Singapore was visited 56 times, and Indonesia was visited 16 times. The remaining countries were each visited less than 10 times. A total of 954 ships left Botany Bay destined for 25 other ports throughout Australia. Melbourne was visited most frequently, with a total of 518 visits. Brisbane was visited 248 times, Sydney Harbour was visited 61 times and Westernport was visited 34 times.

# 2. REVIEW OF EXISTING BIOLOGICAL INFORMATION

Except for information collected by NSW Fisheries and others during the late 1970s and early 1980s for the Maritime Services Board's port development environmental control study (State Pollution Control Commission 1978, 1981), detailed biological information on Botany Bay is relatively limited. Additional references, however, can be found in Leadbitter and Pollard (1986) and McGuinness (1988).

Several conclusions from a recent survey carried out by local councils (Anon. 1998a), however, indicate that the bay has been subject to significant environmental degradation. Urban development, dredging and industrial development of its shores have resulted in losses of seagrass beds, declines in bird populations (e.g. of small plovers), declines in commercial fin-fish catches, the presence of toxic microorganisms in sediments (posing a potential risk to oyster farming), and declines in water quality. Recent studies also indicated that several introduced marine species were already present in Botany Bay. Such introduced species may pose a threat to indigenous marine species by competition and predation.

Many of the introductions which have occurred in Botany Bay have been attributed to ballast water, which is discharged into the bay from ships which arrive from both overseas and other Australian ports. In 1998, 1230 ships visited Botany Bay from many different parts of the world (see Table 1.3). As Port Botany is predominantly an import destination, visiting vessels generally take up rather than discharge ballast water there. When tankers take on export cargo, however, ballast water is discharged, which often contains numerous organisms originating from ports visited previously (Carlton 1985). These organisms may settle and reproduce in the new port, some of them causing concern in relation to their associated dangers to human health, aquaculture and the environment (Anon. 1998b). As well as living in ballast water (and ballast sediment), foreign organisms also often grow on ships' hulls, and if the hulls are cleaned while in port, these organisms also have the potential to settle there and become pests. Such in-water hull cleaning of commercial ships, however, is no longer allowed here and does not presently occur in Botany Bay.

Non-indigenous marine fauna previously found in or known from Botany Bay has included four species of crustaceans, three species of molluscs, several species of worms, toxic dinoflagellates, three species of Japanese gobies and the Japanese sea bass (Anon. 1998c). Introduced marine organisms present in Australian waters in general are reviewed by Pollard and Hutchings (1990a,b).

# 3. SURVEY METHODS

## 3.1. Sampling strategy

The survey protocols used were designed to maximise the likelihood that exotic species present in the port would be detected (see Appendix 3). Sampling was concentrated on habitats and sites in the Port of Botany Bay and adjacent areas of the bay that were most likely to have been colonised by species associated with recognised transport vectors (i.e. shipping, through both hull fouling and ballast water discharge). The types of habitats selected for sampling (in priority order) were:

- active berth structures,
- existing jetty structures,
- proposed port improvement areas,
- known deballasting areas,
- breakwaters,
- channel markers or anchorage buoys, and
- other representative habitats in and around the bay.

Sampling methods 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. As many of the target species were likely to be rare, sampling was concentrated on maximising coverage within a site with minimal sample replication. Replicate sampling was only undertaken in situations where small-scale heterogeneity was likely to influence detection of target species. The sampling methods used, habitats sampled and taxa targeted are summarised in Table 3.1. Detailed descriptions of the existing standard temperate port sampling procedures are given in the protocol of Hewitt and Martin (1996) and summarised in Appendix 3.

## 3.2. Sampling methods

Sampling was distributed over seven main areas (see Fig. 3.1), including:
1) Brotherson Dock
2) Bulk Liquids Berth
3) Kurnell Pier and Quarantine Area
4) Airport Runway Rock Walls
5) Georges River/Botany Bay Confluence
6) Around the Bay Mouth
7) Various Other Sites Around the Bay Shoreline

Sampling methods employed in each of these areas and details of the sites sampled are summarised in Table 3.2, and their locations shown in Figure 3.2. Sampling was most intense in the port area, and focused on habitats on and around wharf piles and the adjacent soft bottom sediments. Visual searches and transects, quadrat scraping, video transects, still photography and coring were undertaken by snorkel or scuba divers; and shore surveys, beach seining, trapping and plankton sampling were carried out from the shore, research vessels or wharves.

**Table 3.1.** Summary of sampling methods used, habitats sampled and target taxa, Port of Botany Bay survey, October 1998.

| Sampling Methods | Habitat(s) Sampled | Target Taxa |
|---|---|---|
| Non-targeted surveys | | |
| Qualitative surveys | | |
| diver search | piles, reefs, soft bottoms | invertebrates, fish, algae |
| video/still photography | piles, reefs, soft bottoms | invertebrates, fish, algae |
| shore survey | beaches, intertidal reefs | invertebrates, fish, algae (wrack) |
| Quantitative surveys | | |
| quadrat scraping | piles, channel markers | invertebrates, algae |
| transect diver search | reefs, breakwaters | invertebrates, algae |
| video/still photography | reefs, breakwaters, soft bottoms | invertebrates, algae |
| large benthic core | soft bottoms | invertebrate infauna |
| beach seine net | soft bottoms | mobile epifauna, fish |
| Targeted surveys | | |
| diver search | piles, reefs, soft bottoms | *Sabella, Asterias, Carcinus* |
| crab trap | piles, soft bottoms | *Carcinus,* fish |
| small dinocore | mud/silt soft bottoms | dinoflagellate cysts |
| phytoplankton net | water column | phytoplankton, dinoflagellates |

Sampling was undertaken between 19 and 29 October 1998. Initial sorting and preservation were carried out immediately after sampling. Further sorting to the level of phylum or class was carried out by students under the supervision of Dr Ron West at the University of Wollongong, and specimens then transferred to the NSW Fisheries' Cronulla Fisheries Centre for more detailed sorting. After being sorted into finer taxonomic groups by site, the samples were then sent to individual specialist taxonomists around Australia to be identified to species level where possible. The initial survey fieldwork was carried out as a joint operation between NSW Fisheries' Coastal Conservation Group, initially supervised by Dr Philip Gibbs, and CRIMP staff led by Dr Chad Hewitt. The remainder of the project and the write up of the results were supervised and coordinated by Dr David Pollard of NSW Fisheries' Threatened Species and Biodiversity Conservation Group.

### 3.3. Public awareness program

A community reference group was formed and a local public awareness program was undertaken during the first week of the survey and continued after the field survey period. Groups or individuals were encouraged to contact NSW Fisheries, CRIMP or the Sydney Ports Corporation with any observations or information that they felt would assist in identifying exotic species in the port area, assessing their impacts, or indicating their possible times of introduction. Wherever possible, survey staff were available to follow up and assess any responses received during the survey period so that observations could be investigated while the survey team was in the area.


**Fig. 3.1.** Locations in and around Botany Bay mentioned in the text.

**Table 3.2.** Summary of the distribution of sampling methods used within sampling sites, Port of Botany Bay survey, October 1998 (see also Fig. 3.2).

| **Site Code** (BB…) | **Site Name** | **Date Sampled** | **Sampling Methods Used** |
|---|---|---|---|
| BD1 | Brotherson Dock Berth 1/1A | 19/10/98 | PS, BC, DC, PN |
| BD2 | Brotherson Dock Berth 2 | 22/10/98 | PS, BC, DC |
| BD4 | Brotherson Dock Berth 4 | 20/10/98 | PS, BC, DC |
| BD5 | Brotherson Dock East Dolphins | 20/10/98 | PS, BC |
| BLB | Bulk Liquids Berth | 19/10/98 | PS, BC, DC, CT, PN |
| RVN | Revetment Wall North | 26/10/98 | BC, DS, CT |
| RVS | Revetment Wall South | 26/10/98 | BC, DS |
| KP1 | Kurnell Pier (outer end) | 21/10/98 | PS, BC, DC, CT |
| KP2 | Kurnell Pier (near shore) | 21/10/98 | PS, BC |
| QA1 | Quarantine Area Buoys | 22/10/98 | BC, DC, PN |
| BP1 | Bonna Point | 29/10/98 | BS, DS, SS |
| KB2 | Kurnell Beach | 21/10/98 | CT |
| 3R1 | Airport 3rd Runway (1) | 22/10/98 | PS, BC, DC, CT |
| 3R2 | Airport 3rd Runway (2) | 22/10/98 | PS, BC, DC, CT |
| 2R1 | Airport 2nd Runway (1) | 23/10/98 | CT, DS |
| 2R2 | Airport 2nd Runway (2) | 23/10/98 | CT, DS |
| CR1 | Cooks River Bridge | 23/10/98 | PS, BC, DC |
| LR1 | Lady Robinsons Beach North (1) | 23/10/98 | BC, BS, DS |
| LR2 | Lady Robinsons Beach North (2) | 29/10/98 | BC, BS, CT, DS, SS |
| GRB | Georges River Bridge | 20/10/98 | PS, BC, DC |
| DP1 | Dolls Point Starboard Marker | 23/10/98 | PS, BC, DC |
| DP2 | Dolls Point Port Marker | 23/10/98 | PS, BC |
| TP1 | Towra Point | 29/10/98 | BS, SS |
| SP1 | Sutherland Point | 21/10/98 | CT, DS |
| LP1 | La Perouse Point | 26/10/98 | CT, DS, SS |
| BI1 | Bare Island | 26/10/98 | DS |
| BI2 | Bare Island Bridge | 26/10/98 | PS |
| FRE | Foreshore Road East | 26/10/98 | BC, BS, CT, DS, SS |
| CH4 | Channel Marker 4 | 21/10/98 | PS, BC, DC |

**Key**: PS: Pile Quadrat Scraping; BC: Large Benthic Core; DC: Small Dino Core; BS: Beach Seine Net; CT: Crab Trap; DS: Qualitative Diver Search; SS: Shore Survey; PN Phytoplankton Net

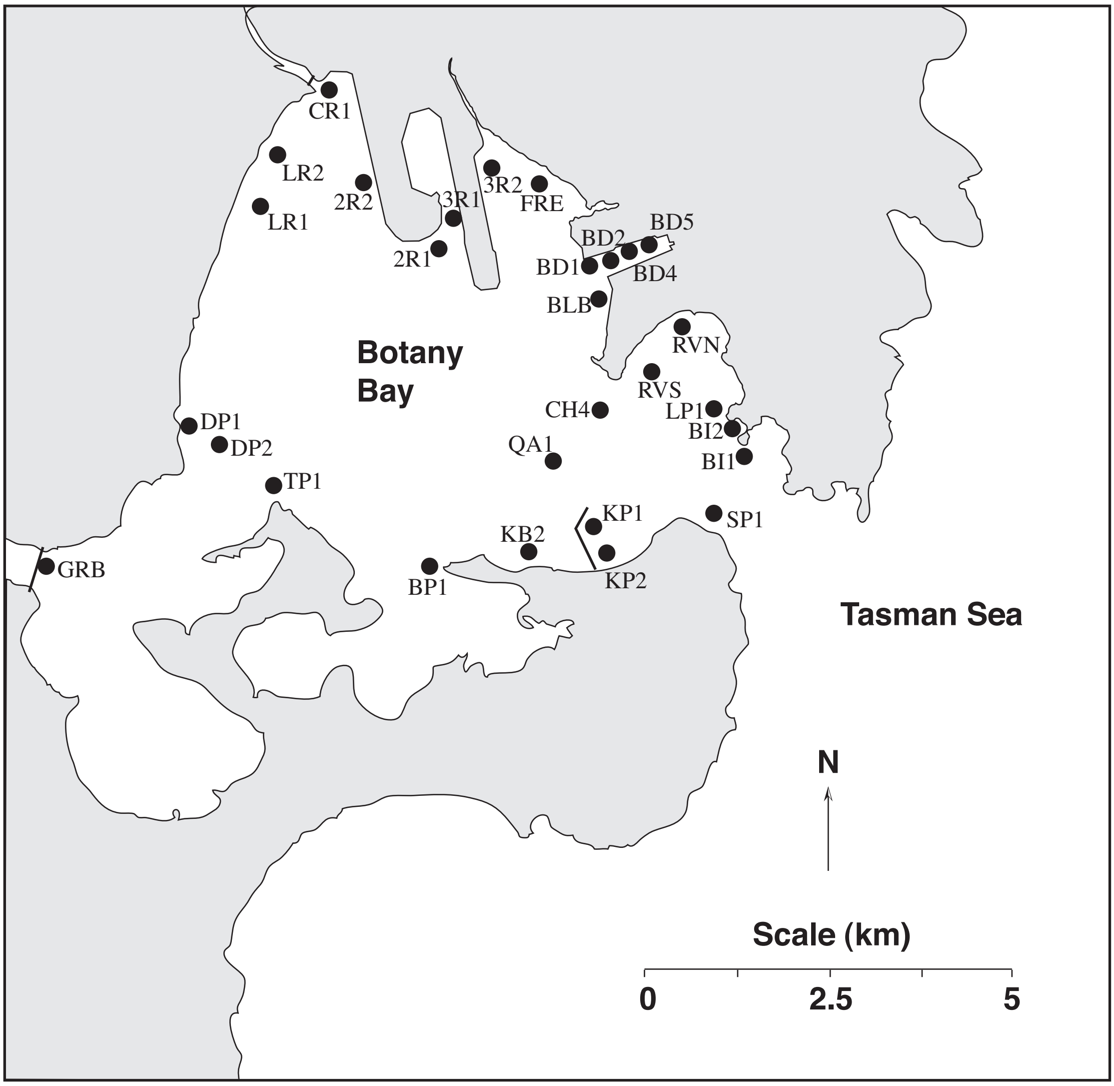


**Fig 3.2**. Sampling sites in Botany Bay mentioned in the text.

# 4. SURVEY RESULTS AND DISCUSSION

## 4.1. Port environment

The Port of Botany Bay is located about 15 kilometres to the south of the Sydney central business district on the central coast of New South Wales, at around latitude 34º 00’ S, longitude 151º 14’ E. The associated catchment is made up of an area of about 1100 $km^2$ and includes the catchments of the Georges, Woronora and Cooks Rivers (Anon. 1999). The principal trade of the port is in container goods, chemicals, and petroleum and petroleum products (S. Hobday, unpubl.). The bay and its foreshores have become highly developed through industrial, residential and past agricultural activities, although its southern shores still comprise unique natural wetlands of international and national significance, most of which are protected in reserves.

The bay is roughly circular in shape, with an entrance about 1100 metres wide, a diameter of about 7 km, and a foreshore length of about 60 km. The bay entrance opens to the Tasman Sea, and the headlands of Henry Head and Cape Banks lie to the north and Sutherland Point and Cape Solander to the south. The bottom sediment of the bay comprises mostly sand, and the depth at the mouth is between 16 and 21 m, the average depth throughout the bay being around 5 m (S. Hobday, unpubl.).

Freshwater enters the bay mainly via the shoals and channels at the entrance to the Georges River in the southwestern corner, and to a lesser extent from the Cooks River in the northwestern corner of the bay. The Cooks River has been diverted from much of its natural flow, and the tidal flow is now far stronger than its freshwater flow into the bay (S. Hobday, unpubl.).

Most of the foreshore is low, sandy and densely urbanised, although the north-eastern shore includes small sheltered beaches at Yarra Bay, Frenchmans Bay and Congwong Cove. The southern shore comprises mainly nature reserves and bushland areas. Most of the northern foreshore has been reclaimed to form the airport runways and Port Botany and its revetment walls. Lady Robinsons Beach along the western shore provides a major recreational facility. The southern shores comprise Quibray Bay, Woolooware Bay and Towra Point, which are undeveloped and support significant saltmarsh, mangrove and seagrass habitats, important as fish nurseries and for oyster leases. The Caltex oil refinery is located at Kurnell in the southeast (S. Hobday, unpubl.).

## 4.2. Marine floral and faunal taxa found during the port survey

The samples of fauna and flora collected, taken mainly from wharf pile and facing scrapings and benthic sediment cores, comprised 14 major animal and plant groups. These groups included the dinoflagellates, macroalgae, poriferans, hydrozoans, anthozoans, polychaetes, several phyla of “other worms”, cirripedes, malacostracans, molluscs, bryozoans, echinoderms, ascidians and fishes. Scientific (genus and species) names in ***bold italics*** at first substantive mention indicate those introduced or cryptogenic (i.e. of unknown origin) species found or known to occur in Botany Bay.

### *4.2.1. Dinoflagellates*

The dinoflagellates are a group of microalgae belonging to the Kingdom Protista, which comprises a wide variety of single celled microorganisms.

Many species of dinoflagellates occur in Australian waters, and these show extreme variation in size and shape. Around 60 of these species can survive for several years as sedentary cysts, which are very different from their motile free swimming forms (Edgar 2000). This may be an adaptation for surviving under unfavourable environmental conditions, and definite identification of some cysts to species cannot be readily undertaken without germinating the cyst into the motile form.

It is these "cyst-forming" dinoflagellate species which are often known for their negative environmental effects. Under suitable conditions they may multiply rapidly to produce "blooms". These blooms can cause the infamous "red tides". Oxygen depletion and/or toxins produced during these blooms may lead to the destruction of marine life over large areas (Edgar 2000). These toxins may concentrate in filter-feeding invertebrates, such as mussels and oysters. Sometimes they may have little direct effect on the host invertebrates, but if the latter are consumed by humans or other vertebrate predators, these toxins can be potentially fatal (Edgar 2000, Paxinos 2000). The cysts of these toxic dinoflagellates usually accumulate and lie dormant in soft bottom sediments until disturbed.

Dr David Hill and Dr Steve Brett of Microalgal Services, Melbourne, undertook analysis of the small sediment cores and phytoplankton net samples collected during the present survey. Analyses of sediment cores revealed the presence of low levels of *Alexandrium* cysts, similar in appearance to *Alexandrium 'catenella* type' cysts, which was the only ABWMAC listed pest species recorded from Botany Bay during the present survey. Germination of these cysts was attempted but proved unsuccessful. Unequivocal determination of cyst species, which requires germination of healthy, viable cysts, was thus not possible in the present survey (primarily due to the poor condition of the sediment cores). No motile *Alexandrium* cells were recorded from the phytoplankton net samples.

***Alexandrium catenella*** is one of four known species of toxic dinoflagellates which have been found in Australian waters. The other three species are *Alexandrium minutum, Alexandrium tamarense* and *Gymnodinium catenatum* (Furlani 1996). All of these species are designated ABWMAC pests, and are highly toxic. They can all pose a threat to human health through the consumption of intoxicated shellfish. Therefore, they have the potential to be detrimental to shellfish production, and particularly to the oyster growing industry in Botany Bay (Anon. 1998c, Furlani 1996).

*Alexandrium catenella* was previously known from coastal estuaries and embayments from the Hawkesbury River, NSW, south to Port Phillip Bay, Victoria (Hallegraeff *et al.* 1991). However, Newcastle has more recently been confirmed to be the most northerly extreme of its known Australian distribution (CSIRO Marine Research 1998). *Alexandrium* cysts resembling this species were also recorded as being present in Botany Bay in a 1993 study (Ecology Lab 1993; Anon. 1998a).

In southern Australia, blooms of *A. catenella* most usually occur for about two to four weeks in the warmer months between December and April. These blooms produce potent neurotoxins which accumulate in shellfish and may result in Paralytic Shellfish Poisoning (PSP) in humans (Furlani 1996). If dredging occurs, and cysts are disturbed and their dispersal thus enhanced, there is a possibility of toxic blooms occurring. To date, however, there is no evidence of any such toxic blooms having occurred in Botany Bay.

*Alexandrium catenella* occurs worldwide in temperate waters. Although it is not known if it was present in Australian waters prior to European settlement, there is no evidence to suggest that PSP had previously occurred in Australian shellfish from any Aboriginal history or customary story. Reports of PSP due to this species in the more recent past have, however, been recorded from Bateman's Bay in 1935, Port Hacking in the 1940s, and from Port Phillip Bay in 1986 (Furlani 1996).

Results from the small benthic core ("dinocore") sampling for dinoflagellates in Botany Bay are presented in Table 4.2.1.1. Of the 29 sites sampled for marine flora and fauna during this survey, 12 were chosen for dinocore sampling (see Table 3.2), with three replicate samples being taken at each site. Core samples from six of these sites were examined microscopically to provide information on cyst types and potentially toxic species. These samples comprised the better preserved cores from those sites thought most likely to contain toxic dinoflagellates. The core samples examined for cysts were from the Brotherson Dock (BD1), Bulk Liquids Berth (BLB), Kurnell Pier (KP1), Cooks River Bridge (CR1), Quarantine Area Buoys (QA1) and Airport Third Runway (3R2) sites.

The cysts of a total of 25 dinoflagellate species were identified in the sediment cores. *Alexandrium 'catenella* type' cysts were reported from sites KP1 (2% of total cysts present), 3R2 (3.2%), BLB (1.9%), and QA1 (4%), but none were observed at CR1 or BD1. While cyst numbers were relatively low, the presence of *Alexandrium* cysts in the sediments of Botany Bay raises the possibility of future potentially toxic blooms. Collection of additional samples may enable unequivocal identification of the *Alexandrium* species present and provide further understanding of cyst distribution and abundance within Botany Bay (S. Brett, pers. comm.).

Additional phytoplankton net sampling for dinoflagellates in the water column was undertaken during both February and March 2000. Samples were collected by vertical tows of a hand deployed 20 µm mesh plankton net according to the protocol outlined in Appendix 3. A single one litre surface water sample was also taken at each site for direct phytoplankton counts. Samples were taken at the Quarantine Area Buoys (QA1), Bulk Liquids Berth (BLB) and Brotherson Dock (BD5) sites. No *A. catenella* cells were found in any of the phytoplankton samples collected during either sampling period. Amongst the phytoplankton species collected, however, were members of the dinoflagellate genera *Dinophysis* and *Gymnodinium* and the diatom genus *Pseudo-nitzschia*. These are also known to be responsible for harmful algal blooms (see Paxinos 2000 and Table 4.2.1.2).

**TABLE 4.2.1.1: DINOFLAGELLATES COLLECTED FROM BOTANY BAY (small benthic dinocore samples)**

| **Family, etc.** | **Species** | **Site** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BD1** | **BD2°** | **BD4°** | **BD5°** | **BLB** | **RVN°** | **RVS°** | **KP1** | **KP2°** | **QA1** | **BP1°** | **KB2°** | **3R1°** | **3R2** | **2R1°** |
| Gonyaulacids | *Alexandrium* sp. | | | | | 1.9 | | | 2.0 | | 4.0 | | | | 3.2 | |
| | *Fragilidium subglobosum* | | | | | 0.9 | | | 1.0 | | | | | | | |
| | *Gonyaulax c.f. verior* | | | | | | | | | | | | | | | |
| | *Gonyaulax* sp. | | | | | | | | | | 1.0 | | | | 3.2 | |
| | *Pentapharsodinium* sp. | 2.0 | | | | | | | | | | | | | | |
| | *Protoceratium reticulatum* | | | | | 6.6 | | | 10.0 | | 5.0 | | | | 4.2 | |
| Protoperidiniids | *Protoperidinium c.f. calidicans* | | | | | | | | | | | | | | | |
| | *Protoperidinium compressum* | 1.0 | | | | 0.9 | | | | | | | | | | |
| | *Protoperidinium conicum* | | | | | | | | | | 2.0 | | | | | |
| | *Protoperidinium leonis* | 3.0 | | | | 7.5 | | | 3.0 | | 4.0 | | | | | |
| | *Protoperidinium minutum* | 7.0 | | | | 3.8 | | | 3.0 | | | | | | | |
| | *Protoperidinium nudum* | | | | | | | | | | | | | | | |
| | *Protoperidinium oblongum* | | | | | 1.9 | | | | | | | | | 1.0 | |
| | *Protoperidinium pentagonum* | | | | | 0.9 | | | 1.0 | | | | | | | |
| | *Protoperidinium punctulatum* | | | | | | | | | | | | | | | |
| | *Protoperidinium subinerme* | | | | | 0.9 | | | 14.0 | | | | | | | |
| | *Protoperidinium* round brown | 35.0 | | | | 21.7 | | | 5.0 | | 25.0 | | | | 21.1 | |
| | *Protoperidinium* other | 2.0 | | | | 4.7 | | | | | 2.0 | | | | | |
| Diplopsalids | *Diplopelta parva* | 1.0 | | | | | | | | | | | | | | |
| | Diplopsalid sp. | | | | | | | | | | 4.0 | | | | | |
| | *Preperidinium meunieri* | | | | | | | | | | | | | | | |
| Others | Gymnodinoid spp. | 31.0 | | | | 24.5 | | | 26.0 | | 25.0 | | | | 11.6 | |
| | *Polykrykos schwartzii* | | | | | 0.9 | | | | | 2.0 | | | | | |
| | *Scrippsiella trochoidea* | 20.0 | | | | 21.7 | | | 35.0 | | 26.0 | | | | 55.7 | |
| | *Scrippsiella* sp. | | | | | | | | | | 1.0 | | | | | |

**Key:** Numbers in columns = % of total cysts present; ° site not sampled or sample not analysed

**TABLE 4.2.1.1: DINOFLAGELLATES COLLECTED FROM BOTANY BAY (small benthic dinocore samples) (continued)**

| **Family, etc.** | **Species** | **Site** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2R2°** | **CR1** | **LR1°** | **LR2°** | **GRB°** | **DP1°** | **DP2°** | **TP1°** | **SP1°** | **LP1°** | **BI1°** | **BI2°** | **FRE°** | **CH4°** |
| Gonyaulacids | *Alexandrium* sp. | | | | | | | | | | | | | | |
| | *Fragilidium subglobosum* | | 1.0 | | | | | | | | | | | | |
| | *Gonyaulax c.f. verior* | | | | | | | | | | | | | | |
| | *Gonyaulax* sp. | | | | | | | | | | | | | | |
| | *Pentapharsodinium* sp. | | 2.9 | | | | | | | | | | | | |
| | *Protoceratium reticulatum* | | 9.6 | | | | | | | | | | | | |
| Protoperidiniids | *Protoperidinium c.f. calidicans* | | | | | | | | | | | | | | |
| | *Protoperidinium compressum* | | | | | | | | | | | | | | |
| | *Protoperidinium conicum* | | | | | | | | | | | | | | |
| | *Protoperidinium leonis* | | 5.8 | | | | | | | | | | | | |
| | *Protoperidinium minutum* | | 1.9 | | | | | | | | | | | | |
| | *Protoperidinium nudum* | | | | | | | | | | | | | | |
| | *Protoperidinium oblongum* | | | | | | | | | | | | | | |
| | *Protoperidinium pentagonum* | | | | | | | | | | | | | | |
| | *Protoperidinium punctulatum* | | | | | | | | | | | | | | |
| | *Protoperidinium subinerme* | | | | | | | | | | | | | | |
| | *Protoperidinium* round brown | | 20.2 | | | | | | | | | | | | |
| | *Protoperidinium* other | | 2.9 | | | | | | | | | | | | |
| Diplopsalids | *Diplopelta parva* | | | | | | | | | | | | | | |
| | Diplopsalid sp. | | | | | | | | | | | | | | |
| | *Preperidinium meunieri* | | | | | | | | | | | | | | |
| Others | Gymnodinoid spp. | | 41.3 | | | | | | | | | | | | |
| | *Polykrykos schwartzii* | | | | | | | | | | | | | | |
| | *Scrippsiella trochoidea* | | 12.5 | | | | | | | | | | | | |
| | *Scrippsiella* sp. | | 1.0 | | | | | | | | | | | | |

**Key:** Numbers in columns = % of total cysts present; ° site not sampled or sample not analysed

**TABLE 4.2.1.2: PHYTOPLANKTON COLLECTED FROM BOTANY BAY (net and water samples)**

| Species | Collected 2/2/00 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site | | | | | | | | | | | |
| | BD5 | | | | BLB | | | | QA1 | | | |
| | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep2 | Rep 3 |
| **Diatoms** | | | | | | | | | | | | |
| *Amphora* sp. | | | | | | | | | | | | |
| *Asterionellopsis glacialis* | | | | | | | | | | | | |
| *Auliscus* sp. | | | | | | | | | | | | |
| *Bacteriastrum* sp. | | | | | | | | x | | | | |
| *Chaetoceros* spp. | | | x | x | | | x | x | | x | xx | x |
| *Chaetoceros peruvianus* | | | | | | | | | | | | |
| *Chaetoceros socialis* | | | | | | | | | | | | |
| *Cocconeis* sp. | | | | | | | | | | | | |
| *Coscinodiscus* spp. | | x | x | x | | x | | x | | x | | x |
| *Cylindrotheca closterium* | | | | | | | | | | | | |
| *Dactyliosolen antarcticus* | | | | | | | | | | x | | |
| *Dactyliosolen fragilissimus* | | | | | | | | | | | | |
| *Detonula pimula* | | | | | | | | | | | | |
| *Ditylum brightwellii* | | | | x | | | | | | | | x |
| *Entomoneis* sp. | | | | | | | | | | | | |
| *Eucampia* sp. | | | | | | | | | | | | |
| *Eucampia zodiacus* | | | | x | | | | x | | | | x |
| *Fragilariopsis* sp. | | | | | | | | | | | | |
| *Grammatophora* sp. | | | | | | | | | | | | |
| *Guinardia striata* | | | | | | | | | | | | |
| *Hemiaulus* sp. | | | | | | | | | | | x | |
| *Leptocylindrus danicus* | | | | x | | | | | | | | |
| *Leptocylindrus minimus* | | | | | | | | x | $6.9 \times 10^3$ | | | x |
| *Licmophora* sp. | | | x | | | | | | | | | |
| *Lithodesmium* sp. | | | | | | | | | | | | |
| *Melosira* sp. | | | | | | | | | | | | |
| *Minidiscus* sp. | | | | | | | | | $1.1 \times 10^6$ | | | |
| *Minidiscus trioculatus* | | | | | | | | | | | | |
| *Minutocellus* sp. | | | | | | | | | | | | |
| *Navicula* sp. | | | | x | | | | | | | | |
| Naviculoid spp. | | | | | | | | | | | | |
| *Nitzschia longissima* | | | x | | | | | | $1.4 \times 10^4$ | | x | |
| *Nitzschia sigmoidea* | | | | | | | | | | | | |
| *Nitzschia* spp. | | | | | | | | | | | | |
| *Paralia sulcata* | | x | | x | | | | | | | | |
| *Pleurosigma* sp. | | | x | x | | | | | | | | |
| *Pseudo-nitzschia* spp. | | | | | | | | | | | | |
| *Pseudo-nitzschia c.f. fraudulenta* | | | | | | | | | | | | |
| *Pseudo-nitzschia pseudodelicatissima* | | | | | | | | | | | | |
| *Pseudo-nitzschia pungens/multiseries* | | | | | | | | | | | | |
| *Rhizosolenia setigera* | | x | x | x | | x | x | | | x | x | |
| *Skeletonema costatum* | | | | | | | | | | | | |
| *Stauroneis* sp. | | | | x | | | | | | | | |
| *Striatella unipunctata* | | | | | | | | | | | | |
| *Surirella* sp. | | | | x | | | | | | | | |
| *Synedra* sp. | | | | | | | | | | | | |
| *Thalassionema* sp. | | x | | | | | x | | | | | |
| *Thalassiosira* sp. | | | | | | | | | | | | |
| **Dinoflagellates** | | | | | | | | | | | | |
| *Amphidinium carterae* | | | | | | | | | | | | |
| *Ceratium furca* | | | | | | x | x | x | | x | x | x |
| *Ceratium candelabrum* | | | | | | | | | | | | |
| *Dinophysis acuminata* | | | | x | | x | x | xx | | x | | x |
| *Dinophysis caudata* | | | | | | | | | | | | |
| *Dinophysis tripus* | | | | | | x | x | | | | x | x |
| *Gonyaulax polygramma* | | | | | | xx | | xxx | | xxx | xxx | xx |
| *Gonyaulax scrippsae* | | x | | | | | x | x | | xxx | x | x |

**Key:** x = rarely observed species; xx = common species; xxx = dominant species in replicate net samples; counts = cells per litre in water samples

**TABLE 4.2.1.2: PHYTOPLANKTON COLLECTED FROM BOTANY BAY (net and water samples) (con't)**

| Species | Collected 2/2/00 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site BD5 | | | | BLB | | | | QA1 | | | |
| | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep2 | Rep 3 |
| *Gonyaulax spinifera* | | | | | | | | | | | x | |
| *Gonyaulax verior* | | | | | | | | | | | | |
| *Gymnodinium aff. pulchellum* | | | | | | | | | $6.9 \times 10^3$ | | | |
| *Gymnodinium sanguineum* | | | | | | | | | | | | |
| *Gymnodinium* spp. | | | | | | | | | $9.7 \times 10^4$ | | | |
| *Gyrodinium* spp. | | | | | | | | | | | | |
| *Heterocapsa rotundata* | | | | | | | | | $6.9 \times 10^3$ | | | |
| *Phalachroma* spp. | | | | | | | | | | | | |
| *Prorocentrum gracile* | | | | | | | x | x | | | | |
| *Prorocentrum micans* | | | | | | | | x | | | | |
| *Prorocentrum minimum* | | | | | | | | | x | | | |
| *Prorocentrum triestinum* | | | | | | | | | x | | | |
| *Protoperidinium claudicans* | | | | | | | | | | x | | x |
| *Protoperidinium depressum* | | | | | | x | | | | | | |
| *Protoperidinium leonis* | | | | | | | | | | | | |
| *Protoperidinium nudum* | | | | | | | | | | | x | x |
| *Protoperidinium obtusum* | | | | | | | | | | | | |
| *Protoperidinium pallidum* | | | | | | | | x | | x | | x |
| *Protoperidinium* spp. | | | | | | | | | | | | |
| *Pyrophacus horologium* | | x | | | | x | x | | | x | x | x |
| *Scrippsiella trochoidea* | | x | | | | | x | x | | x | | x |
| **Prymnesiophytes** | | | | | | | | | | | | |
| *Acanthoica* spp. | | | | | | | | | | | | |
| *Calciopappas caudatus* | | | | | | | | | | | | |
| *Chrysochromulina* spp. | | | | | | | | | $1.0 \times 10^5$ | | | |
| *Emiliania huxleyii* | | | | | | | | | $1.4 \times 10^4$ | | | |
| *Prymnesium patellifera* | | | | | | | | | x | | | |
| Unidentified spp. | | | | | | | | | | | | |
| **Chrysophytes** | | | | | | | | | | | | |
| *Calycomonas* spp. | | | | | | | | | | | | |
| *Ochromonas* spp. | | | | | | | | | | | | |
| *Paraphysomonas* spp. | | | | | | | | | | | | |
| **Cryptomonads** | | | | | | | | | | | | |
| *Hemiselmis* spp. | | | | | | | | | | | | |
| *Leucocryptos marina* | | | | | | | | | $1.4 \times 10^4$ | | | |
| *Plagioselmis prolonga* | | | | | | | | | $1.4 \times 10^4$ | | | |
| *Rhodomonas salina* | | | | | | | | | | | | |
| *Teleaulax acuta* | | | | | | | | | | | | |
| **Prasinophytes** | | | | | | | | | | | | |
| *Nephroselmis* spp. | | | | | | | | | | | | |
| *Pyramimonas* spp. | | | | | | | | | $3.6 \times 10^5$ | | | |
| *Tetraselmis* spp. | | | | | | | | | | | | |
| **Silicoflagellates** | | | | | | | | | | | | |
| *Dictyocha octanaria* | | | | | | | | | | | | |
| *Dictyocha fibula* | | | | | | x | | | | | | |
| **Cyanophytes** | | | | | | | | | | | | |
| *Oscillatoria* sp. | | | | | | | | | | | | |
| **Others** | | | | | | | | | | | | |
| *Apedinella spinifera* | | | | | | | | | | | | |
| *Ebria tripartita* | | | | x | | | x | | $6.9 \times 10^3$ | | | |
| *Euglena* sp. | | | | | | | | | | | | |
| *Eutreptiella* sp. | | | | | | | | | | | | |
| *Heterosigma* sp. | | | | | | | | | | | | |
| *Pelagococcus subviridis* | | | | | | | | | $2.4 \times 10^7$ | | | |
| *Paulinella ovalis* | | | | | | | | | $6.9 \times 10^3$ | | | |
| Unidentified bodonids/heterotrophs | | | | | | | | | | | | |
| Other | | | | | | | | | | | | |

**Key:** x = rarely observed species; xx = common species; xxx = dominant species in replicate net samples; counts = cells per litre in water samples

**TABLE 4.2.1.2: PHYTOPLANKTON COLLECTED FROM BOTANY BAY (net and water samples) (con't)**

| Species | Collected 21/3/00 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site BD5 | | | | BLB | | | | QA1 | | | |
| | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep 2 | Rep 3 | Cells/L | Rep 1 | Rep 2 | Rep 3 |
| **Diatoms** | | | | | | | | | | | | |
| *Amphora* sp. | | | | x | | | | | | | x | |
| *Asterionellopsis glacialis* | | | | | | x | | | $7.2x10^3$ | | | |
| *Auliscus* sp. | | | | | | | | | | | | x |
| *Bacteriastrum* sp. | | | x | x | | x | x | | | | | |
| *Chaetoceros* spp. | $7.8x10^4$ | xx | xx | xx | $1.4x10^5$ | xx | xx | xx | $7.2x10^4$ | x | x | x |
| *Chaetoceros peruvianus* | | | | | | x | | x | | | | |
| *Chaetoceros socialis* | | x | x | x | | | | x | | | | |
| *Cocconeis* sp. | | | | | | | | | | | x | |
| *Coscinodiscus* spp. | | | x | x | | | x | x | | | x | x |
| *Cylindrotheca closterium* | | | | x | $7.4x10^4$ | | | | $1.4x10^4$ | | x | x |
| *Dactyliosolen antarcticus* | | | x | x | | x | x | | | | | |
| *Dactyliosolen fragilissimus* | $7.8x10^3$ | | | | $9.2x10^3$ | | | | $7.2x10^3$ | | | |
| *Detonula pimula* | | x | x | | $9.2x10^3$ | x | | x | | | | |
| *Ditylum brightwellii* | | | x | | $9.2x10^3$ | x | x | x | | x | x | |
| *Entomoneis* sp. | | | | | | x | x | | | | | x |
| *Eucampia* sp. | $1.6x10^4$ | x | x | x | $1.8x10^4$ | x | x | x | $7.2x10^3$ | x | x | x |
| *Eucampia zodiacus* | | | | | | | | | | | | |
| *Fragilariopsis* sp. | | | x | | | | | | | | | |
| *Grammatophora* sp. | | | | | | | | | | | x | |
| *Guinardia striata* | | x | | | $9.2x10^3$ | x | x | | | | | |
| *Hemiaulus* sp. | | | | x | | x | x | x | | | | x |
| *Leptocylindrus danicus* | $9.4x10^4$ | xx | x | | $6.4x10^4$ | x | x | xx | $7.2x10^3$ | xx | x | |
| *Leptocylindrus minimus* | $3.1x10^4$ | x | | xx | | x | | x | $2.2x10^4$ | | x | xx |
| *Licmophora* sp. | | | | | | | | | | | | |
| *Lithodesmium* sp. | | x | x | x | $1.8x10^4$ | | | x | $3.6x10^4$ | xx | xx | xx |
| *Melosira* sp. | | | | | | | | | | | | |
| *Minidiscus* sp. | | | | | | | | | | | | |
| *Minidiscus trioculatus* | $6.2x10^4$ | x | x | | $9.2x10^4$ | xx | x | | $1.4x10^4$ | | | xx |
| *Minutocellus* sp. | | | | | | | | | | | | |
| *Navicula* sp. | | | | | | | | | | | | |
| Naviculoid spp. | $7.8x10^3$ | x | x | x | $7.4x10^4$ | | x | | | | x | |
| *Nitzschia longissima* | | | | | | x | | | | x | | |
| *Nitzschia sigmoidea* | | | | | | x | x | x | | | | |
| *Nitzschia* spp. | $1.6x10^4$ | | | | | | | | $3.6x10^4$ | | | |
| *Paralia sulcata* | | | | | | | | | | | | |
| *Pleurosigma* sp. | | | | | | x | | | | x | x | |
| *Pseudo-nitzschia* spp. | | | x | xx | $9.2x10^3$ | x | x | x | | xx | | xx |
| *Pseudo-nitzschia c.f. fraudulenta* | $5.5x10^4$ | | | | $9.2x10^3$ | | | | $2.2x10^4$ | | | |
| *Pseudo-nitzschia pseudodelicatissima* | | x | x | xx | $3.7x10^4$ | x | x | x | | | | x |
| *Pseudo-nitzschia pungens/multiseries* | | x | x | xx | | x | xx | x | | x | | x |
| *Rhizosolenia setigera* | | x | x | | $9.2x10^3$ | x | x | x | | | x | |
| *Skeletonema costatum* | $8.6x10^4$ | xx | x | xx | $4.1x10^5$ | xxx | xx | xxx | $1.9x10^5$ | xx | xx | xx |
| *Stauroneis* sp. | | | | | | | | | | | | |
| *Striatella unipunctata* | | | | | | | x | | | | | |
| *Surirella* sp. | | | | | | | | | | | | x |
| *Synedra* sp. | | x | | | | | | | | | | |
| *Thalassionema* sp. | | x | xx | x | | x | x | x | $1.4x10^4$ | x | x | x |
| *Thalassiosira* sp. | $2.3x10^4$ | | xx | xx | $3.7x10^4$ | x | x | x | $2.9x10^4$ | | x | |
| **Dinoflagellates** | | | | | | | | | | | | |
| *Amphidinium carterae* | | | x | | | | | | | | | |
| *Ceratium furca* | | x | x | x | | x | x | x | | | x | x |
| *Ceratium candelabrum* | | x | | | | | | | | | | |
| *Dinophysis acuminata* | | | | | | | | | | | | |
| *Dinophysis caudata* | | | | | | x | | | | | | x |
| *Dinophysis tripus* | | x | | | | | | | | | | |
| *Gonyaulax polygramma* | | | | | | x | | x | | | | |
| *Gonyaulax scrippsae* | | | | | | | | | | | | |

**Key:** x = rarely observed species; xx = common species; xxx = dominant species in replicate net samples; counts = cells per litre in water samples

**TABLE 4.2.1.2: PHYTOPLANKTON COLLECTED FROM BOTANY BAY (net and water samples) (con't)**

| | Collected 21/3/00 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Site BD5** | | | | **BLB** | | | | **QA1** | | | |
| | **Cells/L** | **Rep 1** | **Rep 2** | **Rep 3** | **Cells/L** | **Rep 1** | **Rep 2** | **Rep 3** | **Cells/L** | **Rep 1** | **Rep2** | **Rep 3** |
| *Gonyaulax spinifera* | | | x | | | x | x | x | | x | x | x |
| *Gonyaulax verior* | | | | | | x | x | | | | | |
| *Gymnodinium aff. pulchellum* | | | | | | | | | | | | |
| *Gymnodinium sanguineum* | | | | x | | | | | | | | |
| *Gymnodinium* spp. | | | | | $9.2x10^4$ | | | | $7.2x10^3$ | | | |
| *Gyrodinium* spp. | | | | | $2.8x10^4$ | | | | | | | |
| *Heterocapsa rotundata* | | | | x | $3.7x10^4$ | | | | | | | |
| *Phalachroma* spp. | | | | | | | | x | | | | |
| *Prorocentrum gracile* | | | | | | | | | | | | |
| *Prorocentrum micans* | | x | x | | | x | x | x | | x | x | x |
| *Prorocentrum minimum* | | | | | $9.2x10^3$ | | | x | | | | x |
| *Prorocentrum triestinum* | | | | | $9.2x10^3$ | | | | | | | |
| *Protoperidinium claudicans* | | | | | | | | | | | | |
| *Protoperidinium depressum* | | | | | | | | | | | | |
| *Protoperidinium leonis* | | | | x | | | | | | | | |
| *Protoperidinium nudum* | | | | x | | x | | x | | | | |
| *Protoperidinium obtusum* | | x | x | x | | x | x | x | | | | x |
| *Protoperidinium pallidum* | | x | x | x | | x | x | x | | x | x | x |
| *Protoperidinium* spp. | | | x | | | | | x | $7.3x10^3$ | | | |
| *Pyrophacus horologium* | | | | | | | | | | | x | x |
| *Scrippsiella trochoidea* | | | | | | x | x | | | x | | |
| **Prymnesiophytes** | | | | | | | | | | | | |
| *Acanthoica* spp. | | | | | $1.8x10^4$ | | | | | | | |
| *Calciopappas caudatus* | | | | | $9.2x10^3$ | | | | | | | |
| *Chrysochromulina* spp. | $2.0x10^5$ | | | | $1.9x10^5$ | | | | $1.0x10^5$ | | | |
| *Emiliania huxleyii* | | | | | $7.4x10^4$ | | | | | | | |
| *Prymnesium patellifera* | | | | | $3.7x10^4$ | | | | | | | |
| Unidentified spp. | | | | | $9.2x10^4$ | | | | | | | |
| **Chrysophytes** | | | | | | | | | | | | |
| *Calycomonas* spp. | | | | | $9.2x10^3$ | | | | | | | |
| *Ochromonas* spp. | | | | | $4.6x10^4$ | | | | | | | |
| *Paraphysomonas* spp. | | | | | $9.2x10^3$ | | | | | | | |
| **Cryptomonads** | | | | | | | | | | | | |
| *Hemiselmis* spp. | $7.8x10^3$ | | | | $6.4x10^4$ | | | | $7.2x10^3$ | | | |
| *Leucocryptos marina* | | | | | $2.8x10^4$ | | | | | | | |
| *Plagioselmis prolonga* | $1.8x10^5$ | | | | $4.6x10^4$ | | | | $2.9x10^4$ | | | |
| *Rhodomonas salina* | | | | | $2.8x10^4$ | | | | $7.2x10^3$ | | | |
| *Teleaulax acuta* | | | | | | | | | $7.2x10^3$ | | | |
| **Prasinophytes** | | | | | | | | | | | | |
| *Nephroselmis* spp. | $1.6x10^4$ | | | | $1.8x10^4$ | | | | | | | |
| *Pyramimonas* spp. | $1.7x10^5$ | | | | $1.2x10^5$ | | | | $7.9x10^4$ | | | |
| *Tetraselmis* spp. | | | | | $2.8x10^4$ | | | | | | | |
| **Silicoflagellates** | | | | | | | | | | | | |
| *Dictyocha octanaria* | | x | x | x | | x | x | x | | | x | |
| *Dictyocha fibula* | | | | | | | | | | | | |
| **Cyanophytes** | | | | | | | | | | | | |
| *Oscillatoria* sp. | | | x | | | | | | | | | |
| **Others** | | | | | | | | | | | | |
| *Apedinella spinifera* | | | | | $9.2x10^3$ | | | | | | | |
| *Ebria tripartita* | | | x | | | | x | x | | | | |
| *Euglena* sp. | | | | | $9.2x10^3$ | | | | | | | |
| *Eutreptiella* sp. | | | | | $1.8x10^4$ | | | | | | | |
| *Heterosigma* sp. | | | x | | | | | | | | | |
| *Pelagococcus subviridis* | | | | | | | | | | | | |
| *Paulinella ovalis* | $2.3x10^4$ | | | | | | | | $1.4x10^4$ | | | |
| Unidentified bodonids/heterotrophs | $3.9x10^4$ | | | | $1.4x10^5$ | | | | | | | |
| Other | | | | | $9.2x10^3$ | | | | | | | |

**Key:** x = rarely observed species; xx = common species; xxx = dominant species in replicate net samples; counts = cells per litre in water samples

### *4.2.2. Macroalgae*

The term macroalgae refers to the main group of primarily attached macroscopic marine plants, or seaweeds, which inhabit the coastal shallows and deeper sunlit regions of the continental shelf. Seaweeds, together with the seagrasses, are the major primary producers in inshore coastal regions, and kelp beds can far exceed the richest agricultural lands in terms of plant material produced annually (Christianson *et al*. 1981). Macroscopic algae, together with the seagrasses and microscopic algae (mainly phytoplankton) form the basis of marine and estuarine food chains.

Macroalgae are classified into three main groups: the Chlorophyta, or green algae; the Phaeophyta, or brown algae; and the Rhodophyta, or red algae. Around 113 species of green algae (Millar and Kraft 1994a), 140 species of brown algae (Millar and Kraft 1994b) and 400 species of red algae (Millar and Kraft 1993) are known to occur in eastern Australian waters.

The macroalgae samples collected from Botany Bay were sent to Dr Allan Millar at the National Herbarium, Royal Botanic Gardens, Sydney, for identification. A total of 57 species were identified from 25 families, with no confirmed introduced species being found (see Table 4.2.2). Many of those species identified are common to New South Wales and Australia, and many are "cosmopolitan", being common worldwide.

Also included in the samples was one species of "blue-green alga" (Cyanophyta), and one species of seagrass, *Halophila ovalis*, the latter from the angiosperm family Hydrocharitaceae.

The green alga ***Caulerpa filiformis***, a chlorophyte, is easily recognised by its bright green colour and its "simple, flattened, strap-like shape". It was first recorded in Australia in 1923, and since then this alga has proliferated to become a dominant plant on intertidal rock platforms in the Sydney area (Edgar 2000). Local scientists initially thought it was introduced from South Africa. However, recent genetic studies (Pillmann *et al*. 1997) have shown that the local *C. filiformis* differs from the South African form and that the species is probably native to both countries (i.e. it is probably not an introduced species in Australia). The recent perceived proliferation of this species in the Sydney area may be due to its ability to utlilise increased nutrient loadings better than other related algae. In Australian waters it occurs along the central New South Wales coast from south of Wollongong, around the Sydney area (including Botany Bay), and northwards to Port Stephens (Edgar 2000; D. Pollard and R. Pethebridge, pers. obs.). *Caulerpa filiformis* was found amongst pile scraping samples from Dolls Point (DP1), and amongst qualitative samples taken at Sutherland Point (SP1) in Botany Bay.

A second (native) species belonging to this genus (i.e. *Caulerpa scapelliformis)* has also been invasive of submerged reefs in Botany Bay (Davis *et al*. 1997), though it was not collected during the present study.

Another alga, ***Pterosiphonia bipinnata***, was recorded for the first time in Australia during the present survey. This cryptogenic species had previously been recorded from Japan, Alaska and the USSR, and is a rhodophyte from the family Rhodomelaceae. According to Dr A. Millar, this species "appears to be a new record for New South Wales and possibly Australia. It is a tiny epiphyte, easily overlooked, and most likely is a native and not an introduction." Specimens of this species were found in pile scrapings from the Brotherson Dock (BD1) and Dolls Point (DP2) sites.

**TABLE 4.2.2: MACROALGAL AND SEAGRASS FLORA COLLECTED FROM BOTANY BAY**

| **Family, etc.** | **Species** | **Site** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BD1** | **BD2** | **BD4** | **BD5** | **BLB** | **RVN** | **RVS** | **KP1** | **KP2** | **QA1** | **BP1** | **KB2** | **3R1** | **3R2** | **2R1** |
| **Cyanophyta** | Blue-green alga | | | | | | | | 1C | 1C | | | | | | |
| **Rhodophyta** | | | | | | | | | | | | | | | | |
| Ceramiaceae | *Antithamnion amphigeneum* | | | | | | | | | | | | | | | 1Q |
| | *Centroceras clavulatum* | | | | | | | | | | | | | | | |
| | *Ceramium codii* | | | | 1P | | | | | | | | | | | |
| | *Ceramium filiculum* | | | 1P | | | | | 1P | | | | | | | |
| | *Ceramium macilentum* | | | | | | | | 1P | | | | | 1P | | |
| | *Ceramium* sp. | | | | 3P | | | | | | | | | | | |
| | *Spyridia filamentosa* | | | | | | | | | | | 1Q | | | | |
| Champiaceae | *Champia compressa* | | | | | | | | | | | | | | | |
| | *Champia parvula* | | | | | | | | | | | | | | | |
| Corallinaceae | *Amphiroa anceps* | | | | | | | | | | | | | | | |
| | *Corallina officinalis* | | | | | | 1Q | | | | | | | | | |
| | *Haliptilon roseum* | | | | | | | | | | | | | | | 2Q |
| Crouanaceae | *Crouania capricornica* | | | | | | | | | | | | | | | |
| Dasyaceae | *Dasya iyengarii* | | | | 1P | | | | | | | | | 1P | | |
| | *Dasya trichophora* | | | | | | | | | 1C | | | | | | |
| Delesseriaceae | *Acrosorium venulosum* | | | | | | | | | | | | | | | |
| | *Caloglossa leprieurii* | | | | | | | | | | | | | | | |
| | *Haraldiophyllum sinuosum* | | | | 1P | | | | | | | | | | | |
| | *Nitophyllum* sp. | | | | | | | | | 1P | | | | | | |
| | *Patulophycus eclipes* | | | | | | 1Q | | | | | | | | | |
| | *Phycodrys australasica* | | | 1P | | | | | | | | | | | | 1Q |
| | *Schizoseris pygmaea* | | | | | | | | | | | | | 3P | | |
| | *Valeriemaya geminata* | | | | | | | | | | | | | | | |
| Galaxauraceae | *Scinaia tsinglanensis* | | | | | | | | | | | | | | | |
| | *Pterocladia capillacea* | | | | | | | | | | | | | 1P | | |
| Gracilariaceae | *Gracilaria* sp. | | | | | | 1C | | | | | | | 1P | | 1Q |
| Hypneaceae | *Hypnea boergesenii* | | | | | | | | | | | 2Q | | | | |
| | *Hypnea spinella* | | | | | | | | | | | | | | | |
| Rhodomelaceae | *Chondria* sp. | | | | | | | | 1P | | | 1Q | | | | |
| | *Chondria succulenta* | | | | | | 1C | | | 1P | | | | 1C | 1P | |
| | *Polysiphonia blandii* | | | | | | | | | | | | | | | |
| | *Polysiphonia constricta* | | | | | | | | | 1P | | | | 1P | | |
| | *Polysiphonia* sp. | | | 1P | 2P | | | | | | | | | | | |
| | *Polysiphonia sphaerocarpa* | | | | | | | | 2P | | | | | 1C | 1P | |
| | *Pterosiphonia bipinnata* ** | 1P | | | | | | | | | | | | | | |
| | *Stypopodium flabelliforme* | | | | | | | | | | | | | | | |
| Rhodymeniaceae | *Rhodymenia leptophylla* | | | | 3P | | | | | 1P | | | | | 1P | 1Q |
| Solieriaceae | *Soliera tenera* | | | | | | | | | | | | | | | |
| | *Sarconema* sp. | | | | | | | | | | | | | | | |
| **Phaeophyta** | | | | | | | | | | | | | | | | |
| Alariaceae | *Ecklonia radiata* | | | | | | | | | | | | | | | |
| Dictyotaceae | *Homeostrichus sinclairii* | | | | | | | | | | | | | | | 1Q |
| | *Taonia australasica* | | | | | | | | | | | | | | | |
| Dictyotaceae- | *Dilophus intermedius* | | | | | | | | | | | | | | | |
| Dictyotaea | *Dictyota dichotoma* | | | | 4P | | | | 5P | 1P | | | | 6P | 4P | 4Q |
| | *Dictyota* sp. | | 1P | | 4P | | | | | 1P | | | | 1P | 3P 1Q | |
| Dictyotaceae- | *Padina gymnospora* | | | | | | | | | | | | | | | |
| Zonariaea | *Zonaria diesingiana* | | | | | | | | | | | | | | | |
| Ectocarpaceae | Ectocarpalean sp. | | | | | | | | 1P | | | | | | | |
| Sargassaceae | *Sargassum* sp. | | | | | | 1Q | | | | | | | 3P | | |
| Scytosiphonaceae | *Colpomenia sinuosa* | | | | | | | | | | | | | | | |
| Lomentariaceae | *Lomentaria catenata* | | | | | | | | 1P | | | | | | | |
| | *Lomentaria monoclamydea* | | | | | | | | 1P | | | | | | | |
| Sphacelariales | *Sphacelaria cirrosa* | | | | | | | | 1P | | | | | | | |
| **Chlorophyta** | | | | | | | | | | | | | | | | |
| Anadyomenaceae | *Microdictyon umbillicatum* | | | | | | | | | | | 1Q | | | | |
| Caulerpaceae | *Caulerpa filiformis* ** | | | | | | | | | | | | | | | |
| Cladophoraceae | *Chaetomorpha linum* | | | | | | | | | | | | | | | |
| | *Cladophora feredayi* | | | | | | | | 2P | | | | | | | |
| | *Cladophoropsis herpestica* | | | | 1P | | 1Q | | 3P | 2P | | | | 1P | | |
| | *Cladophora* sp. | | | | | | | | 1P | 1P | | | | | | |
| Codiaceae | *Codium fragile* | | | | | | | | | 1P | | | | 1P | | |
| | *Codium harveyi* | | | | | | | | | | | | | | | |
| Ulvaceae | *Enteromorpha intestinalis* | | | | | | | | 2P | | | | | | | |
| | *Ulva lactuca* | | | | | | | | | | | | | | 1P | |
| | *Ulva* sp. | | | | | | | | | | | 1Q | | | | |
| **Seagrasses** | | | | | | | | | | | | | | | | |
| Hydrocharitaceae | *Halophila ovalis* | | | | | | | | | | | | | | 1C | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q: 1 qualitative sample; ** cryptogenic species

**TABLE 4.2.2: MACROALGAL AND SEAGRASS FLORA COLLECTED FROM BOTANY BAY (continued)**

| Family, etc. | Species | Site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
| **Cyanophyta** | Blue-green alga | | | | | | | | | | | | | | 1C |
| **Rhodophyta** | | | | | | | | | | | | | | | |
| Ceramiaceae | *Antithamnion amphigeneum* | | | | | | | | | | | | | | |
| | *Centroceras clavulatum* | | | | | | 1P | | | | | | | | |
| | *Ceramium codii* | | | | | | | | | | | | | | |
| | *Ceramium filiculum* | | | | | | 1P | | | | | | | | |
| | *Ceramium macilentum* | | | | | | 1P | | | | | | | | |
| | *Ceramium* sp. | | | | | | | | | | | | | | |
| | *Spyridia filamentosa* | | | | | | | | | | | | | | |
| Champiaceae | *Champia compressa* | | | | | | | | | 1Q | | 1Q | | | |
| | *Champia parvula* | | | | | | 1P | | | | | | | | |
| Corallinaceae | *Amphiroa anceps* | | | | | | 1P | | | 2Q | | | | | |
| | *Corallina officinalis* | 1Q | | | | | | | | | | 2Q | | | |
| | *Haliptilon roseum* | | | | | | 1P | | | 1Q | | | | | |
| Crouanaceae | *Crouania capricornica* | | | | | | 1P | | | | | | | | |
| Dasyaceae | *Dasya iyengarii* | | | | | | | | | | | | | | |
| | *Dasya trichophora* | | | | | | | | | | | | | | |
| Delesseriaceae | *Acrosorium venulosum* | | | | 1C 1Q | | | 1P | | | | | | | |
| | *Caloglossa leprieurii* | | | | | 1P | | | | | | | | | |
| | *Haraldiophyllum sinuosum* | | | | | | | 1P | | | | | | | |
| | *Nitophyllum* sp. | | | | | | | | | 1Q | | | | | |
| | *Patulophycus eclipes* | | | | | | | | | | | | | | |
| | *Phycodrys australasica* | | | | | | | | | | | | | | |
| | *Schizoseris pygmaea* | | | | | | | | | | | | | | |
| | *Valeriemaya geminata* | | | | | | | 1P | | | | | | | |
| Galaxauraceae | *Scinaia tsinglanensis* | | | | | | | | | 1Q | | | | | |
| | *Pterocladia capillacea* | | | | | | | | | | | | | | |
| Gracilariaceae | *Gracilaria* sp. | | | 1C 1Q | | | 2C | | | | | | | 1C | |
| Hypneaceae | *Hypnea boergesenii* | | | | | | | | | | | | | | |
| | *Hypnea spinella* | | | | | | 1P | | | | | | | | |
| Rhodomelaceae | *Chondria* sp. | | | | | | | | | | | | | | |
| | *Chondria succulenta* | | | | | | | | | | | | | | |
| | *Polysiphonia blandii* | | | | | | 1P | | | | | | | | |
| | *Polysiphonia constricta* | | | | | | | | | 1Q | | | | | |
| | *Polysiphonia* sp. | | 1P | | | 1P | | 2P | | | | | 1P | | |
| | *Polysiphonia sphaerocarpa* | | | | | | | | | | | | 1P | | |
| | *Pterosiphonia bipinnata* ** | | | | | | | 2P | | | | | | | |
| | *Stypopodium flabelliforme* | | 1C | | | | | | | | | | | | |
| Rhodymeniaceae | *Rhodymenia leptophylla* | | | | | 1 | | | | | | | | | |
| Solieriaceae | *Soliera tenera* | | | | | | | | | 1P | | | | | |
| | *Sarconema* sp. | | | 1P | | | | | | | | | | | |
| **Phaeophyta** | | | | | | | | | | | | | | | |
| Alariaceae | *Ecklonia radiata* | | | 1Q | | | | 1P | | | | | 2P | | |
| Dictyotaceae | *Homeostrichus sinclairii* | | | | | | | | | | | | | | |
| | *Taonia australasica* | | | | 1Q | | 1P | | | | | | | | |
| Dictyotaceae- | *Dilophus intermedius* | | | | | | | | | 1Q | | | | | |
| Dictyotaea | *Dictyota dichotoma* | | | | | | | | | | | | | | |
| | *Dictyota* sp. | 1Q | | | | | 1P | | | | | 1P | 1P | | |
| Dictyotaceae- | *Padina gymnospora* | | | 1Q | | | | | | 1Q | | | | | |
| Zonariaea | *Zonaria diesingiana* | | | | | | | | | | | 1P | | | |
| Ectocarpaceae | Ectocarpalean sp. | | | | | | | | | | | | | | |
| Sargassaceae | *Sargassum* sp. | | | 1Q | | | 1P | | | 1Q | | 1P 1Q | 1P | | 1C |
| Scytosiphonaceae | *Colpomenia sinuosa* | | | | | | | | | 1Q | | | 1P | | |
| Lomentariaceae | *Lomentaria catenata* | | | | | | | | | | | | | | |
| | *Lomentaria monoclamydea* | | | | | | | | | | | | | | |
| Sphacelariales | *Sphacelaria cirrosa* | | | | | | 1P | | | | | | | | |
| **Chlorophyta** | | | | | | | | | | | | | | | |
| Anadyomenaceae | *Microdictyon umbillicatum* | | | | | | | | | | | | | | |
| Caulerpaceae | *Caulerpa filiformis* ** | | | | | | 1P | | | 1Q | | | | | |
| Cladophoraceae | *Chaetomorpha linum* | | | | 1C | | | | | | | | | | |
| | *Cladophora feredayi* | | | | | | | | | | | 1Q | | | |
| | *Cladophoropsis herpestica* | | | 1Q | | | | | | | | | | | |
| | *Cladophora* sp. | | | | | | | | | | | | | | |
| Codiaceae | *Codium fragile* | | | | | | | | | | | | | | |
| | *Codium harveyi* | | | 1Q | | | | | | 2Q | | | | | |
| Ulvaceae | *Enteromorpha intestinalis* | | | | | | 1P | | | | | | | | |
| | *Ulva lactuca* | | | | | | 1P | | | | | | 1P | | |
| | *Ulva* sp. | | | | | 1P | | | | | | | | | |
| **Seagrasses** | | | | | | | | | | | | | | | |
| Hydrocharitaceae | *Halophila ovalis* | | | | | | | | | 2Q | | | | | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q: 1 qualitative sample; ** cryptogenic species

### *4.2.3. Poriferans*

The Phylum Porifera, or sponges, includes about 6000 marine and 100 freshwater species. Nearly 1000 of these species occur in southern Australia (Edgar 2000).

Sponges occur anywhere there is a suitable substratum, such as on rocks, shells, submerged timber, coral, sand or mud. They survive best where there is a strong current or wave action, because they are filter feeders. They often tend to be more dominant in caves and deeper water, and less dominant in shallow waters where the faster growing seaweeds tend to dominate (Edgar 2000). Carnivorous animals generally avoid sponges as prey because of their sharp spicules and toxic chemicals.

Professor Pat Bergquist from the University of Auckland, New Zealand, identified the sponges collected from Botany Bay. Of the 22 taxa identified, 7 were identified to species level, and the rest to genus level (see Table 4.2.3). All of those identified to species level were found not to be outside their normal distributional ranges. It is impossible to comment on the usual geographic distributions of those sponges identified only to genus.

**TABLE 4.2.3: PORIFERAN FAUNA COLLECTED FROM BOTANY BAY**

| **Family, etc.** | **Species** | **Site** | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BD1** | **BD2** | **BD4** | **BD5** | **BLB** | **RVN** | **RVS** | **KP1** | **KP2** | **QA1** | **BP1** | **KB2** | **3R1** | **3R2** | **2R1** |
| **Demospongiae** | | | | | | | | | | | | | | | | |
| **Order: Axinellida** | | | | | | | | | | | | | | | | |
| Axinellidae | *Axinella* sp. | | | 1P | | | | | | | | | | | | |
| **Order: Dendroceratida** | | | | | | | | | | | | | | | | |
| Darwinellidae | *Chelonaplysilla violacea* Lendenfeld | 6P | 6P | 8P | 2P | | | | | 2P | | | | | | 2Q |
| | *Darwinella gardineri* Topsent | | | | | | | | 1P | | | | | | | |
| Dictyodendrillidae | *Dictyodendrilla cavernosa* Lendenfeld | 1P | | | | | | | | | | | | | | |
| **Order: Dictyoceratida** | | | | | | | | | | | | | | | | |
| Irciniidae | *Ircinia rubra* | | | | 1P | | | | | 1P | | | | | | 2Q |
| Dysideidae | *Dysidea* sp. 1 | 4P | 5P | 6P | 4P | 5P | | | 2P | | | | | 1P | | |
| | *Dysidea* sp. 2 | | 1P | | | | | | | | | | | | | |
| | *Dysidea* sp. 3 | | | 1P | | | | | | | | | | | | |
| Spongiidae | *Spongia irregularis* Lendenfeld | | | | | | | | | | | | | | | |
| **Order: Halichondrida** | | | | | | | | | | | | | | | | |
| Halichondriidae | *Halichondria* sp. | | | | | | | | | | | | | | | |
| **Order: Haplosclerida** | | | | | | | | | | | | | | | | |
| Callyspongiidae | *Callyspongia diffusa* Ridley | 1P | | | | | | | 3P | 2P | | | | | | |
| | *Callyspongia* sp. | | 1P | 1P | | 1C 1P | | | 2P | | | | | | | |
| | *Dactylia palmata* Carter | | 1P | | | | | | 1C | | | | | | | |
| Haliclonidae | *Haliclona* sp. 1 | | | | | 1P | | | 2P | | | | | | | |
| | *Haliclona* sp. 2 | | 2P | 4P | 1P | | | | 1P | 6P | | | | | | |
| | *Haliclona* sp. 3 | | | 3P | | | | | | | | | | | | |
| | *Haliclona* sp. 4. | | | | | | | | | | | | | | | |
| **Order: Poecilosclerida** | | | | | | | | | | | | | | | | |
| Mycalidae | *Mycale* sp. | | | | | | | | | 1P | | | | | | |
| Myxillidae | Myxillid sp. | | | | | | | | | | | | | | | |
| Raspailiidae | *Rasapailia* sp. | | 1P | | | | | | | | | | | | | |
| Tedaniidae | *Tedania* sp. | | | | | | | | 1P | | | | | | | |
| **Class: Calcarea** | Calcarea sp. unidentified | | | 2P | | | | | | | | | | | | |
| **Order: Leucosoleniida** | | | | | | | | | | | | | | | | |
| Sycettidae | *Sycon* sp. | 3P | 2P | 6P | 5P | 1P | | | 2P | 1P | | | | 1P | | |
| Unidentifiable | | 16P | 5P | 8P | 10P | 17P | | | | 7P | | | | 5P | | 1Q |
| Poor label | | | | | | | | 1 | | 2P | | | | | | |

**Key:** 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1: 1 qualitative sample

**TABLE 4.2.3: PORIFERAN FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family, etc. | Species | Site 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Demospongiae** | | | | | | | | | | | | | | | |
| **Order: Axinellida** | | | | | | | | | | | | | | | |
| Axinellidae | *Axinella* sp. | | | | | | | | | | | | | | |
| **Order: Dendroceratida** | | | | | | | | | | | | | | | |
| Darwinellidae | *Chelonaplysilla violacea* Lendenfeld | | 1P | | | | | | | | | | | | |
| | *Darwinella gardineri* Topsent | | | 1 | | | | | | | | | | | |
| Dictyodendrillidae | *Dictyodendrilla cavernosa* Lendenfeld | | | | | | | | | | | | | | |
| **Order: Dictyoceratida** | | | | | | | | | | | | | | | |
| Irciniidae | *Ircinia rubra* | | 1P | | | | | | | 1Q | | | | | |
| Dysideidae | *Dysidea* sp. 1 | | 1P | | | | | | | | | | | | 2P |
| | *Dysidea* sp. 2 | | | | | | | | | | | | | | |
| | *Dysidea* sp. 3 | | | | | | | | | | | | | | |
| Spongiidae | *Spongia irregularis* Lendenfeld | | | | | | | | | | | 1Q | | | |
| **Order: Halichondrida** | | | | | | | | | | | | | | | |
| Halichondriidae | *Halichondria* sp. | | | | | | 1P | | | | | | | | |
| **Order: Haplosclerida** | | | | | | | | | | | | | | | |
| Callyspongiidae | *Callyspongia diffusa* Ridley | | 1P | | | | 1P | | | | | | | | 2P |
| | *Callyspongia* sp. | | | | | | | | | | | | | | |
| | *Dactylia palmata* Carter | | | | | | | | | | | | | | |
| Haliclonidae | *Haliclona* sp. 1 | | | | | | | | | | | | | | |
| | *Haliclona* sp. 2 | | | | | | | | | | | | | | |
| | *Haliclona* sp. 3 | | | | | | | | | | | | | | |
| | *Haliclona* sp. 4. | | | | | | | | | | | | | | 3P |
| **Order: Poecilosclerida** | | | | | | | | | | | | | | | |
| Mycalidae | *Mycale* sp. | | | | | | | 1P | | | | | | | |
| Myxillidae | Myxillid sp. | | | | | 7P 1C | | | | | | | | | 1P |
| Raspailiidae | *Rasapailia* sp. | | | | | | | | | | | | | | |
| Tedaniidae | *Tedania* sp. | | | | | | | | | | | | | | |
| **Class: Calcarea** | Calcarea sp. unidentified | | | | | | | | | | | | | | |
| **Order: Leucosoleniida** | | | | | | | | | | | | | | | |
| Sycettidae | *Sycon* sp. | | | | | | | | | | | | | | |
| Unidentifiable | | | 2P | | | 4P | 1P | 1P | | | | 2Q | 2P | | 2P |
| Poor label | | | | | | | | | | | | | | | |

**Key:** 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1: 1 qualitative sample

### *4.2.4. Hydrozoans*

The Class Hydrozoa belongs to the Phylum Coelenterata, the cnidarians, which include the hydras, jellyfishes, sea anemones and corals (Barnes 1987). Marine hydrozoans, or hydroids, are generally small colonial branching forms, which are often plant-like in appearance, and are therefore not commonly recognised or well known, often being casually dismissed as "seaweeds". However, around 2700 species exist (Barnes 1987), and they are most commonly found attached to wharf pilings, rocks and shells.

Dr Jeanette Watson of the Hydrozoan Research Laboratory, Melbourne, identified the hydrozoans from the present study. Only four species were found (see Table 4.2.4). These were ***Clytia hemisphaerica***, ***Obelia dichotoma, Phialella quadrata*** and ***Antenella secundaria***. *Clytia hemisphaerica* and *P. quadrata* were found at Brotherson Dock (BD5), *A. secundaria* was found at Kurnell Pier (KP2), and *O. dichotoma* was found at the Bulk Liquids Berth (BLB) and Channel Marker 4 (CH4) sites. All of these species were found in pile scraping samples collected from the above sites, and all are cryptogenic in origin. According to Dr J. Watson, "*Obelia dichotoma* is a cosmopolitan species that, if it did not colonise the Australasian region in the geological past, almost certainly did so on the hulls of the earliest sailing ships. It is a very common temperate to cool-temperate Australian species".

**TABLE 4.2.4: HYDROZOAN FAUNA COLLECTED FROM BOTANY BAY**

| Family | Species | Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
| Campanulariidae | *Clytia hemisphaerica* ** | | | | 1P | | | | | | | | | | | |
| | *Obelia dichotoma* ** | | | | | 2P | | | | | | | | | | |
| Phialellidae | *Phialella quadrata* ** | | | | 2P | | | | | | | | | | | |
| Plumulariidae | *Antenella secundaria* ** | | | | | | | | | 2P | | | | | | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q; 1 qualitative sample; ** cryptogenic species

**TABLE 4.2.4: HYDROZOAN FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family | Species | Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 | |
| Campanulariidae | *Clytia hemisphaerica* ** | | | | | | | | | | | | | | | |
| | *Obelia dichotoma* ** | | | | | | | | | | | | | | 1P | |
| Phialellidae | *Phialella quadrata* ** | | | | | | | | | | | | | | | |
| Plumulariidae | *Antenella secundaria* ** | | | | | | | | | | | | | | | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q; 1 qualitative sample; ** cryptogenic species

### *4.2.5. Anthozoans*

The anthozoans comprise the anemones, the hard and soft corals and the sea pens, and can occur as either solitary polyps or colonies of polyps (Edgar 2000, Barnes 1987).

The scleractinians, or hexacorals, are hard or stony corals belonging to the Class Anthozoa. The living polyps of hexacorals are encased inside a hard calcareous skeleton, and they include the reef building corals which are most common in tropical waters. Non-reef building forms also frequently occur in more temperate regions, such as Botany Bay.

A total of 63 samples of hexacorals were collected during the Botany Bay sampling, and these were initially examined at the NSW Fisheries Research Institute by Dr D. Pollard. From this examination it appeared that all of the specimens were of the one species, *Culicia tenella***.** Table 4.2.5 lists the sites at which this species was collected.

*Culicia tenella* is a relatively common species in temperate Australian waters, which can be found from Perth in Western Australia to the Solitary Islands in NSW, including around Tasmania (Edgar 2000).

These samples were later sent to Dr Peter Harrison of Southern Cross University, Lismore, who confirmed that the specimens looked most like this widespread species *Culicia tenella*, and can therefore at this stage be listed as ***Culicia c.f. tenella***. This species is usually found in small colonies on hard surfaces where there is low light (for example, in submarine caves) (Edgar 2000).

The anemones are familiar and conspicuous, usually solitary, soft bodied anthozoans, which commonly inhabit temperate rocky shores in southern Australia.

A total of 49 samples of anenomes were collected from Botany Bay during the present study. These were sorted into 9 different “taxa” or types, most or all of which were probably native species. Unfortunately, due to the lack of any available taxonomic expertise for this group, these “taxa” could not be identified to species level. The majority of these anenomes were collected from Brotherson Dock and Kurnell Pier, and some samples were also collected from the Airport Runways, Bulk Liquids Berth, Sutherland Point, and at the entrances to the Georges and Cooks Rivers.

| TABLE 4.2.5: ANTHOZOAN FAUNA COLLECTED FROM BOTANY BAY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family, etc. | Species | Site | | | | | | | | | | | | | | |
| | | BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
| **Order Scleractinia** | | | | | | | | | | | | | | | | |
| Rhizangiidae | *Culicia c.f. tenella* ** | 13 | 16 | 12 | 4 | 4 | | | 6 | 4 | | | | 2 | 1 | |
| **Key:** 1,2 etc = numbers of samples collected; ** cryptogenic species | | | | | | | | | | | | | | | | |

| TABLE 4.2.5: ANTHOZOAN FAUNA COLLECTED FROM BOTANY BAY | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family, etc. | Species | Site | | | | | | | | | | | | | | |
| | | 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 | Poor label |
| **Order Scleractinia** | | | | | | | | | | | | | | | | |
| Rhizangiidae | *Culicia c.f. tenella* ** | | | | | | | | | | | | | | | 1 |
| **Key:** 1,2 etc = numbers of samples collected; ** cryptogenic species | | | | | | | | | | | | | | | | |

### *4.2.6. Polychaetes*

The polychaete worms comprise the largest class of the annelid (or segmented) worms, with most species being marine. Polychaetes often dominate soft sediments in terms of both their abundance and numbers of species.

No previous port studies have emphasised introduced polychaetes in New South Wales waters. A study by Hutchings *et al.* (1989) identified introduced species from other invertebrate groups in Twofold Bay, but mentioned no polychaetes. Records from the Australian Museum indicate a list of eight species which have been confirmed as introduced, or likely to have been introduced, to Australian waters. These species include *Neanthes succinea* (possibly cosmopolitan*), Boccardia chilensis* (probably from Chile), *Pseudopolydora paucibranchiata* (probably from Japan*), Capitella capitata* (probably from California)*, Sabella spallanzanii* (from the Mediterranean Sea), *Euchone limnicola* (probably from California*), Ficopomatus enigmaticus* (likely to be from Europe) and *Hydroides ezoensis* (thought to be from Japan). *Sabella spallanzanii* was introduced from Europe, and has been found in large numbers in Port Phillip Bay, Victoria. It has also been found in Northern Tasmania, Gulf Saint Vincent near Adelaide in South Australia, and Cockburn Sound in Western Australia, as well as in small numbers in Twofold Bay near Eden, New South Wales (CSIRO Marine Research 1997).

The polychaetes collected from Botany Bay were examined by Dr Peggy O'Donnell from the Ecology Lab, Balgowlah, NSW. The specimens were identified to family level, and families known to contain introduced species were identified to species level. Two introduced species, *Boccardia chilensis* and *Capitella capitata*, were identified from the samples. The giant fan worm, *Sabella spallanzanii*, which proliferated and contributed to the decline of scallop fisheries and other native invertebrates in Port Phillip Bay, was not present in these samples (O'Donnell 2000). Table 4.2.6 lists the polychaete families that were identified from Botany Bay.

***Boccardia chilensis*** (Family Spionidae) was probably introduced from Chile, and was first recorded from Australian waters in 1971 (O'Donnell 2000). In Australian waters, this species has been recorded from New South Wales and Tasmania. It is found in various habitats, including on oysters and in the benthos associated with oyster leases, in rock pools, among polychaete tubes, within gastropod shells, and among coralline algae.

The two specimens of *Boccardia chilensis* collected from Botany Bay were found amongst pile scrapings, one from the Cooks River Bridge (CR1) and the other from the Georges River Bridge (GRB) sites. This species may have arrived in the bay via the movements of oysters from other estuaries to oyster leases in the Botany Bay estuary and the Georges River system (O'Donnell 2000).

***Capitella capitata*** (Family Capitellidae) may have been introduced from California. It is a small burrowing species, which is often associated with organically enriched sediments adjacent to waste treatment plant outfalls in other parts of Australia and in California. This species is opportunistic, and is known to quickly colonise and dominate benthic habitats exposed to sewage effluent. Because of this opportunistic nature, it is considered important to monitor the distribution of *Capitella capitata* in Australian waters (O'Donnell 2000).

Only one specimen of *Capitella capitata* was recorded during the survey, in a large benthic core sample taken off Lady Robinsons Beach (LR1) on the western shore of Botany Bay.

**TABLE 4.2.6: POLYCHAETE FAUNA COLLECTED FROM BOTANY BAY**

| **Family** | **Site** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **BD1** | **BD2** | **BD4** | **BD5** | **BLB** | **RVN** | **RVS** | **KP1** | **KP2** | **QA1** | **BP1** | **KB2** | **3R1** | **3R2** |
| Ampharetidae | | | | | | | | | | | | | | |
| Amphinomidae | | | | | | 2C | | | | | | | | |
| Capitellidae | | | | | 2P | 1C | 1C | | | | | | | |
| Chaetopteridae | 5P | 4P | 5P | 1P | 3P | | | | | | | | 2P | |
| Chrysopetalidae | | | | | | | | | | | | | | |
| Cirratulidae | 8P 1C | 9P | 9P | 1P | 7P 1C | | | 7P | 4P 1C | | | | 2P | 2P |
| Eunicidae | 7P | 10P | 8P | 1P | 3P | 1Q | | 6P | 4P | | | | 3P | 3P |
| Glyceridae | 2C | 1C | | | 2C | | | | | | | | 1C | |
| Goniadidae | | 1C | | | | | | | | | | | | |
| Hesionidae | | | | | | | | 2P | 1P | | | | | |
| Lumbrineridae | 7P | 9P 1C | 9P | 1P | 7P 1C | | | 9P 2C | 6P 1C | 1P | | | 3P 1C | 3P |
| Nephtyidae | | | | | | | | | | | | | | |
| Nereididae | 5P 1C | 5P | 2P | | 1P | | | 3P 1C | 3P 1C | | | | 3P | 2P 1Q |
| Onuphidae | | | | | 1C | 1C | | 1C | | | | | | |
| Opheliidae | | | | | | | | 1P | | | | | | |
| Orbiniidae | | 1C | | | | | | | 1C | | | | 1C | |
| Oweniidae | | | | | | | | | | | | | | |
| Pectinariidae | | | | | | | | | | | | | | |
| Phyllodocidae | | 1C | | | | | | | 1P | | | | 2P | 1P |
| Poecilochaetidae | | 1C | | | 1C | | | | | | | | | |
| Polynoidae | 6P | 4P 1C | 6P | 1P | 3P | | 1C | 6P | 4P 1C | | 1Q | | 3P | 2P |
| Sabellariidae | | | | | | | | | | | | | | 1P |
| Sabellidae | 7P | 5P 1C | 7P | 1P | 7P | | | 4P | 2P | | | | 1P | |
| Serpulidae | 9P | 10P | 10P | 1P | 7P | 1Q | | 6P | 1P 1C | | | | 3P | 3P 1Q |
| Sigalionidae | | | | | | | | | | | | | | 1C |
| Spionidae | | 1P | 2P | | | | | | | | | | 1P | 1P |
| Syllidae | 4P | 7P | 8P | 1P | 5P | | 1C | 9P | 6P | | | | 1P | |
| Terebellidae | 6P | 5P | 3P | | 5P | | | 6P | 5P 1C | 1P | | | 3P | 2P 1Q |
| Trichobranchidae | | 1P | | | | | | | | | | | | |
| Poor label | 4C | | | | | | | | | | | | | |

**Key:** 1,2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample

**TABLE 4.2.6: POLYCHAETE FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family | Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2R1 | 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
| Ampharetidae | | | | | | | | | | | | | | | 3C |
| Amphinomide | | | | | | | | | | | | | | | |
| Capitellidae | | | | | | | | | | | 2C | | | | |
| Chaetopteridae | | | | | | | | | | | | | | | |
| Chrysopetalidae | | | | | | | | | | | 1Q | | | | |
| Cirratulidae | 1Q | | 1P 1C | 1Q | | | | 1P | | 1Q | | | | | 2P 1C |
| Eunicidae | | | 1P 2C | | | 1P | 1P | 1P | | 2Q | | | | | |
| Glyceridae | | | 1P 1C | | 1C | | | 2C | | | | | | 2C | 1C |
| Goniadidae | | | | | | | | | | | 1C | | | | |
| Hesionidae | | | 2C | | 1C | | 1P | | | | 1Q | | | | |
| Lumbrineridae | | | 1C | | | | 1C | | | | | | 1P | | 3P 2C |
| Nephtyidae | | | | | | | | 1C | | | | | | | |
| Nereididae | 1Q | 1Q | 3P | | | 1P 1C | 1C | 2P 3C | | 2Q | 1Q | 1Q | 3P | | 1P |
| Onuphidae | | | | | 2C | | 1C | | | 1Q | | | | | 2C |
| Opheliidae | | | | | | | | | | | | | | | |
| Orbiniidae | | | | | | | 1C | | | | | | | | |
| Oweniidae | | | | | 1C | | | | | | | | | 2C | |
| Pectinariidae | | | | | | | | | | | | | | | |
| Phyllodocidae | | | | | 1C | 1P | 1C | 1P | | | | | | | |
| Poecilochaetidae | | | | | | | | | | | | | | | |
| Polynoidae | 1Q | | | | | 2P | | 1P | | | 1C 1Q | | 2P | 1Q | 1C |
| Sabellariidae | | | | | | | | | | | | | | | |
| Sabellidae | | | | | | 1P | | | | 3Q | | | 1P | | 1P 2C |
| Serpulidae | 2Q | | 1P | | | 3P | | | | 1Q | | 1Q | 1P | 1Q | 2P |
| Sigalionidae | | | | | | | | | | | | | | | |
| Spionidae | | | 1P | | | 1P | | | | | | | | | 1P |
| Syllidae | 1Q | | 3P 1C | | | 1P | | 2P | | 2Q | 1C 1Q | | 1P | 1C | 2P |
| Terebellidae | | | | | | | | | | 1Q | | | 1P | | 2P |
| Trichobranchidae | | | | | | | | | | | | | | | |
| Poor label | | | | | | | | | | | | | | | |

**Key:** 1,2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample

### *4.2.7. Other worms*

The worms other than polychaetes collected from Botany Bay were sent to Dr Leslie Newman at Southern Cross University, Lismore, NSW, for analysis and identification. These worms comprised five groups, including the Phylum Sipunculida (peanut worms); Phylum Platyhelminthes, Order Polycladida (flatworms); Phylum Nemertinea (ribbon worms); Phylum Annelida, Class Hirudinae (leeches); and Phylum Echiura (spoon worms). Table 4.2.7 lists the other worms that were identified from the Botany Bay samples.

The sipunculids are well described by their common name of peanut worms. They are unsegmented, leech like animals, having a cylindrical body with a fat trunk which extends to a slender extensible proboscis or introvert. All of the 330 known species are from marine or estuarine habitats. They range in size from a few millimetres to around 50 centimetres, most being around 10 to 50 mm long. These worms live in a variety of habitats, including burrows in sand or mud, amongst the rhizomes of seagrasses, and in discarded mollusc shells and holes which they bore into soft rock (Edgar 2000).

The sipunculids collected from Botany Bay comprised five species and were found at 12 of the sites sampled. They were the most abundant of the above worm groups found in the Botany Bay samples in terms of numbers present. *Phascolosoma annulatum* was the most common species, with 509 specimens being collected from 12 sites. The largest numbers (76%) of this species were found at the Brotherson Dock sites (BD1, BD2, BD4 and BD5). *Phascolosoma annulatum* is currently known from coastal waters in South Australia, Victoria and Tasmania and at Green Cape in far southern NSW (Newman, unpubl. data).

The second most common sipunculan species was *Themiste* sp., 48 specimens of which were found at seven sites. Again the majority of specimens (79%) were found at the Brotherson Dock sites. Several species of this genus are known from New South Wales waters (Newman, unpubl. data).

The platyhelminths, or flatworms, are worms with a soft, flattened, unsegmented body. About 25,000 species are known worldwide, and this group contains four main classes, three of which are parasitic (Edgar 2000). The free-living turbellarians are mainly aquatic forms which swim or are propelled by cilia beating on their undersurface. Most are less than 10 mm long and they are commonly found in mud or sand. These free-living turbellarians include members of the Order Polycladia, which are usually brightly coloured and are generally rare. In temperate Australian waters 25 species have so far been recorded and many species are yet to be scientifically named (Edgar 2000).

In the Botany Bay samples, the polyclads were relatively rare, with only 30 specimens from 5 species being found at 12 sites. The most common species was Acotylian sp. 1, which was found in low numbers at 9 sites. Most of the polyclads found in Botany Bay belonged to the Families Stylochidae and Planoceridae. These two families are commonly known as oyster leeches, and are notorious pests of commercial bivalve molluscs (rock oysters, mussels and giant clams) and barnacles. It is possible that some of these worms may have been introduced to Botany Bay via ballast water discharge (Newman, unpubl. data).

The nemerteans, or ribbon worms, have a smooth muscular body with minute cilia which produce mucus, which gives them a slippery feel. They range in size from a few millimetres to tens of metres long. The larger species are often flattened and distinctively patterned, and may readily break apart if handled. A large proboscis which can be everted through the mouth is used for hunting prey by entanglement or piercing with barbs. The most common prey include polychaetes, flatworms, molluscs and crustaceans. These worms live in shallow water under rocks, in sand or among seaweeds. About 1000 species are known worldwide and about 20 species have been recorded from southern Australia. Many of the Australian species have not yet been named (Edgar 2000).

The nemerteans were the most diverse group of these other worms found in the Botany Bay samples. A total of 8 species were identified from 11 sites. Because few studies have been carried out on this group in temperate Australian waters, identification is difficult. The most common species found belongs to the Family Emplectonematidae, and this was commonly found at six of the sites. This species is probably a new record for Australian waters. The remaining taxa were all found at 3 or less sites, and so were relatively rare. A detailed histological examination of the digestive and reproductive systems would be required to identify these taxa to species level.

Only two taxa of marine leeches (hirudineans) were collected from two of the sampling sites. One was identified to the Family Piscicolidae, and the other was a broken specimen which was unidentifiable.

Several specimens of an unidentified echiurid spoon worm were collected from one site, but as all of these specimens were poorly preserved their identification was not possible.

**TABLE 4.2.7: "OTHER WORMS" COLLECTED FROM BOTANY BAY**

| Family, etc. | | Site BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phylum Sipunculida** | | | | | | | | | | | | | | | | |
| Phacolosomidae | *Phascolosoma annulatum* | 3P | 3P | 3P | 3P | 3P | | | 3P | 3P | | | | 3P | 3P | |
| | *Phascolosoma* sp. | | 2P | | | | | | 1P | 1P | | | | | | |
| Golfingiidae | *Themiste* sp. | 3P | 3P | 3P | 2P | | | | | 3P | | | | | | |
| Unidenfied family | Sipunculan sp. F | | 2P | | | | | | | | | | | | | |
| | Sipunculan sp.G | | | 1P | | | | | | | | | | | | |
| **Phylum Platyhelminthes** | | | | | | | | | | | | | | | | |
| Stylochidae? | Acotylean sp. 1 | 2P | 1P | 1P | 2P | 2P | | | 3P | | | | | 1P | 1P | |
| | Acotylean sp. 9 | 1P | | | | | | | | | | | | | | |
| Planocerotidae? | Acotylean sp. 2 | | | | | | | | | | | | | | | |
| | Acotylean sp. 4 | | | | | | | | | | | | | | | |
| Unidentified family | Acotylean sp. 10 | | | | | | | | | | | | | | | |
| **Phylum Nemertinea** | | | | | | | | | | | | | | | | |
| cf Emplectonematidae | Nemertean sp. A | | | | | | | | 1P | 1P | | | | | | |
| Unidentified families | Nemertean sp. B | | | | | 1P | | | | | | | | | | |
| | Nemertean sp. C | | | | 1P | | | | | | | | | | | |
| | Nemertean sp. D | | | | | | | | 1P | | | | | 1P | | |
| | Nemertean sp. E | 1P | | | | | | | | 1P | | | | | | |
| | Nemertean sp. F | | | | | | | | | 1P | | | | | | |
| | Nemertean sp. G | | | | 1P | 1P | | | | | | | | | | |
| | Nemertean sp. H | | | | 1P | | | | | | | | | | | |
| **Phylum Annelida** | | | | | | | | | | | | | | | | |
| Piscicolidae | leech sp. 1 | | | | | 1P | | | | | | | | | | |
| Unidentified family | leech sp. 2 | | | | | 1P | | | | | | | | | | |
| **Phylum Echiura** | spoon worm sp. 1 | | | | | | | | | | | | | | | |

**Key:** 1,2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample

**TABLE 4.2.7: "OTHER WORMS" COLLECTED FROM BOTANY BAY (continued)**

| Family, etc | Species | Site 2R2 | CR1 | CR2 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Phylum Sipunculida** | | | | | | | | | | | | | | | | |
| Phacolosomidae | *Phascolosoma annulatum* | | 1P | 1P | | | | | | | | | | | | 1P |
| | *Phascolosoma* sp. | | | | | | | | | | | | | | | |
| Golfingiidae | *Themiste* sp. | | | | | | | | | | | | | | | |
| Unidenfied family | Sipunculan sp. F | | | | | | | | | | | | | | | |
| | Sipunculan sp.G | | | | | | | | | | | | | | | |
| **Phylum Platyhelminthes** | | | | | | | | | | | | | | | | |
| Stylochidae? | Acotylean sp. 1 | | | | | | | | | | | | | | | 1P |
| | Acotylean sp. 9 | | | | | | | | | | | | | | | |
| Planocerotidae? | Acotylean sp. 2 | | | 1C | | | 1P | | 1P | | | | | | | |
| | Acotylean sp. 4 | | | | | | | | 1P | | | | | | | |
| Unidentified family | Acotylean sp. 10 | | | | | | | | 1P | | | | | | | |
| **Phylum Nemertinea** | | | | | | | | | | | | | | | | |
| cf Emplectonematidae | Nemertean sp. A | | 3P | | | | 2P | 1P | 1P | | | | | | | |
| Unidentified families | Nemertean sp. B | | | | | | | | | | | | | | | |
| | Nemertean sp. C | | | | | | | | | | | | | | | |
| | Nemertean sp. D | | | | | | | | | | | | | | | 1P |
| | Nemertean sp. E | | | | | | | | | | | | | | | |
| | Nemertean sp. F | | | | | | | | | | | | | | | |
| | Nemertean sp. G | | | | | | | | | | | | | | | |
| | Nemertean sp. H | | | | | | | | | | | | | | | |
| **Phylum Annelida** | | | | | | | | | | | | | | | | |
| Piscicolidae | leech sp. 1 | | | | | | | | | | | | | | | |
| Unidentified family | leech sp. 2 | | | | | | | | | | | | | | | |
| **Phylum Echiura** | spoon worm sp. 1 | | | | | | | | | | 3Q | | | | | |

**Key:** 1,2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample

### *4.2.8. Crustaceans*

The crustaceans include such familiar groups of commercially exploited seafood animals as the prawns, crabs and lobsters. More than 40,000 species of crustaceans have been described worldwide, with probably about 100,000 species actually in existence (Edgar 2000). They occur in all marine and freshwater environments, and are often amongst the dominant groups of mobile animals in the plankton, seaweeds and sediments.

The crustaceans are divided into five classes, including the Branchiopoda (water fleas), Cirripedia (barnacles), Copepoda (copepods), Ostracoda (mussel or seed shrimps) and Malacostraca (higher crustaceans).

### *4.2.8.1. Cirripedes*

The Class Cirripedia, or barnacles, comprises about 1000 species worldwide, and in the adult stage they mostly live on rocks or other hard surfaces (Edgar 2000).

Dr Diana Jones of the Western Australian Museum, Perth, identified the barnacles collected from Botany Bay. A total of fourteen species occurred, and these are listed in Table 4.2.8.1. These included six known fouling species, three (***Megabalanus rosa*, *Megabalanus tintinnabulum*** and ***Megabalanus zebra*)** of which had not previously been recorded from Botany Bay. *Megabalanus rosa* was introduced to Australian waters from Japan, and *Megabalanus tintinnabulum* and *Megabalnus zebra* are both cryptogenic in origin, with the former being a cosmopolitan species.

Specimens of *Megabalanus rosa* were collected in pile scraping samples from the Brotherson Dock (BD1, BD2, BD4 and BD5), Kurnell Pier (KP1 and KP2), Dolls Point (DP1 and DP2), Bare Island (BI2) and Channel Marker 4 (CH4) sites. They were also found in large benthic core samples collected from Kurnell Pier (KP1). *Megabalanus tintinnabulum* specimens were found in wharf pile scraping samples collected from the Brotherson Dock (BD2), Kurnell Pier (KP2) and Bare Island (BI2) sites. Specimens of *Megabalanus zebra* were found in wharf pile scraping samples collected from the Brotherson Dock (BD1) and Kurnell Pier (KP1) sites.

According to Dr D. Jones, *Megabalanus rosa* has previously been recorded from the north-western and central-western coasts of Western Australia, and also from the lower east coast of Australia, with ships' hull fouling being the most likely introduction vector. The appearance of this species in Western Australia appears to be recent, with the first specimens having been collected in 1981. Allen (1953) recorded *M. rosa,* together with *M. volcano* and *B. albicostatus*, on aircraft carriers and other vessels returning to Australia after service in Korean and Japanese waters, though it was not known where these vessels docked. Allen did not, however, record these species as establishing on the Australian coastline. Pope (1945), in her key to the sessile barnacles found on rocks, boats, wharf piles and other installations in Port Jackson and adjacent waters, did not record *M. rosa* from this locality.

**TABLE 4.2.8.1: CIRRIPEDE FAUNA COLLECTED FROM BOTANY BAY**

| Family | Species | Site | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
| Iblidae | *Ibla quadrivalvis* | 1P | | | | | | | | | | | | | | |
| Tetraclitidae | *Austrobalanus imperator* | 6P | 6P | 4P | 1P | 2P | | | 12P | 3P | | | | | | |
| | *Tetraclitella purpurascens* | 2P | 1P | | | | | | | | | | | | 1Q | |
| | Tetraclitid sp. | | 1P | | 1P | | | | | | | | | | | |
| | *Tesseropora rosea* | | | | | | | | | 1P | | | | | | |
| Archaeobalanidae | *Hexaminius foliarum* | | | | | | | | | | | | | | | |
| | *Hexaminius popeiana* | | | | | | | | | | | | | | | |
| Balanidae | *Balanus trigonus* | 20P | 16P | 15P | 18P | 18P | 1C | | 30P | 13P | | | | 8P | 5P | 1Q |
| | *Balanus variegatus* | 5P | 6P | 3P | 6P | 10P | | | 18P 1C | 9P | | | | | 2P | 1Q |
| | *Austromegabalanus nigrescens* | | | | | | | | | | | | | | | |
| | *Megabalanus ajax* | | | | | | | | | | | | | | | |
| | *Megabalanus rosa* * | 6P | 4P | 1P | 1P | 4P | | | 19P 1C | 3P | | | | | | |
| | *Megabalanus tintinnabulum* ** | | 1P | | | | | | | 1P | | | | | | |
| | *Megabalanus zebra* ** | 2P | | | | | | | 4P | | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample; T: crab trap sample

**TABLE 4.2.8.1: CIRRIPEDE FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family | Species | Site 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 | No label |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iblidae | *Ibla quadrivalvis* | | | | | | | | | | | | | | | |
| Tetraclitidae | *Austrobalanus imperator* | | | | | | | | | | | 1Q | 4P | | 5P | 3P |
| | *Tetraclitella purpurascens* | | | | | | | | | | | | 2P | | 2P | |
| | Tetraclitid sp. | | | | | | | | | | | | | | | |
| | *Tesseropora rosea* | | | | | | | | | | | | 3P | | | |
| Archaeobalanidae | *Hexaminius foliarum* | | 4P | | | 2P | | | | | | | | | | |
| | *Hexaminius popeiana* | | 4P | | | 2P | | | | | | | | | | |
| Balanidae | *Balanus trigonus* | 1P | | | | 4P | | | | | | 1Q | 3P | | 9P 2C | 4P |
| | *Balanus variegatus* | 1P | 19P | 2Q | 1Q | 14P | 6P | 5P | | | | 1Q | 1P | | 8P | 5P |
| | *Austromegabalanus nigrescens* | | | | | | | | | | | | 1P | | | |
| | *Megabalanus ajax* | | | | | | | | | | | | | | 1P | |
| | *Megabalanus rosa* * | | | | | | 1P | 3P | | | | | 3P | | 7P | 3P |
| | *Megabalanus tintinnabulum* ** | | | | | | | | | | | | 1P | | | |
| | *Megabalanus zebra* ** | | | | | | | | | | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C**:** benthic core sample; Q: qualitative sample; T: crab trap sample

### *4.2.8.2. Malacostracans*

The remainder of the crustaceans collected from Botany Bay were identified as belonging to the Class Malacostraca. The malacostracans include the Order Decapoda, which includes the familiar prawns, lobsters and crabs. Dr Gary Poore and Dr Simon Heislers, from Museum Victoria, Melbourne, and Anna Murray and Shane Ahyong from the Australian Museum, Sydney, identified the malacostracans collected from Botany Bay. Table 4.2.8.2 lists the taxa collected during the present survey.

Amongst the decapods identified were four families from the Infraorder Anomura, which is the group including the hermit crabs, porcelain crabs and mole crabs (Jones and Morgan 1994). Five families were identified from the Infraorder Brachyura, a group comprising the true crabs, which is one of the most dominant groups of decapod crustaceans along Australian coastlines (Jones and Morgan 1994). One family of Thalassinidea (ghost shrimps) and three families of Caridea (carid shrimps) were also identified.

***Palaemonella rotumana***, from the family Palaemonidae, was the only cryptogenic species from the Infraorder Caridea identified from the Botany Bay samples. "This species has been recorded widely and relatively frequently in the literature from the Indo-West Pacific and Queensland, often in association with crinoids. The species has been recorded previously from near Perth, Western Australia, and this may be the first record for the Sydney region" (Poore and Heislers, pers. comm.). Poore and Heislers also stated that Botany Bay is probably the southern limit of the distribution of this species, and that it is unlikely to have been introduced.

Non-decapod malacostracan crustaceans identified included thirteen families of the order Amphipoda (beach hoppers), three families of Isopoda (slaters or pill bugs), one family of Mysidacea (opossum shrimps), and two families of Tanaidacea (tanaids).

The amphipods, or beach hoppers, comprise about 8000 described and many times more undescribed species (Edgar 2000). The amphipods collected included mainly members of the most common family, the Corophioidae, of which 11,119 specimens were identified from 59 samples. The amphipod samples were made up of 11 families, with three exotic species being identified from the family Corophioidae. Dr G. Poore identified the presence of the following introduced and cryptogenic species:

***Corophium ascherusicum*** originated in the Mediterranean region and/or the United Kingdom, and has been reported from the North Sea, North Atlantic, Mediterranean Sea, Black Sea, South

Atlantic, off South and East Africa, Sri Lanka, and in the North Pacific. This species was first recorded from the Southern Hemisphere in New Zealand in 1881, and the first report in Australian waters was from Port Jackson, NSW. Subsequent reports of this species have been made from Bunbury and the Swan River (Western Australia); Mallacoota, Gippsland Lakes, Western Port and Port Phillip Bay (Victoria); and eastern Tasmania (Poore and Storey 1999). Numerous specimens of this species were found in the Botany Bay samples (Poore and Heislers, pers. comm.).

***Corophium acutum*** was introduced to Australian waters, probably from the Mediterranean Sea. There were abundant specimens found in the Botany Bay samples (Poore and Heislers, pers. comm.).

***Paracorophium excavatum*** is a species described from New Zealand, but the natural distribution of which is unknown. It is found in the eastern and south-eastern states of Australia. Occasional specimens were found amongst the Botany Bay samples (Poore and Heislers, unpubl.).

***Caprella equilibra*** is a widespread cryptogenic species. All specimens from the family Caprellidae collected from Botany Bay were of this species. A total of 2 specimens was collected from the Cooks River Bridge (CR1), and 73 specimens from the Dolls Point (3 from DP1 and 70 from DP2) sites (Poore and Heislers, pers. comm.).

The isopods are a very large group of crustaceans which includes the pill bugs and slaters, with most of the 10,000 or so described species being marine (Edgar 2000, Barnes 1987).

The isopods collected from Botany Bay during the present survey were made up of four families, and included one introduced, one cryptogenic and two endemic species from the family Sphaeromatidae.

***Paracerceis sculpta*** was the only introduced isopod species collected from Botany Bay during the present survey, a single specimen of which was found at Lady Robinsons Beach (LR1) (Poore and Heilsers, unpubl.). This species was introduced to Australian waters from California, with its natural range probably extending from California to Mexico. It was first recorded from Australia at Townsville, Queensland, in 1975, and is also found in Port Phillip Bay, Victoria (Poore and Storey 1999).

Numerous specimens of the cryptogenic species ***Pseudosphaeroma campbellense*** were also found. This species was first described from New Zealand, but is now thought to be an endemic species which is also present in Port Phillip Bay (Poore and Heislers, pers. comm.).

Another isopod species identified from the Botany Bay samples was *Sphaeroma quoianum*, which is a common endemic species and the most abundant species in the Botany Bay collections (Poore and Heislers, unpubl.). One specimen of the endemic species *Dynoides barnardi* was also present in the samples from Botany Bay (Poore and Heislers, pers. comm.).

Other malacostracans collected included four families of anomurans (hermit crabs), eight families of brachyurans (true crabs), three families of carids (carid shrimps), one family of mysids (opossum shrimps), two families of tanaidacids (tanaids), and one family of thalassinids (ghost shrimps).

**TABLE 4.2.8.2: MALACOSTRACAN FAUNA COLLECTED FROM BOTANY BAY**

| **Family, etc.** | **Species** | **Site** | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **BD1** | **BD2** | **BD4** | **BD5** | **BLB** | **RVN** | **RVS** | **KP1** | **KP2** | **QA1** | **BP1** | **KB2** | **3R1** | **3R2** |
| **Amphipoda** | | | | | | | | | | | | | | | |
| Caprellidae | *Caprella equilibra* Say, 1818 | | | | | | | | | | | | | | |
| Gammaridae | | | | | | | | | | | | | | | |
| Corophioidea | | 25P | 31P | 6P | 12P 1C | 7P | 3C | | 53P 2C | 84P | 3C | | | | 52P 21C 1Q |
| Hyalidae | | | | | | | | | | | | | | | |
| Melitidae | | 2P | 5P | 2P | 1P | 5P | 2C 1Q | | 34P | 7P | | | | | 1P 1Q |
| Dexaminidae | *Paradexamine c.f. moorehousei* Sheard, 1938 | | 1P | | | | | | | | | | | | |
| Iphimediidae | *Iphimedia discreta* Stebbing, 1910 | | | | | | | | | 1P | | | | | |
| Leucothoidae | *Leucothoe commensalis* Haswell, 1880 | 2P | | | | 3P | | | 6P | | | | | | |
| | *Paraleucothoe novaehollandiae* (Haswell, 1880) | 1P | | | | 2P | | | 17P | 7P | | | | | |
| | *Leucothoella gracilis* (Haswell, 1880) | | | | | | | | 4P | 2P | | | | | |
| Liljeborgiidae | *Liljeborgia* sp. | | | | | 3P | | | | | | | | | |
| Phoxocephalidae | *Tickalerus birubi* Barnard & Drummond, 1978 | | | | | | | 1C | | | | | | | |
| | *Birubius batei?* ( Haswell, 1879) | | | | | | | | | | | | | | 4C |
| | *Uldanamia pillare* Barnard & Drummond, 1978 | | | | | | | 1C | | | | | | | |
| Podoceridae | *Podocerus* sp. (1 male, 1 female) | | | | | | | | 1P | | | | | | |
| Urohaustoriidae | *Urohaustorius merkanius* Barnard & Drummond, 1982 | | | | | | | | | | | | | | 1C |
| **Anomura** | | | | | | | | | | | | | | | |
| Diogenidae | *Dardanus crassimanus* | | | | | | | | | | | | | | |
| Galatheidae | *Galathea australiensis* | | 1P | | | | | | | | | | | | |
| Paguridae | Unidentifiable specimen | | | | | | | | | 1P | | | | | |
| Porcellanidae | *Ancylocheles gravelei* | | | | | | | | | | | | | | |
| **Brachyura** | | | | | | | | | | | | | | | |
| Goneplacidae | *Rhizopa gracilipes* | 1C | | | | | | | | | | | | | |
| Grapsidae | | 1P | | | | 1P | | | 4P | | | | | | 1P |
| Hymenosomatidae | | 1P | 1P | 3P | 9P | 3P | | | 12P | 19P | | 1Q | | 7P | 5P |
| Pinnotheridae | *Ostracotheres holothuriensis* | | | | | 1P | | | 3P | | | | | | |
| Majiidae | *Hyastenus diacanthus* | | | | 1P | | | | | | | | | | |
| | *Leptomithrax sternocostulatus* | | | | | | | | 1P | | | | | | |
| Pilumnidae | | 24P | 45P | 41P | 36P | 21P | | | 53P | 15P | | | | 5P | 9P |
| Portunidae | *Portunus pelagicus* | | | | | | | | | 2P 1T | | | | 2T | |
| | *Nectocarcinus integrifrons* | | | | | | | | | 1C | | | | | |
| Xanthidae | *Actaea peronii* | 1P | | | | 2P | | | | | | | | | |
| **Caridea** | | | | | | | | | | | | | | | |
| Alpheidae | Alpheid sp. | 5P 2C | 4P | 1C | 1C | 3P | | | 7P | 7P | | | | | 2P |
| | *Alpheus* sp. 1 | | 1P | | | | | | | 2P | | | | | |
| | *Alpheus* sp. 2 | 2C | | 1C | 1C | | | | | | | | | | 2P |
| | *Alpheus* sp. 3 | 5P | 2P | | | 3P | | | 1P | 6P | | | | | |
| | *Athanas dimorphus* | | 5P | | | | | | | | | | | | |
| | *Synalpheus tumidomanus* | | | | | | | | 6P | 2P | | | | | |
| Hippolytidae | *Hippolyte australiensis* | | | | | | | | | | | | | | |
| Palaemonidae | | | 3P | | 2P | | | | | | | | | | |
| **Isopoda** | | | | | | | | | | | | | | | |
| Anthuridea | *Paranthura c.f. grevillea* Poore, 1984 | | | | | | | | | | | | | | |
| | *Cruranthura peroni* (Poore, 1981) | | | | | | | | | | | | | | |
| Cirolanidae | *Natatolana* sp. | | | | | | | | | | | | | | |
| Sphaeromatidae | | | 2P | 4P | | | | | 5P | | | | | | |
| Janiridae | *Ianieropsis* sp. (*epilittoralis* group) | | | | | | | | | | | | | | |
| **Mysidacea** | | | | | | | | | | | | | | | |
| Mysidae | *Heteromysis waitei* Tattersall, 1927 | | | | | | | | | | | | | | |
| **Tanaidacea** | | | | | | | | | | | | | | | |
| Paratanaidae | | | | | | | | | | 4P | | | | | |
| Tanaidae | | | | | | | | | | | | | | | |
| **Thalassinidea** | | | | | | | | | | | | | | | |
| Callianassidae | *Biffarius arenosus* | 1C | | | 1C | | | | | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C**:** benthic core sample; Q: qualitative sample; T: crab trap sample

**TABLE 4.2.8.2: MALACOSTRACAN FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family, etc. | Species | Site 2R1 | 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Amphipoda** | | | | | | | | | | | | | | | | |
| Caprellidae | *Caprella equilibra* Say, 1818 | | | 2P | | | | 3P | 70P | | | | | 1P | | |
| Gammaridae | | | | | | | | | | | | | | | | |
| Corophioidea | | 7QF | | 1975P 80C | | 40Q | 4170P | 1500P | 2000P | | 3Q | | | 23P | 1C | 8P 11C |
| Hyalidae | | | | 2P | | 4Q | 1P | 50P | 15P | | | | | 9P | | |
| Melitidae | | | | 53P | | | | | | | 1Q | | | 2P | | 32P |
| Dexaminidae | *Paradexamine c.f. moorehousei* Sheard, 1938 | | | | | | | | | | | | | | | |
| Iphimediidae | *Iphimedia discreta* Stebbing, 1910 | | | | | | | | | | | | | | | |
| Leucothoidae | *Leucothoe commensalis* Haswell, 1880 | | | | | | | | | | | | | | | 4P |
| | *Paraleucothoe novaehollandiae* (Haswell, 1880) | | | | | | | | | | | | | | | 3P |
| | *Leucothoella gracilis* (Haswell, 1880) | | | | | | | | | | | | | | | |
| Liljeborgiidae | *Liljeborgia* sp. | | | | | | | | | | | | | | | |
| Phoxocephalidae | *Tickalerus birubi* Barnard & Drummond, 1978 | | | | | | | | | | | | | | | |
| | *Birubius batei?* ( Haswell, 1879) | | | | | | | | | | | | | | | |
| | *Uldanamia pillare* Barnard & Drummond, 1978 | | | | | | | | | | | | | | | |
| Podoceridae | *Podocerus* sp. (1 male, 1 female) | | | | | | | | | | | | | 1P | | |
| Urohaustoriidae | *Urohaustorius merkanius* Barnard & Drummond, 1982 | | | | | | | | | | | | | | | |
| **Anomura** | | | | | | | | | | | | | | | | |
| Diogenidae | *Dardanus crassimanus* | | | | | | | | | | | | | | | |
| Galatheidae | *Galathea australiensis* | | | | | | | | | | | | | | | |
| Paguridae | Unidentifiable specimen | | | | | | | | | | | | | | | |
| Porcellanidae | *Ancylocheles gravelei* | | | | | | | | | | | | | | | |
| **Brachyura** | | | | | | | | | | | | | | | | |
| Goneplacidae | *Rhizopa gracilipes* | | | | | | | | | | | | | | | |
| Grapsidae | | | | 3P | | | | 1P | | | 1Q | | | 2P | | 10P |
| Hymenosomatidae | | | | | | 1Q | | | 2P | | | | | 1P | | |
| Pinnotheridae | *Ostracotheres holothuriensis* | | | | | | | | | | | | | | | 1P |
| Majiidae | *Hyastenus diacanthus* | | | | | | | | | | | | | | | |
| | *Leptomithrax sternocostulatus* | | | | | | | | | | | | | | | |
| Pilumnidae | | | | 13P | | | 23P 4C | | 1P | | 2Q | | | 1P | | 5P |
| Portunidae | *Portunus pelagicus* | | 1T | | | 3T | | | | | | | | | 1T | |
| | *Nectocarcinus integrifrons* | | | | | | | | | | | | | | | |
| Xanthidae | *Actaea peronii* | | | | | | | | | | | | | | | |
| **Caridea** | | | | | | | | | | | | | | | | |
| Alpheidae | Alpheid sp. | | | | | | | | | | | | | | 7P | |
| | *Alpheus* sp. 1 | | | | | | | | | | | | | | | |
| | *Alpheus* sp. 2 | | | | | | | | | | | | | | 1P | |
| | *Alpheus* sp. 3 | | | | | | | | | | | | | | 6P | |
| | *Athanas dimorphus* | | | | | | | | | | | | | | | |
| | *Synalpheus tumidomanus* | | | | | | | | | | | | | | | |
| Hippolytidae | *Hippolyte australiensis* | | | | | | | | | | | 1P | | | | |
| Palaemonidae | | | | | | | | | | | | | | | | |
| **Isopoda** | | | | | | | | | | | | | | | | |
| Anthuridea | *Paranthura c.f. grevillea* Poore, 1984 | | | | | | | | 1P | | | | | | | |
| | *Cruranthura peroni* (Poore, 1981) | | | 9P | | | | | 1P | | | | | | | |
| Cirolanidae | *Natatolana* sp. | | | | | | | | | | | | | | 1C | |
| Sphaeromatidae | | 1QF | | 117P | 1Q | | 15P | 1P | | | | | | | 2P | |
| Janiridae | *Ianieropsis* sp. (*epilittoralis* group) | | | | | | | | | | | 2P | | | | |
| **Mysidacea** | | | | | | | | | | | | | | | | |
| Mysidae | *Heteromysis waitei* Tattersall, 1927 | | | | | 1Q | | | | | | | | | 1P | |
| **Tanaidacea** | | | | | | | | | | | | | | | | |
| Paratanaidae | | | | | | | | | | | | | | | | |
| Tanaidae | | | | | | 1Q | | | | | | | | | | |
| **Thalassinidea** | | | | | | | | | | | | | | | | |
| Callianassidae | *Biffarius arenosus* | | | | | | | | | | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample; T: crab trap sample

## *4.2.9. Molluscs*

The molluscs are invertebrates with bodies comprising a head and a muscular foot separated by a visceral mass containing the digestive, reproductive and excretory organs. This visceral mass is covered by a sheet of tissue called the mantle, with a space (the mantle cavity) between it and the visceral mass for the gills. In many groups a calcareous external shell, secreted by the mantle, protects the animal. However, in some forms this shell has been reduced or is internal or absent (Edgar 2000).

Despite having the same overall morphological pattern, various mollusc groups include species with different body forms, such as clams, snails, squids and chitons. John Pogonoski from the Australian Museum and NSW Fisheries, Sydney, identified the molluscs collected from Botany Bay at the Cronulla Fisheries Centre. These molluscs are listed in Table 4.2.9.

A total of 74 species were identified from Botany Bay, including 32 bivalve species, 38 gastropod species, 2 chiton species and 2 cephalopod species. This is only a small number of species, considering that at least 500 mollusc taxa have been recorded from Botany Bay between the years 1850 and 2000 (J. Pogonoski, pers. comm.). According to J. Pogonoski, "most of these species would be expected to occur in the outer parts of the bay, which have marine conditions essentially similar to the open coastline outside the bay. Habitat degradation in Botany Bay over the last two centuries has reduced the distributions and/or abundances of some of these species to the extent that some may not occur here today. Although this large number of species would not be expected to be found over such a short sampling period, more species would have been encountered if more soft sediment habitats had been sampled using techniques such as grabs and/or sieves."

A total of two species were recorded from outside their previously recorded ranges. Three specimens of the bivalve oyster *Dendostrea folium* (one live animal, two dead valves) were identified. This species was the first record for NSW, not having previously been recorded south of southern Queensland. The bivalve mussel *Modiolus victoriae* was also a first record for Botany Bay and the Sydney region. This species, of which three specimens were identified, had not previously been recorded north of Twofold Bay, NSW.

No known introduced species were present in the samples. However, most of the eight introduced species, which had been previously collected from the greater Sydney region, probably also occur in Botany Bay. These introduced mollusc species known from the Sydney region include six gastropods *(Polycera capensis, Polycera hedgpethi, Thecacera pennigera, Corambe* sp., *Zeacumantus subcarinatus* and *Maoricolpus roseus)* and two bivalves (*Theora lubrica* and *Crassostrea gigas)* (J. Pogonoski, pers. comm.).

**TABLE 4.2.9: MOLLUSCAN FAUNA COLLECTED FROM BOTANY BAY**

| Family, etc. | Species | Site BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gastropoda** | | | | | | | | | | | | | | | | |
| Anabathronidae | *Pisinna c.f. frauenfeldi* | | | | | | | | | | | | | | | |
| Aplysiidae | *Aplysia* sp. | | | | 1P | | | | | | | | | 1P | 1P | 1Q |
| Cerithiidae | *Cacozeliana c.f. granaria* | | | | | | | | | 1P | | | | | | |
| Chromodorididae | *Noumea* sp. | | | | | | | | | | | | | | | |
| Columbellidae | *Anachis atkinsoni* | | | | 1P | | | | | | | | | | | |
| | *Mitrella c.f. semiconvexa* | | | | | | | | | | | | | | | |
| | *Mitrella* sp. | | | | | | | | | | | | | | | |
| Dendrodorididae | *Dendrodoris* sp. | | 1P | | | | | | | | | | | | | |
| Dorididae | *Noedoris chrysoderma* | | | | | | | | 1P | | | | | | | |
| Facellinidae | *Austraeolis cacaotica* | | | | | | | | | | | | | | 1P | |
| Fissurellidae | *Amblychilepas nigrita* | | | | | | | | | | | | | | | |
| | *Montfortula rugosa* | | | | | | | | | | | | | | | |
| | *Tugali parmophoidea* | | | | 2P | | | | | 1P | | | | 1P | | |
| Lottiidae | *Patelloida* sp. | | | | | | | 1C | | | | | | | | 3Q |
| | *Scutellastra chapmani* | | | | | | | | | | | | | | | |
| Marginellidae | Unidentified | | | | | | 1C | | | | | | | | | |
| Muricidae | *Agnewia tritoniformis* | | | | | | | | | | | | | 3P | 1P | |
| | *Bedeva hanleyi* | | | | | | | | | 1P | | | | | 1P 1C | |
| | *Dicathais orbita* | | | | | | 1Q | | | | | | | | | |
| | *Morula marginalba* | | | | | | | | | | | | | 1P | | |
| Nacellidae | *Cellana tramoserica* | | | | | | 1 | | | | | | | | | |
| Nassaridae | *Nassarius particeps* | | | | | | 1C | | | | | | | | | |
| | *Nassarius* sp. | | | | | | | | 1P | | | | | | | |
| Philinidae | *Philine* sp. | | | | | | 1Q | | | | | | | | | |
| Plakobranchidae | *Elysia* sp. | | | | | | | | | | | | | | | |
| Pyramidellidae | *Turbonilla* sp. | | | | | | | | | | | | | | | 3Q |
| Ranellidae | *Cabestana spengleri* | | | 1P | 2P | 3P | | | | 1P | | | | | 1P | 1Q |
| | *Cymatium parthenopeum* | 2P | | | 5P | 1P | | | 5P | 1P 1T | | | | 19P | | |
| Siphonoriidae | *Siphonaria funiculata* | | | | | | | | | | | | | | | |
| | *Siphonaria* sp. | | | | | | 1 | | | | | | | | | |
| | *Calthalotia fragum* | | | | | | | | | | | | | | | |
| Trochidae | *Cantharidella picturata* | | | | | | | | | | | | | | | |
| | *Fossarina patula* | | | | | | | | | | | | | | | |
| | *Herpetopoma aspersa* | | 1P | 1P | 3P | 2P | | | 5P | 2P | | | | 5P | | |
| | *Phasianotrochus eximius* | | | | | | | | | | | | | | | |
| | *Stomatella impertusa* | | | | | | | | | | | | | | | |
| | *Astralium tentoriformis* | | | | | | | | | | | | | | | |
| Turbinidae | *Turbo torquatus* | | | | | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | | | | | | |
| Anomiidae | *Anomia trigonopsis* | | | | | 1P | | | | | | | | | 3P | |
| | *Monia zelandica* | | 1P | | 1P | | | | 1P | | | | | | | |
| Arcidae | *Barbatia pistachia* | | 3P | 1P | | | | | | | | | | | | |
| Cardiidae | *Fulvia tenuicostata* | | 1C | | | | | | | | | | | | | |
| | *Cardita excavata* | 1P | | | | | | | | | | | | | | |
| Galeommatidae | *Diplodonta tasmanica* | | | | | | | | | | | | | | 1C | |
| | *Kellia* sp. | 5P | 4P | 2P | 3P | 2P | | | 4P | 8P | | | | 4P | 7P | |
| | *Lasaea australis* | 7P 1C | 2P | 3P | | | 1Q | | 1P | 1P | | | | 1P | 1P | 1Q |
| | *Mysella vitrea* | | | | | | | | | | | | | 11C | 15C | |
| Hiatellidae | *Hiatella australis* | 94P | 68P | 133P | 86P | 48P | 2C | | 138P | 31P | | | | 71P | 40P | 2Q |
| Lucinidae | *Wallucina assimilis* | | | | | | | | | | | | | | | |
| Mactridae | *Mactra pusilla* | | | | | | | | | | | | | 1C | | |
| | *Spisula trigonella* | | 1C | | 1C | 1C | | | | | | | | | 8C | |
| Mesodesmatidae | *Paphies elongata* | | | | | | | | | | | | | | | |
| Mytilidae | *Modiolus victoriae* | | | 1P | 1P | 1P | | | | | | | | | | |
| | *Musculus alganus* | | | | | | | | | | | | | | 1P | |
| | *Musculus c.f. cumingianus* | | | | 4P | 2P | | | 4P | 1P | | | | 2P | 1P | |
| | *Musculus* sp. | | | | 1P | | | | | | | | | | | |
| | *Mytilus galloprovincialis* | 2P | 1P | 9P | 2P | 1P | | | 1P | 1P | | | | 1P | | |
| | *Trichomusculus barbatus* | 80P | 79P | 130P | 16P | 11P | | | 16P | 9P | | | | 12P | 14P 1Q | 8Q |
| | *Trichomya hirsuta* | 1P | 2P | | | 1P | | | 49P | 52P | | | | 17P | 36P | 72Q |
| | *Xenostrobus securis* | | | | | | | | | | | | | | | |
| Ostreidae | *Dendostrea folium* | 1P | | | | | | | 1C | | | | | | | |
| | *Ostrea angasi* | 35P | 22P | 10P | 34P | 8P | | | 2P | 24P | | | | 11P | 8P | |
| | *Saccostrea glomerata* | | 3P | | | | | | | | | | | 2P | 6Q | 1Q |
| | *Gari modesta* | | | | | | | | | | | | | 1C | | |
| Psammobiidae | *Electroma georgiana* | | | | | | | | | | | | | | | |
| Pteriidae | *Irus crenatus* | | 1P | | | | | | | 1P | | | | | | |
| Veneridae | *Gouldiopa australis* | | | | | | | | | | 2C | | | | | |
| | *Notocallista disrupta* | | | | | | | | 1C | | | | | | | |
| | *Tapes dorsatus* | | | | | | | | | | | | | | 1C | |
| | *Venerupis anomala* | | | | | | 1Q | | 1P | | | | | | | |
| **Polyplacophora** | | | | | | | | | | | | | | | | |
| Chitonidae | *Chiton pellisserpentis* | | | | | | | | | | | | | | 2Q | |
| Ischnochitonidae | *Ischnochiton australis* | | | | | | | | | | | | | | | |
| **Cephalopoda** | | | | | | | | | | | | | | | | |
| Octopodidae | Octopus sp. | | | | | | 1T | | | | | | | | | |
| Sepiadariidae | *Sepioloidea lineolata* | | | | | | | | | 1T | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C**:** benthic core sample; Q: qualitative sample; T: crab trap sample

**TABLE 4.2.9: MOLLUSCAN FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family, etc. | Species | Site 2R2 | CR1 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gastropoda** | | | | | | | | | | | | | | | |
| Anabathronidae | *Pisinna c.f. frauenfeldi* | | | 12Q | | | | | | | | | | | |
| Aplysiidae | *Aplysia* sp. | | | 1C | | | | | | | | | | | |
| Cerithiidae | *Cacozeliana c.f. granaria* | | | | | | | | | | | | | | |
| Chromodorididae | *Noumea* sp. | | | | | | | | | 1Q | | | | | |
| Columbellidae | *Anachis atkinsoni* | | | 1Q | | | | | | | | | | | |
| | *Mitrella cf semiconvexa* | | | | | | | | | 1Q | | | | | |
| | *Mitrella* sp. | | | | | | | | | 1Q | | | | | |
| Dendrodorididae | *Dendrodoris* sp. | | | | | | | | | | | | | | |
| Dorididae | *Noedoris chrysoderma* | | | | | | | | | | | | | | |
| Facellinidae | *Austraeolis cacaotica* | | | | | | | | | | | | | | |
| Fissurellidae | *Amblychilepas nigrita* | | | | | | | | | 1Q | | | | | |
| | *Montfortula rugosa* | | | | | | | | | | | | 1P | | |
| | *Tugali parmophoidea* | | | | | | | | | | | | | | 3P |
| Lottiidae | *Patelloida* sp. | | 2P | 2Q | | 2P | | | | | | | 8P | | |
| | *Scutellastra chapmani* | | | 1Q | | | | | | | | | | | |
| Marginellidae | Unidentified | | | | | | | | | | | | | | |
| Muricidae | *Agnewia tritoniformis* | | | | | | | | | | | 1Q | 1P | | |
| | *Bedeva hanleyi* | | | | | | | | | | | | | | |
| | *Dicathais orbita* | | | | | | | | | | | | | | |
| | *Morula marginalba* | | | | | | | | | | | | | | |
| Nacellidae | *Cellana tramoserica* | | | | | | | | | | | | | | |
| Nassaridae | *Nassarius particeps* | | | | | | | | | | | | | | |
| | *Nassarius* sp. | | 1P | | | | | | | | | | | | |
| Philinidae | *Philine* sp. | | | | | | | | | | | | | | |
| Plakobranchidae | *Elysia* sp. | | | | | | | | | | | | 1P | | |
| Pyramidellidae | *Turbonilla* sp. | | | 1Q | | | | | | | | | | | |
| Ranellidae | *Cabestana spengleri* | | | | | | 1P | | | | | | | | |
| | *Cymatium parthenopeum* | | | | | | | | | 2Q | | | | | |
| Siphonoriidae | *Siphonaria funiculata* | | | | | | | | | | | | 4P | | |
| | *Siphonaria* sp. | | | | | | | | | | | | 3P | | |
| | *Calthalotia fragum* | | | | | | | | | 1Q | | | | | |
| Trochidae | *Cantharidella picturata* | | | | | | | | | 1Q | | | | | |
| | *Fossarina patula* | | | | | | | | | | | | 1P | | |
| | *Herpetopoma aspersa* | | | | | | | | | | | | | | |
| | *Phasianotrochus eximius* | | | | | | | | | 1Q | | | | | |
| | *Stomatella impertusa* | | | | | | | | | 1Q | | | | | |
| | *Astralium tentoriformis* | | | | | | | | | | | 3Q | | | |
| Turbinidae | *Turbo torquatus* | | | | | | | | | 1Q | | | 1P | | |
| **Bivalvia** | | | | | | | | | | | | | | | |
| Anomiidae | *Anomia trigonopsis* | | | | | | | | | | | | | | |
| | *Monia zelandica* | | | | | | | | | | | 1Q | | | |
| Arcidae | *Barbatia pistachia* | | | | | | | | | | | | | | |
| Cardiidae | *Fulvia tenuicostata* | | | | | | | | | | | | | | |
| | *Cardita excavata* | | | | | | | | | 1Q | | | | | |
| Galeommatidae | *Diplodonta tasmanica* | | | | | | | | | | | | | | |
| | *Kellia* sp. | | | | | | 1P | | | | | | | | |
| | *Lasaea australis* | | 8P | | | 11P | | | | | | | 13P | | |
| | *Mysella vitrea* | | | 1Q | | | | | | | | | | | |
| Hiatellidae | *Hiatella australis* | 1Q | | 2Q | | | 4P | 2P | | 2Q | | 2Q | 2P | | 50P |
| Lucinidae | *Wallucina assimilis* | | 1C | | | | | | | | | | | | |
| Mactridae | *Mactra pusilla* | | | | | | | | | | | | | | |
| | *Spisula trigonella* | | 1C | 1Q | 2C | | 9C | 12C | | | | | | | |
| Mesodesmatidae | *Paphies elongata* | | | | | | | 1P | | | | | | | |
| Mytilidae | *Modiolus victoriae* | | | | | | | | | | | | | | |
| | *Musculus alganus* | | | | | | | | | | | | 1P | | |
| | *Musculus c.f. cumingianus* | | | | | | | | | | | | | | |
| | *Musculus* sp. | | | | | | | | | | | | | | |
| | *Mytilus galloprovincialis* | | 34P | | | 3P | 11P | 8P | | | | | | | |
| | *Trichomusculus barbatus* | | 1P | | | | | | | 4Q | | 2Q | | | 1P |
| | *Trichomya hirsuta* | 11Q | 34P 1C | | | 54P | | 3C | | 15Q | | 5Q | | | |
| | *Xenostrobus securis* | 1Q | 25P | | | | | | | | | | | | |
| Ostreidae | *Dendostrea folium* | | | | | | | | | | | | | | |
| | *Ostrea angasi* | | | | | 94P | | | | | | | | | 2P |
| | *Saccostrea glomerata* | | 23P | | | 1P | | | | | | | | | |
| | *Gari modesta* | | | | | | | | | | | | | | |
| Psammobiidae | *Electroma georgiana* | | | | | | | | | 1Q | | | | | |
| Pteriidae | *Irus crenatus* | | 3P | | | 1P | | | | | | | | | |
| Veneridae | *Gouldiopa australis* | | | | 1C | | | | | | | | | | |
| | *Notocallista disrupta* | | | | | | | | | | | | | | 1C |
| | *Tapes dorsatus* | | 3C | | | | | | | | | | | | |
| | *Venerupis anomala* | | | | | | | | | | | | | | |
| **Polyplacophora** | | | | | | | | | | | | | | | |
| Chitonidae | *Chiton pellisserpentis* | | | | | | | | | | | | | | |
| Ischnochitonidae | *Ischnochiton australis* | | | | | | | | | 1Q | | | | | |
| **Cephalopoda** | | | | | | | | | | | | | | | |
| Octopodidae | Octopus sp. | | | | | | | | | | | | | | |
| Sepiadariidae | *Sepioloidea lineolata* | | | | | | | | | | | | | | |

**Key:** 1, 2 etc. = numbers of specimens collected; P: pile scraping sample; C: benthic core sample; Q: qualitative sample; T: crab trap sample

### *4.2.10. Bryozoans*

The bryozoans, or moss animals, are a group of invertebrates, which, together with four other taxa, possess a food catching organ called a lophophore (Barnes 1987). In the bryozoans, the lophophore is a crown of tentacles which protrudes from a protective covering. Although each individual animal is minute, bryozoans are colonial animals and may form large aggregations up to a metre across. About 5000 species occur worldwide, with the southern and south-eastern coasts of Australia containing about 500 species (Edgar 2000). They are sessile animals, and mostly occur on hard substrates in marine environments. Only a few species have stalks, which allow them to live in the sand.

Dr R. Nair, taxonomic consultant of Wentworthville, New South Wales, identified the bryozoans collected from Botany Bay. Table 4.2.10 lists a total of 23 species identified from 15 families. In all, 12 of these species are introduced, with 2 species being cryptogenic in origin. A brief description of the introduced species is as follows:

Three species from the family Vesiculariidae identified from the Botany Bay samples have been introduced. These are *Amathia distans, Bowerbankia* sp. and *Zoobotryon verticillatum*.

***Amathia distans*** occurs throughout many parts of the world, including France, the Mediterranean Sea, Red Sea, Atlantic Coast of America, Java and Japan. It is uncertain as to when and where it was first recorded in Australia, and little is known of its ecology in southern Australia. It can be confused with native species of the same genus (Hewitt *et al.* 1999). This species was collected from Botany Bay in pile scraping samples from the Brotherson Dock (BD2 and BD5), Kurnell Pier (KP1 and KP2) and Dolls Point (DP2) sites. It was also found in qualitative samples from the Cooks River Bridge (CR1) and Airport Second Runway (2R1) sites.

***Bowerbankia*** species were first recorded in Australia in the 1970s, and were probably introduced through shipping (Hewitt *et al*. 1999). Specimens recorded from Victoria could be *B. imbricata* or *B. gracilis*, which are both important fouling organisms. In the Botany Bay samples, specimens of this genus were collected from pile scraping samples taken from the Brotherson Dock (BD4 and BD5), Kurnell Pier (KP1 and KP2), Cooks River Bridge (CR1) and Dolls Point (DP2) sites. Specimens were also found in qualitative samples from the Lady Robinsons Beach (LR2) site.

***Zoobotryon verticillatum*** is an erect species, growing in the form of translucent colonies with irregular branching. The colonies of this species may cover large areas. It is a fouling species that lives in warmer waters worldwide, and is now a major fouling organism in New South Wales, South Australia and Western Australia. It has not yet been recorded from Victoria (Hewitt *et al.* 1999). Specimens of this species were collected from pile scraping samples and large benthic core samples taken at the Kurnell Pier (KP1) site, and from pile scraping samples taken at the Cooks River Bridge (CR1) site.

***Conopeum seurati,*** from the family Membraniporidae, is an encrusting species, growing in the form of pale brownish white crusts. This species originated in Tunisia, and its distribution now ranges from the estuarine waters of Britain, the northern Mediterranean Sea, Caspian Sea, Sea of Azov, the east coast of Florida and New Zealand. It has also previously been recorded in South Australian waters (Gordon 1986; R. Nair, unpubl.). Specimens of this species were found in pile scraping samples from the Brotherson Dock (BD1 and BD2), Kurnell Pier (KP2), Airport Third Runway (3R1 and 3R2), Sutherland Point (SP1) and Bare Island (BI2) sites. This species was also found in large benthic core samples taken at the Revetment Wall (RVN) and Channel Marker 4 (CH4) sites, and also from a qualitative sample taken at the Airport Second Runway (2R1) site.

Introduced species from the family Bugulidae included *Bugula flabellata*, *Bugula neritina* and *Bugula stolonifera*.

***Bugula flabellata*** was introduced to New South Wales and South Australia from southern Britain (it occurs in the North Atlantic Ocean and the Mediterranean Sea) in the late 1940s. This species commonly occurs on rocky shores and on dark sublittoral rock surfaces in warm-temperate Australian waters (Furlani 1996; Hewitt *et al*. 1999). It is now widely distributed in New South Wales, Victoria, South Australia and Western Australia. It probably arrived attached to the hulls of ships; however, this is not certain. *Bugula flabellata* is rarely confused with native species, though it may often be confused with other exotic species. There is little information on the impact of this species on other Australian fauna (Hewitt *et al*. 1999). Specimens of this species were found in pile scraping samples from the Brotherson Dock (BD1 and BD5), Kurnell Pier (KP1 and KP2), Airport Third Runway (3R1), Dolls Point (DP2) and Channel Marker 4 (CH4) sites. It was also found in large benthic core samples from the Kurnell Pier (KP1) and Dolls Point (DP2) sites.

***Bugula neritina*** was first recorded from Victoria in the 1880s, and now occurs in many ports throughout southern Australia, including some in New South Wales, Victoria and South Australia. It is often present in isolated ports (e.g. Point Turton, Yorke Peninsula, South Australia) without occurring in nearby waters. This species was introduced to Australia from Europe, and has a wide distribution throughout the world, being only absent from cold polar and subarctic/subantarctic waters (Furlani 1996; Hewitt *et al*. 1999). The impact of this species on the native marine fauna in Australian waters is unknown (Furlani 1996). Specimens of *Bugula neritina* were found in pile scraping samples from the Brotherson Dock (BD2, BD4 and BD5), Bulk Liquids Berth (BLB), Kurnell Pier (KP1 and KP2), Airport Third Runway (3R1), Dolls Point (DP1) and Channel Marker 4 (CH4) sites. They were also found in qualitative samples taken at the Cooks River Bridge (CR1) and Lady Robinsons Beach (LR1) sites.

***Bugula stolonifera*** is native to western Europe, southern Britain, the Mediterranean Sea and the Adriatic Sea, and also occurs in New Zealand. It has been present in Australian waters since the 1880s, and because of this early date of introduction, it therefore probably arrived attached to ships' hulls (Hewitt *et al*. 1999). It is unlikely that this species has much impact on other animals in Australian waters. Specimens of *Bugula stolonifera* were found in pile scraping samples from the Brotherson Dock (BD1, BD4 and BD5), Kurnell Pier (KP2), Airport Third Runway (3R2), Cooks River Bridge (CR1), Georges River Bridge (GRB) and Dolls Point (DP1) sites. They were also found in large benthic core samples from the Cooks River Bridge (CR1) site.

***Cryptosula pallasiana,*** from the family Cryptosulidae, is an encrusting species with pinkish-orange or orange crusts. It originated in the Mediterranean Sea, and is a widespread fouling species, being found in ports, harbours and estuarine situations worldwide. In Australia, this species has been recorded previously from Tasmanian, Victorian and NSW waters (Gordon 1989; R. Nair, unpubl.). Specimens of *Cryptosula pallasiana* were collected from pile scraping samples taken at the Brotherson Dock (BD1, BD2 and BD4), Kurnell Pier (KP2), Airport Third Runway (3R2), Georges River Bridge (GRB) and Dolls Point (DP2) sites. They were also found in large benthic core samples taken at the Cooks River Bridge (CR1) site, and in qualitative samples from the Sutherland Point (SP1) site.

***Schizoporella unicornis**,* from the family Schizoporellidae*,* is a an encrusting form which lives in bays, harbours and on the open coast down to 60 m depth (Furlani 1996). It is native to Japan, and was introduced to Sydney in the 1940s. A subsequent introduction occurred after 1953 in both South Australian and Western Australian waters. Its introduction was probably via ship's hull fouling or oyster mariculture (Furlani 1996). It now occurs in Port Jackson (Sydney), in South Australia, and at Fremantle in Western Australia. A closely related form is the dominant fouling organism immediately below the waterline on the hulls of yachts and other small boats in Pittwater, just to the north of Sydney (D. Pollard, pers. obs.). The ecological impact of this species in Australian waters, however, is unknown. Specimens of *Schizoporella unicornis* were found in pile scrapings at the Brotherson Dock (BD2, BD4 and BD5), Bulk Liquids Berth (BLB), Kurnell Pier (KP1 and KP2), Airport Third Runway (3R2) and Channel Marker 4 (CH4) sites. They were also found in large benthic core samples taken at the Brotherson Dock (BD5) and Channel Marker 4 (CH4) sites, as well as from qualitative samples taken at the Lady Robinsons Beach (LR1) site.

***Tricellaria occidentalis,*** from the family Candidae, grows as "erect, bushy, buff coloured colonies". This species was originally described from Santa Barbara, California, and is found from British Columbia to southern California and Baja California, and also in China, Japan, Venice and New Zealand. Previous Australian reports are from South Australia, New South Wales and Victoria (R. Nair, unpubl.). Specimens of this species were found in pile scrapings at the Brotherson Dock (BD2 and BD5), Bulk Liquids Berth (BLB), Kurnell Pier (KP1 and KP2), Airport Third Runway (3R1), Dolls Point (DP1) and Channel Marker 4 (CH4) sites. They were also found in large benthic core samples taken at the Kurnell Pier (KP1 and KP2) and the Airport Third Runway (3R1) sites, and in qualitative samples from the Lady Robinsons Beach (LR2) site.

***Watersipora subtorquata,*** from the family Watersiporidae, was introduced to Queensland, New South Wales, South Australia and Western Australia in about 1889. It originated from Mexico, and now comprises a significant component of the hull fouling cover in these areas. The species is colonial and encrusting, and lives on jetties and wharf piles around the low water mark (Furlani 1996). The impact of this species in Australian waters is unknown. Specimens of *Watersipora subtorquata* were found in pile scraping samples at the Brotherson Dock (BD1, BD2, BD4 and BD5), Kurnell Pier (KP1 and KP2), Airport Third Runway (3R1 and 3R2), Georges River Bridge (GRB), Sutherland Point (SP1), Bare Island (BI2) and Channel Marker 4 (CH4) sites. They were also found in large benthic core samples taken at the Cooks River Bridge (CR1), Lady Robinsons Beach (LR1) and Channel Marker 4 (CH4) sites. In the qualitative samples, this species was collected from the Brotherson Dock (BD1), Airport Second Runway (2R1), Cooks River Bridge (CR2), Lady Robinsons Beach (LR1 and LR2), Bare Island (BI1) and Foreshore Road East (FRE) sites.

The two cryptogenic species identified were *Electra tenella*, from the family Electridae, and *Fenestrulina* sp., from the family Microporellidae.

***Electra tenella*** grows as greyish white calcareous crusts and is of unknown origin. This species grows typically along the Atlantic coast of Florida, and is also found in other parts of Florida, Puerto Rico, Brazil, Japan, India and Europe. It is not known if there are previous reports from Australia. Specimens of this species were collected from pile scraping and large benthic core samples taken at the Cooks River Bridge (CR1) site, and from large benthic core samples taken at the Georges River Bridge (GRB) site.

***Fenestrulina* sp.** is also cryptogenic in origin (R. Nair, unpubl.). Specimens of this species were found in quadrat scrapings from the Kurnell Pier (KP1 and KP2), Airport Third Runway (3R1 and 3R2) and Dolls Point (DP2) sites.

**TABLE 4.2.10: BRYOZOAN FAUNA COLLECTED FROM BOTANY BAY**

| Family | Species | Site BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 | 2R2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adeonidae | *Adeona grisea* | | | | | | | | | | | | | | | | |
| Arachnopusiidae | *Arachnopusia unicornis* | | | | | | 1C | | | | | | | | | | |
| Beaniidae | *Beania quadricornuta* | 15P | 7P | 9P | 8P | 18P | | 1C | 7P | 14P 2C | | | | 3P | | | |
| | *Beania* sp. | | | | 1P | | | | | | | | | | | | |
| Bugulidae | *Bugula dentata* | | | | | | | 1Q | | | | | | | | | |
| | *Bugula flabellata* * | | | | 1P | 1P | | | 12P 1C | 2P | | | | 2P | | | |
| | *Bugula nertina* * | | 3P | 1P | 2P | 4P | | | 9P | 14P | | | | 4P | | | |
| | *Bugula stolonifera* * | 1P | | 2P | 2P | 6P | | | | 1P | | | | | 1P | | |
| Candidae | *Tricellaria occidentalis** | | 4P | | 7P | 3P | | | 4P | 11P 1C | | | | 4P 1C | | | |
| Celleprorariidae | *Celleporaria fusca* | 13P 1C | 8P | 3P | | 12P 3C | 2C | | 4P | 9P 3C | | | | | | 1Q | |
| Cryptosulidae | *Cryptosula pallasiana* * | 1P | 2P | 1P | | | | | | 2P | | | | | 1P | | |
| Electridae | *Electra tenella* ** | | | | | | | | | | | | | | | | |
| Membraniporidae | *Biflustra savartii* | | | | | | | | | | | | | | | | |
| | *Conopeum seurati* * | 5P | 3P | | | | 1C | | | 2P | | | | 2P | 2P | 1Q | |
| Micropellidae | *Fenestrulina* sp. ** | | | | | | | | 3P | 4P | | | | 1P | 1P | | |
| Phidoloporidae | *Tryphyllozoon* sp. | | | | | | 2Q | | | | | | | | | | |
| Smittinidae | *Pleurocodonellina signata* | | | | | | | | | | | | | | | | |
| Schizoporellidae | *Schizoporella unicornis* * | | 1P | 1P | 8P 2C | 11P | | | 2P 1C | 1P 1C | | | | 2P | 2P | | |
| Vesiculariidae | *Amathia distans* * | | 4P | | 2P | | | | 2P | 1P | | | | | | 1QF | |
| | *Amathia* sp.* | | | | 2P | | | | | | | | | | | | |
| | *Bowerbankia* sp.* | | | 1P | 1P | | | | 2P | 2P | | | | | | | |
| | *Zoobotryon verticillatum* * | | | | | | | | 3P 1C | | | | | | | | |
| Watersiporidae | *Watersipora subtorquata* * | 1Q | 5P | 8P | 3P | 1P | | | 10P | 16P | | | | 3P | 3P | 1Q | |
| | Damaged specimen | | | | | | | 1C | | | | | | | | | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q: 1 qualitative sample; * introduced species; ** cryptogenic species

**TABLE 4.2.10: BRYOZOAN FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family | Species | Site CR1 | CR2 | LR1 | LR2 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 | Poor label |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adeonidae | *Adeona grisea* | | | | | | | | | | | | | | 1C | |
| Arachnopusiidae | *Arachnopusia unicornis* | | | | | | | | | | | | | | 1C | |
| Beaniidae | *Beania quadricornuta* | | | | 1Q | | | | | 1P | | | | | 6P | |
| | *Beania* sp. | | | | | | | | | | | | | | | |
| Bugulidae | *Bugula dentata* | | | | | | | | | | | | | | | |
| | *Bugula flabellata* * | | | | | | | 1P 1C | | | | | | | 1P | |
| | *Bugula nertina* * | 1Q | | 1Q | | | 3P | | | | | | | | 4P | 1 |
| | *Bugula stolonifera* * | 1P 1C | | | | 2P | 1P | | | | | | | | | |
| Candidae | *Tricellaria occidentalis** | | | | 1Q | | 3P | | | | | | | | 2P | 3 |
| Celleprorariidae | *Celleporaria fusca* | 1P 1C | | | | | 1C | | | 1Q | | 2Q | | | | 2 |
| Cryptosulidae | *Cryptosula pallasiana* * | 1C | | | | 2P | | 1P | | 1Q | | | | | | |
| Electridae | *Electra tenella* ** | 4P 1C | | | | 1C | | | | | | | | | | |
| Membraniporidae | *Biflustra savartii* | 1C | | | | 2P | 2P | 1P | | | | | | | | |
| | *Conopeum seurati* * | | | | | | | | | 1P | | | 1P | | 1C | 1P |
| Micropellidae | *Fenestrulina* sp. ** | | | | | | | 3P | | | | | | | | |
| Phidoloporidae | *Tryphyllozoon* sp. | | | | | | | | | | | | | | | |
| Smittinidae | *Pleurocodonellina signata* | | | | | 1C | | | | | | | | | | |
| Schizoporellidae | *Schizoporella unicornis* * | | | 1Q | | | | | | | | | | | 4P 3C | |
| Vesiculariidae | *Amathia distans* * | 1Q | 1Q | | | | | 2P | | | | | | | 3P | |
| | *Amathia sp.** | | | | | | | | | | | | | | | |
| | *Bowerbankia sp.* * | 1P | | | 1Q | | | 1P | | | | | | | | |
| | *Zoobotryon verticillatum* * | 1P | | | | | | | | | | | | | | |
| Watersiporidae | *Watersipora subtorquata* * | 1C | 1Q | 1C 3Q | 1Q | 2P | | | | 2P | | 1Q | 5P | 1Q | 5P 1C | 3 |
| | Damaged specimen | | | | | | | | | | | | | | | |

**Key**: 1P: 1 pile scraping sample; 1C: 1 benthic core sample; 1Q: 1 qualitative sample; * introduced species; ** cryptogenic species

## 4.2.11. *Echinoderms*

The echinoderms (Phylum Echinodermata) include the conspicuous and often brightly coloured sea stars and feather stars. Over 6000 species belong to this phylum, which is unique in its features. Originally, scientists thought the echinoderms were related to the anenomes and jellyfishes, because they possessed structures that radiate out from a central disc (hence the one name Radiata was initially created to cover both of these groups). However, it is now known that the echinoderms are more closely related to the vertebrates, as they possess an internal calcareous skeleton (Edgar 2000).

Echinoderms are divided into five classes, including the crinoids (feather stars), asteroids (sea stars), ophiuroids (brittle stars), echinoids (sea urchins) and holothurians (sea cucumbers) (Edgar 2000). The Botany Bay samples comprised seven species of ophiuroids, including *Ophiothrix spongicole, Ophiothrix* sp., *Ophiactis resiliens*, *Ophiactis* sp., and an additional three unidentified species. The five asteroid specimens collected were of the one species, *Coscinasterias muricata*. These echinoderms were identified by John Pogonoski from the Australian Museum, and none appeared to be exotic introductions.

### *4.2.12. Chordates*

Several groups of chordates belonging to the Subphylum Urochordata (or tunicates) do not have backbones, and all of these live in marine environments (Barnes 1987; Edgar 2000). These include three classes, the Ascidiacea, the Thaliacea and the Larvacea. The Ascidiacea are the most common and make up the majority of the species of attached tunicates (Barnes 1987). The Phylum Chordata also includes the vertebrates, or animals with backbones (i.e. the fishes, amphibians, birds, reptiles and mammals).

#### *4.2.12.1. Ascidians*

The ascidians, or sea squirts, are primitive sessile chordates in which the body is encased in a complex secreted outer covering, the tunic.

The ascidians collected from Botany Bay were sent to CRIMP in Hobart and identified by Kirrily Moore and Nicole Mays. A total of 27 species from 6 families were identified. Table 4.2.12.1 lists these ascidians, which were collected from various sites in Botany Bay.

The only introduced species found, ***Botrylloides leachi,*** is one of the most widespread introduced ascidian species, which originated from the north-eastern Atlantic Ocean and the Mediterranean Sea, and later spread from the Red Sea to the tropical Indo-West Pacific (Hewitt *et al*. 1999). It was first collected from Port Jackson, New South Wales, in the 1890s, and was subsequently recorded from Port Phillip Bay, Victoria, in 1901. It now also occurs in South Australian and Tasmanian waters.

This species is colonial, with colonies reaching over one metre across in South Australia, where it is also a dominant competitor of native ascidian species. *Botryloides leachi* is capable of overgrowing most other species, and overseas it has been noted to deter the settlement of other species and thus significantly influence the community structure of fouling assemblages (Hewitt *et al*. 1999).

This species was found to be present in samples from the Brotherson Dock (BD1, BD2, BD4 and BD5), Bulk Liquids Berth (BLB), Revetment Wall (RVS) and Kurnell Pier (KP1 and KP2) sites.

**TABLE 4.2.12.1 ASCIDIAN FAUNA COLLECTED FROM BOTANY BAY**

| Family | Species | Site BD1 | BD2 | BD4 | BD5 | BLB | RVN | RVS | KP1 | KP2 | QA1 | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ascidiidae | *Ascidia c.f. sydneiensis* | | 1 | | | | | | | | | | | | | |
| | *Ascidia* sp. | | 1 | | | | | | | | | | | | | |
| | *Phallusia* sp. | | | | | | | | | | | | | | | 2 |
| Didemnidae | *Diplosoma listerianum* | | | | | | | | PR | | | | | | | |
| | Didemnidae sp. | | | | | PR | | | PR | | | | | | | |
| Molgulidae | *Molgula ficus* | 39 | 21 | 5 | 51 | 37 | | | 26 | 5 | | | | 2 | 22 | |
| Polyclinidae | *Aplidiopsis* sp. | | | | | PR | | | | | | | | | | |
| | *Aplidium* sp. | | | | | | | | | | | | | | | |
| Pyuridae | *Halocynthia dumosa* | 39 | 16 | 3 | 25 | 8 | | | 1 | | | | | | 2 | |
| | *Herdmania monus* | 6 | | | | 3 | | 1 | 10 | | | | | | | |
| | *Microcosmos squamiger* | 539 | 289 | 106 | 475 | 222 | | | 26 | 41 | | | | 434 | 710 | |
| | *Pyura elongata* | 5 | 9 | 4 | 6 | | | | | 1 | | | | | | |
| | *Pyura fissa* | | 2 | | | | | | | | | | | | | |
| | *Pyura irregularis* | 24 | 22 | 13 | 21 | 2 | | | 1 | | | | | | 2 | |
| | *Pyura* sp.D | 1 | 6 | | | | | | | | | | | 2 | | |
| | *Pyura sacciformis* | | | 2 | | | | | | | | | | | | |
| | *Pyura stolonifera* | 28 | 20 | | 116 | 45 | | | 7 | 13 | | | | 18 | 34 | |
| Styelidae | *Botrylloides leachi* * | PR | PR | PR | PR | PR | | PR | PR | PR | | | | | | |
| | *Botrylloides magnicoecum* | | | PR | PR | PR | | | PR | PR | | | | | | |
| | *Botrylloides perspicuum* | | | | | | | | | | | | | | | |
| | *Cnemidocarpa areolata* | 5 | 4 | 4 | 9 | 1 | 1 | | 28 | 25 | | | | | 19 | |
| | *Cnemidocarpa* sp. | | 5 | | | | | | | | | | | | | |
| | *Cnemidocarpa tripartita* | | | | | | | | | 1 | | | | | | |
| | *Polycarpa* sp. | | | 4 | | | | | | | | | | | | |
| | *Styela canopus* | 1 | 2 | | 1 | | | | | | | | | | | |
| | No gonads | | | 1 | 2 | | | | 3 | 2 | | | | | | |
| Ascidiacea | Ascidiacea sp. | | | PR | | PR | | | PR | | | | | | | |
| | Damaged specimen | | | | | | | | 4 | 4 | | | | | | |

**Key**: 1, 2 etc.= numbers of specimens collected; PR: present; * introduced species

| Family | Species | 2R2 | CR1 | LR1 | GRB | DP1 | DP2 | TP1 | SP1 | LP1 | BI1 | BI2 | FRE | CH4 | No label |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ascidiidae | *Ascidia c.f. sydneiensis* | | | | | | | | | | | | | | |
| | *Ascidia* sp. | | | | | | | | | | | | | | |
| | *Phallusia* sp. | | | | | | | | | | | | | | |
| Didemnidae | *Diplosoma listerianum* | | | | | | | | | | | | | PR | |
| | Didemnidae sp. | | | | | | | | | | | | | PR | |
| Molgulidae | *Molgula ficus* | | | | | 1 | | | | | | | | 6 | 4 |
| Polyclinidae | *Aplidiopsis* sp. | | | | | | | | | | | | | PR | |
| | *Aplidium sp.* | | | | | | | | | | PR | | | | |
| Pyuridae | *Halocynthia dumosa* | | | | | | | | | | | | | | |
| | *Herdmania monus* | | | | | | | | | | | | | 14 | |
| | *Microcosmos squamiger* | | 2 | 9 | | 25 | | | | | | | | 27 | 44 |
| | *Pyura elongata* | | | | | | | | | | | | | | |
| | *Pyura fissa* | | | | | | | | | | | | | | |
| | *Pyura irregularis* | | | | | | | | | | | | | | |
| | *Pyura* sp.D | | | | | | | | | | | | | | |
| | *Pyura sacciformis* | | | | | | | | | | | | | | |
| | *Pyura stolonifera* | | | | | | | | | | | | | 5 | 13 |
| Styelidae | *Botrylloides leachi* * | | | | | | | | | | | | | | |
| | *Botrylloides magnicoecum* | | | | | | | | | | | | | PR | |
| | *Botrylloides perspicuum* | | | | | | | | | | | | | PR | |
| | *Cnemidocarpa areolata* | | | 1 | | 5 | | | | | | | | 6 | |
| | *Cnemidocarpa* sp. | | | | | | | | | | | | | | |
| | *Cnemidocarpa tripartita* | | | | | | | | | | | | | | |
| | *Polycarpa* sp. | | | | | | | | | | | | | | |
| | *Styela canopus* | | | | | | | | | | | | | | |
| | No gonads | | | | | | | | | | | | | | |
| Ascidiacea | Ascidiacea sp. | | PR | | | | | | PR | | PR | | | PR | |
| | Damaged specimen | | | | | | | | | | | | | | |

**Key**: 1, 2 etc. = numbers of specimens collected; PR: present; * introduced species

### *4.2.12.2. Fishes*

The ecological implications of introduced marine fishes in Australia are discussed in some detail in the review by Pollard and Hutchings (1990a). Dr D. Pollard and Mr B. Louden, from NSW Fisheries, identified the fishes collected from Botany Bay during the present survey. Amongst these fishes, no introduced species were found. However, previous work in Botany Bay has indicated the presence of three species of Japanese gobies, including ***Acanthogobius flavimanus, Tridentiger trigonocephalus*** and ***Acentrogobius pflaumi*** (M. Lockett, pers. comm.). A single specimen of the Japanese sea bass ***Lateolabrax japonicus*** was also found in the bay in 1983 (Pollard and Hutchings 1990a). Table 4.2.12.2 summarises those native fish species collected from Botany Bay during the present study. A full listing of the fishes previously found in Botany Bay by the senior author and his NSW Fisheries colleagues is given in State Pollution Control Commission (1981).

**TABLE 4.2.12.2: FISH FAUNA COLLECTED FROM BOTANY BAY**

| Family | Species | Common Name | Site BD1° | BD2° | BD4° | BD5° | BLB | RVN | RVS | KP1° | KP2° | QA1° | BP1 | KB2 | 3R1 | 3R2 | 2R1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clupeidae | *Hyperlophus vittatus* | Sandy sprat | | | | | | | | | | | | | | | |
| Muraenidae | *Gymnothorax prasinus* | Green moray eel | | | | | | | | | | | | | | | |
| Congridae | *Conger wilsoni* | Short-finned conger eel | | | | | 3T(3) | | | | | | | | | | |
| Plotosidae | *Cnidoglanis macrocephalus* | Estuary catfish | | | | | | | | | | | | | | | 1S(1) 1T(1) |
| Moridae | *Pseudophycis barbata* | Bearded cod | | | | | | | | | | | | | | | |
| Atherinidae | *Atherinomorus ogilbyi* | Ogilby's hardyhead | | | | | | | | | | | | | | | |
| Syngnathidae | Juvenile seahorse | Seahorse | | | | | | | | | | | | | | | |
| Scorpaenidae | *Centropogon australis* | Fortescue | | | | | 1T(1) | | | | | | | | 1T(1) | | 2T(2) |
| Triglidae | *Chelidonichthys kumu* | Red gurnard | | | | | | | | | | | | | | | |
| Platycephalidae | Juvenile flathead | Flathead | | | | | | | | | | | | | | | |
| | *Platycephalus arenarius* | Northern sand flathead | | | | | | | | | | | 1S (1) | | | | |
| | *Platycephalus fuscus* | Dusky flathead | | | | | | | | | | | | | | | |
| | *Platycephalus bassensis* | Sand flathead | | | | | | | | | | | | | | | |
| Ambassidae | *Ambassis jacksoniensis* | Glass perchlet | | | | | | | | | | | | | | | |
| Serranidae | *Acanthistius ocellatus* | Eastern wirrah | | | | | | | | | | | | | | | |
| Apogonidae | *Siphamia roseigaster* | Pink-bellied siphonfish | | | | | | | | | | | | | 1T(1) | | |
| Sillaginidae | *Sillago cilliata* | Sand whiting | | | | | | | | | | | | | | | |
| Sparidae | *Acanthopagrus australis* | Yellowfin bream | | | | | | | | | | | 1S(1) | | | | |
| | *Chrysophrys auratus* | Snapper | | | | | | | | | | | | | | | |
| | *Rhabosargus sarba* | Tarwhine | | | | | | | | | | | | | | | |
| Mullidae | *Upeneichthys lineatus* | Blue-striped goatfish | | | | | | 1T(1) | | | | | | | | | |
| Girellidae | *Girella tricuspidata* | Blackfish | | | | | | | | | | | | | | | |
| Scorpididae | *Atypichthys strigatus* | Australian mado | | | | | | | | | | | | | | | |
| Mugilidae | *Liza argentea* | Flat-tail mullet | | | | | | | | | | | | | | | |
| Clinidae | *Cristiceps argyropleura* | Silver-sided weedfish | | | | | | | | | | | | | | | |
| Gobiidae | *Favonigobius lateralis* | Long-finned goby | | | | | | | | | | | 2S(6) | | | | |
| | *Favonigobius exquisitus* | Exquisite sand goby | | | | | | | | | | | | | | | |
| | *Istigobius hoesei* | Sloth goby | | | | | | | | | | | | | | 1T(2) | |
| | Unidentified goby | Goby | | | | | | | | | | | | | | | |
| Pleuronectidae | *Ammotretis rostratus* | Long-snouted flounder | | | | | | | | | | | | | | | |
| Monacanthidae | *Brachaluteres jacksonianus* | Pygmy leatherjacket | | | | | | | | | | | | | | | |
| Tetraodontidae | *Torquigener squamicauda* | Scaly-tailed toadfish | | | | | | | | | | | | | | | |

**Key**: 1S: 1 seine net sample; 1T: 1 crab trap sample; (1): 1 fish caught; ° site not sampled for fish

**TABLE 4.2.12.2: FISH FAUNA COLLECTED FROM BOTANY BAY (continued)**

| Family | Species | Common Name | Site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2R2 | CRI° | LR1 | LR2 | GRB° | DP1° | DP2° | TP1 | SP1 | LP1 | BI1° | BI2° | FRE | CH4° |
| Clupeidae | *Hyperlophus vittatus* | Sandy sprat | | | 1S(1) | S(12) | | | | | | | | | | |
| Muraenidae | *Gymnothorax prasinus* | Green moray eel | | | | | | | | | | 2T(2) | | | | |
| Congridae | *Conger wilsoni* | Short-finned conger eel | | | | | | | | | 1T(1) | | | | | |
| Plotosidae | *Cnidoglanis macrocephalus* | Estuary catfish | | | | | | | | | | | | | | |
| Moridae | *Pseudophycis barbata* | Bearded cod | | | | | | | | | | 2T(2) | | | | |
| Atherinidae | *Atherinomorus ogilbyi* | Ogilby's hardyhead | | | | | | | | 2S(6) | | | | | | |
| Syngnathidae | Juvenile seahorse | Seahorse | | | 1S(1) | | | | | | | | | | | |
| Scorpaenidae | *Centropogon australis* | Fortescue | 2T(2) | | 1S(1) | 1T(1) | | | | | | | | | | |
| Triglidae | *Chelidonichthys kumu* | Red gurnard | | | 1S(1) | | | | | | | | | | 1S(1) | |
| Platycephalidae | Juvenile flathead | Flathead | | | | | | | | | | | | | 1S(1) | |
| | *Platycephalus arenarius* | Northern sand flathead | | | 1S(3) | | | | | 1S(1) | | | | | | |
| | *Platycephalus fuscus* | Dusky flathead | | | 1S(1) | | | | | | | | | | 1S(1) | |
| | *Platycephalus bassensis* | Sand flathead | | | 1S(5) | | | | | | | | | | | |
| Ambassidae | *Ambassis jacksoniensis* | Glass perchlet | | | | 1S(2) | | | | | | | | | | |
| Serranidae | *Acanthistius ocellatus* | Eastern wirrah | | | | | | | | | 1T(1) | | | | | |
| Apogonidae | *Siphamia roseigaster* | Pink-bellied siphonfish | | | | | | | | | | | | | 1T(1) | |
| Sillaginidae | *Sillago cilliata* | Sand whiting | | | | | | | | 1S(2) | | | | | 2S(34) | |
| Sparidae | *Acanthopagrus australis* | Yellowfin bream | | | 1S(1) | | | | | 1S(2) | | | | | | |
| | *Chrysophrys auratus* | Snapper | | | | 2S(2) | | | | | | | | | | |
| | *Rhabosargus sarba* | Tarwhine | | | | | | | | 1S(1) | | | | | | |
| Mullidae | *Upeneichthys lineatus* | Blue-striped goatfish | | | | | | | | | | | | | | |
| Girellidae | *Girella tricuspidata* | Blackfish | | | 1S(1) | | | | | | | | | | | |
| Scorpididae | *Atypichthys strigatus* | Australian mado | | | | | | | | | 2S(126) | 1T(1) | | | | |
| Mugilidae | *Liza argentea* | Flat-tail mullet | | | 2S(7) | | | | | | | | | | | |
| Clinidae | *Cristiceps argyropleura* | Silver-sided weedfish | | | | | | | | | 1S(2) | | | | | |
| Gobiidae | *Favonigobius lateralis* | Long-finned goby | | | 2S(6) | | | | | 1S(2) | | | | | 2S(61) | |
| | *Favonigobius exquisitus* | Exquisite sand goby | | | | | | | | | | | | | 1S(2) | |
| | *Istigobius hoesei* | Sloth goby | | | | | | | | | | | | | | |
| | Unidentified goby | Goby | 1T(1) | | | | | | | | | | | | | |
| Pleuronectidae | *Ammotretis rostratus* | Long-snouted flounder | | | 1S(1) | | | | | 1S(1) | | | | | | |
| Monacanthidae | *Brachaluteres jacksonianus* | Pygmy leatherjacket | | | | | | | | | 1S(1) | | | | | |
| Tetraodontidae | *Torquigener squamicauda* | Scaly-tailed toadfish | | | | 1S(1) | | | | 1S(2) | | | | | | |

**Key**: 1S: 1 seine net sample; 1T: 1 crab trap sample; (1): 1 fish caught; ° site not sampled for fish

## 4.3. Environmental data recorded during the port survey

The environmental data recorded in conjunction with the sampling operations is summarised in Table 4.3. Sampling was carried out during daylight hours (between 9.25 and 15.45) between 19 and 29 October 1998. Bottom depths at the sampling sites ranged from 1.5 (at BP1 and TP1) to 20.0 m (at BLB and CH4), with secchi depths ranging from 1.3 (at LR2) to 7.0 m (at RVS). Surface temperatures ranged from 18.0 (at LR2) to 22.8°C (at FRE), and bottom temperatures from 17.5 (at LR2) to 21.7°C (at FRE); surface salinities ranged from 32.1 (at BD4 and BD5) to 35.3‰ (at TP1), and bottom salinities from 33.7 (at CR1 and LR1) to 35.0‰ (at LP1).

**TABLE 4.3: ENVIRONMENTAL DATA COLLECTED FROM BOTANY BAY DURING THE PORT SURVEY**

| Sample Site | Sample Date | Sample Time | Bottom Depth (m) | Secchi Depth (m) | Bottom Temp. ($^o$C) | Bottom Temp. ($^o$C) | Surface Salinity (‰) | Bottom Salinity (‰) |
|---|---|---|---|---|---|---|---|---|
| BD1 | **19.10.98** | 11.45 | 16.5 | 5.0 | 20.0 | 19.5 | 32.6 | 34.6 |
| BD2 | 22.10.98 | 10.45 | 17.5 | 3.3 | 20.3 | 20.0 | 34.1 | 34.3 |
| BD4 | 20.10.98 | 14.10 | 15.0 | 4.1 | 20.5 | 19.7 | **32.1** | 34.5 |
| BD5 | 20.10.98 | 15.30 | 11.5 | 3.7 | 21.0 | 19.5 | **32.1** | 34.5 |
| BLB | **19.10.98** | 15.00 | **20.0** | 3.8 | 20.3 | 19.5 | 32.9 | 34.6 |
| RVN | 26.10.98 | 13.10 | 4.7 | 4.7 | 22.0 | 21.0 | 34.2 | 34.5 |
| RVS | 21.10.98 | 11.30 | 11.0 | **7.0** | 22.0 | 21.0 | 34.2 | 34.5 |
| KP1 | 21.10.98 | 12.00 | 12.5 | **7.0** | 20.0 | 19.7 | 34.7 | 34.6 |
| KP2 | 21.10.98 | 14.45 | 2.5 | 2.5 | 19.5 | 19.5 | 34.6 | 34.6 |
| QA1 | 22.10.98 | 12.50 | 14.0 | 4.5 | 20.8 | 20.5 | 34.5 | 34.7 |
| BP1 | **29.10.98** | 11.20 | **1.5** | 1.5 | 19.1 | 19.0 | 34.8 | 34.8 |
| KB2 | 21.10.98 | - | - | - | - | - | - | - |
| 3R1 | 22.10.98 | 15.20 | 2.0 | 2.0 | 20.5 | 20.5 | 33.9 | 33.9 |
| 3R2 | 22.10.98 | **15.45** | 2.5 | 2.5 | 20.8 | 20.8 | 34.3 | 34.3 |
| 2R1 | 23.10.98 | 12.30 | 2.8 | 2.8 | 20.8 | 20.5 | 34.3 | 34.5 |
| 2R2 | 23.10.98 | 14.55 | 4.0 | 1.7 | 21.5 | 20.5 | 33.3 | 34.1 |
| CR1 | 23.10.98 | 9.55 | 4.5 | 3.5 | 20.8 | 20.5 | 33.1 | **33.7** |
| LR1 | 23.10.98 | 14.40 | 2.5 | 2.5 | 21.3 | 21.0 | 33.7 | **33.7** |
| LR2 | **29.10.98** | **9.25** | 4.0 | **1.3** | **18.0** | **17.5** | 34.3 | 34.6 |
| GRB | 20.10.98 | 10.10 | 8.5 | 1.7 | 20.5 | 20.5 | 33.0 | 33.2 |
| DP1 | 23.10.98 | 10.55 | 5.3 | 2.0 | 20.8 | 20.5 | 33.5 | 34.0 |
| DP2 | 23.10.98 | 11.40 | 5.0 | 2.5 | 22.0 | 20.5 | 34.3 | 34.8 |
| TP1 | **29.10.98** | 12.10 | **1.5** | - | 19.5 | - | **35.3** | - |
| SP1 | 21.10.98 | 14.55 | 2.5 | 2.5 | 21.0 | 20.5 | 34.7 | 34.2 |
| LP1 | 21.10.98 | 10.20 | 2.0 | 2.0 | 22.0 | 21.5 | 34.5 | **35.0** |
| BI1 | 26.10.98 | 10.20 | 4.5 | 4.5 | 21.7 | 20.7 | 34.5 | 34.8 |
| BI2 | 26.10.98 | 9.50 | 3.0 | 3.0 | 21.5 | 21.0 | 34.6 | 34.8 |
| FRE | 26.10.98 | 13.55 | 3.6 | 3.6 | **22.8** | **21.7** | 34.1 | 34.2 |
| CH4 | 21.10.98 | 10.00 | **20.0** | 4.0 | 20.0 | 20.0 | 33.8 | 34.8 |

**Note**: Numbers in bold indicate highest and lowest figures for each column

## 4.4. Public awareness program

A reference group was convened in order to monitor the progress of the Botany Bay Introduced Marine Pests Survey. This reference group comprised a cross section of stakeholders within and around the survey area, with the aim of assisting Sydney Ports Corporation and NSW Fisheries to disseminate information, comment on various stages of the survey, and offer suggestions on relevant issues. The members of this reference group were from various local government agencies (i.e. Randwick City, Sutherland Shire and Botany City Councils), Caltex Refining Pty Ltd, Botany Bay Planning and Protection Council, Botany and Eastern Region Environment Protection Council, Department of Land and Water Conservation, Environment Protection Authority, Teekay Shipping (Australia) Pty Ltd, Australian Quarantine and Inspection Service, and Eastern Beaches & Botany Bay Catchment Committee. Mr Shane Hobday, of the Sydney Ports Corporation, convened the reference group, and the first meeting was held on 22 October 1998. Dr Philip Gibbs from NSW Fisheries and Dr Chad Hewitt from CRIMP spoke to the group at this meeting about previous surveys of introduced marine pests in Australian ports, and about the possible vectors, controls and management of these pests. A final meeting of this reference group and other interested stakeholders was held later in 2000 to outline and discuss the findings of this report and the overall results of the study.

# 5. POTENTIAL IMPACTS OF INTRODUCED SPECIES FOUND IN THE PORT

The analysis of specimens collected during the present survey has detected the presence of only one ABWMAC target introduced marine pest species (Appendix 1, Schedule 1), the toxic dinoflagellate *Alexandrium* sp. An additional 33 introduced and/or cryptogenic (i.e. status unknown) species, were also detected. These included two species of algae, two species of polychaetes, four species of hydrozoans, one anthozoan, ten species of crustaceans, thirteen species of bryozoans and one ascidian (see Table 5). Most (13 out of 18) of these introduced species newly recorded from Botany Bay are not included in, and can now be added to, the official list of exotic species known to be present in Australian waters (see Appendix 1, Schedule 3). During previous surveys four introduced fish species have also been collected from Botany Bay. No other ABWMAC pest species were detected within the port.

Several species of toxic dinoflagellates can form extensive blooms, which can in turn produce potent neurotoxins. These neurotoxins are concentrated by shellfish, and when these are eaten by humans they can cause Paralytic Shellfish Poisoning (PSP). Toxicity may develop in both wild and cultured shellfish. Marine animals may also be affected during blooms as a result of physical damage, oxygen depletion and the effects of the toxins, either directly or through the food chain (White 1980, 1982; Gosselin *et al.* 1989; Geraci *et al.* 1989; Jones 1991). Impacts are likely to be greatest on shellfish mariculture activities.

*Alexandrium catenella* is commonly recorded in coastal bays and estuaries from Port Phillip Bay, Victoria (Hallegraeff *et al*. 1991), and northwards along the Victorian and New South Wales coasts (Sonnemann and Hill 1996) to the Hunter River at Newcastle, New South Wales. This species has caused toxic PSP blooms in Sydney Harbour. There is no indication, however, that this dinoflagellate species causes, or has ever in the past caused, toxic blooms in Botany Bay.

The vast majority of the introduced and cryptogenic species detected in the Port of Botany Bay are not known to have any significant impacts on native animal and plant communities.

The most diverse and abundant groups of introduced fouling organisms found in Botany Bay were the bryozoans. The arborescent bryozoans *Bugula flabellata* and *Bugula neritina* are found in port regions throughout the world. In Australia, *Bugula flabellata* is also known from the Gulf Saint Vincent in South Australia and from Jervis Bay to Eden in New South Wales (Furlani 1996). *Bugula neritina* has been found in Spencer Gulf and the Gulf Saint Vincent, South Australia (Furlani 1996), and Port Kembla, New South Wales (Moran and Grant 1993). A species of *Schizoporella* (probably *Schizoporella errata)* is a dominant bryozoan hull fouling organism in Pittwater (Broken Bay, to the north of Sydney) (Afsar 2000). Several of the other species of bryozoans found in Botany Bay are widespread, both and in other Australian port environments and worldwide.

The barnacle *Megabalanus rosa* has been recorded from the north-western and central-western coasts of Western Australia and the southern coastline of eastern Australia (D. Jones, pers. comm.), and Kott (1985) reported that the ascidian *Botrylloides leachi* may be widespread throughout Australian waters.

**Table 5.** List of ABWMAC target marine pest species and other introduced and cryptogenic species collected from Botany Bay in October 1998.

| Phylogenetic Group | ABWMAC Target Pest Species | Introduced Species | Cryptogenic Species |
|---|---|---|---|
| Dinoflagellates | *Alexandrium* sp. | | |
| Macroalgae | | | *Caulerpa filiformis*<br>*Pterosiphonia bipinnata* |
| Hydrozoans | | | *Clytia hemisphaerica*<br>*Phialella quadrata*<br>*Antenella secundaria*<br>*Obelia dichotoma* |
| Anthozoans | | | *Culicia c.f. tenella* |
| Polychaetes | | *Boccardia chilensis**<br>*Capitella capitata** | |
| Crustaceans<br>Cirripedes | | <br>*Megabalanus rosa* | <br>*Megabalanus tintinnabulum*<br>*Megabalanus zebra* |
| Malacostracans | | *Corophium ascherusicum**<br>*Corophium acutum**<br>*Paracerceis sculpta* | *Palaemonella rotumana*<br>*Paracorophium excavatum*<br>*Caprella equilibra*<br>*Pseudosphaeroma campbellense* |
| Bryozoans | | *Amathia distans**<br>*Bowerbankia* sp.*<br>*Zoobotryon verticillatum**<br>*Conopeum seurati**<br>*Bugula flabellata*<br>*Bugula neritina**<br>*Bugula stolonifera**<br>*Cryptosula pallasiana*<br>*Schizoporella unicornis*<br>*Tricellaria occidentalis**<br>*Watersipora subtorquata** | *Electra tenella*<br>*Fenestrulina* sp. |
| Chordates<br>Ascidians | | <br>*Botrylloides leachi** | |

** Introduced species found in Botany Bay during the present study but not yet listed in Schedule 3 of Appendix 1.*

# 6. ORIGINS OF AND POSSIBLE VECTORS FOR THE INTRODUCTION OF EXOTIC SPECIES FOUND IN THE PORT

Exotic marine species found in Botany Bay are likely to have been introduced to the port by one of three mechanisms:

1. by natural range expansion of species introduced to other parts of the south-eastern coast of the Australian mainland;
2. directly to the port by shipping using the port, either in ballast water or by hull fouling; or
3. by domestic translocation via commercial fishing and recreational vessels.

Those species likely to have become established in Botany Bay as a result of natural range expansion may include some of the bryozoans and other species with a planktonic phase in their life history. For all species, however, additional domestic translocations may have occurred through human activities (e.g. fishing, marine farming, coastal shipping, etc.). The exotic or cryptogenic bryozoans, hydroids, barnacles and ascidians found have broad distributions throughout south-eastern Australia and are well known to establish on the hulls of vessels, as well as having a planktonic life history phase which could live in ballast water tanks. These species are likely to have been introduced through multiple invasion events.

Several species are also 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 such as dredges. Extensive hull fouling can develop on these slow-moving 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 survival of species encrusting their hulls, leading to the entry to and potential colonisation of the port by a diverse adult invertebrate community.

Because of the high frequency of ship visits to the port, several species are likely to have been introduced directly to Botany Bay via either international or domestic shipping. The toxic dinoflagellate *Alexandrium* sp. is likely to have been translocated either from within Australia by domestic transfer of ballast water from infected ports, or directly from overseas ports. The origin of this toxic dinoflagellate in the Port of Botany Bay thus remains problematic. The resting cysts of *Alexandrium* species may survive for 5-10 years in sediments but fossilisation of cysts is not known to occur. The origin of cysts therefore cannot be inferred from fossil records. *Alexandrium catenella* is known from other coastal estuaries and embayments in New South Wales (Hallegraeff *et al.* 1991) and may have been transported via coastwise ballast water movements. The distribution of *Alexandrium* sp. within the bay may also indicate multiple inoculations over time or from bloom forming events that may have occurred in the past.

Japanese shipping activities may pose the biggest threat of transporting such exotic pathogens into Australia because of the large number of ships visiting and the prevalence of these pathogens in Japanese ports. Introduced marine organisms are thought to arrive in Australia from Japan at a rate of twice that from all other countries combined (Anon. 1998c).

# 7. EFFECT OF THE PORT ENVIRONMENT AND PORT PRACTICES ON COLONISATION AND SURVIVAL OF INTRODUCED SPECIES

The resident fauna of the Port of Botany Bay is indicative of a relatively marine-dominated estuarine environment, partly enclosed and sheltered from the open coast, but with significant exposure to variations in wind and wave height. Of the introduced species detected in the port, the majority of species are not restricted to estuarine environments and some may be capable of extending their ranges beyond the Botany Bay locale.

Port enhancement activities such as maintenance dredging, berth development and revetment construction create disturbed and novel habitats, which may in turn lead to increased invasion success. Many introduced species appear to require some form of disturbance in order to enter an existing native community. These activities in the port may have influenced the establishment of some encrusting or fouling species in the past.

Hull cleaning activities, either in the water (brush-cart cleaning) or in dry dock, can have significant influences on the inoculation and establishment of introduced species. However, neither of these activities is allowed or now occurs in Botany Bay.

Maintenance dredging practices are unlikely to influence the distribution of most species in the port, with the exception of possibly redistributing the cysts of toxic dinoflagellate species.

# 8. 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 those characteristics which are most important will depend on the environmental tolerances of individual species. In the absence of this species-level information, however, some general observations can still be made on the risks of new introductions to the Port of Botany Bay.

The periodic presence of slow-moving, long-residence vessels, such as dredges, in a port may present an opportunity for significant fouling communities to establish themselves while these vessels reside in that port. Previous work in the North Pacific has demonstrated the ability for such vessels to transport complete assemblages over long distances (Carlton 1985). Long residence times may allow for reproductive populations of marine organisms to establish themselves.

# 9. ASSESSMENT OF THE RISK OF TRANSLOCATION OF INTRODUCED SPECIES FOUND IN THE PORT

An assessment of risks of translocation of introduced species from the Port of Botany Bay to other ports by shipping involves similar considerations to those discussed in assessing the risks of new introductions. Any vessels loading ballast water in Botany Bay are therefore likely to discharge this Botany Bay water in other Australian or overseas ports. The likelihood of the transport to and successful establishment of species in those new environments will be determined by their presence in the water column during ballast water uptake in Botany Bay, as well as their survival during the voyage and the environmental regime in the recipient port. This information is outlined in Hayes and Hewitt (1998) as a foundation of the risk assessment-based Decision Support System being developed by the Australian Quarantine and Inspection Service (AQIS).

A number of vessels are likely to move organisms around via hull fouling. These organisms are likely to include various encrusting bryozoans, hydroids, barnacles and ascidians. The majority of domestic traffic occurs within south-eastern Australia and is likely to be between ports with relatively similar environments (see Table 1.3). Consequently, the risk of translocation and establishment of introduced species through this vector is relatively high.

# 10. RECOMMENDATIONS

## 10.1. Management of existing introduced species in the port

Most of the introduced species detected during this survey of Botany Bay appear to be well established in the port. For these species, their eradication from the port by physical removal ceases to be a realistic option. Many of these species are now widespread in south-eastern Australian waters and controls aimed at limiting their spread are likely to be ineffective.

The following recommendations are therefore made in relation to the results of this study:

- That an on-going (possibly bi-annual, in December and March) phytoplankton (net sample) monitoring program in the port would be desirable to establish the presence and seasonality of any toxic dinoflagellate species which may be released by ballast water discharge or periodically bloom from cysts already established in the port sediments. (As an *Alexandrium* species of the '*catenella* type' is already established in the port, the formation of blooms either directly from extant cysts or from future ballast water discharge of this species could contribute directly to fish kill events and also impact negatively on local shellfish culture and consumption.)

- That the extent to which these cysts may be transferred to other areas of the port, or to other ports via ballast water uptake, could be ascertained by sampling of sediments and water prior to and during any future dredging activities and dredge spoil discharge.

- That a longer-term dinocore monitoring program should be initiated for encysted dinoflagellates, with qualitative evaluations of the main berth areas on an annual basis.

- Based upon the frequency of ship visits and ballast water discharges, that a more targeted survey of introduced species in the port, including dinoflagellate coring, should be undertaken in three years time, particularly targeting areas of active ballast water discharge (bulk cargo berths and anchorage points) and any dredge spoil disposal sites.

## 10.2. Prevention of new introductions to the port

There is currently no available information on which to base an estimate of the risks of further introductions to the port via hull fouling. It is therefore recommended that the port management initiate a program of periodic inspection of the hulls of a range of international and domestic vessels that regularly use the port to provide information on the levels and composition of such fouling.

In relation to future shipping activities in the port, current activity by AQIS should result in additional database development concerning 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 accurate naming and identification of last and next ports of call.

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# APPENDICES

## APPENDIX 1. SCHEDULE OF INTRODUCED SPECIES

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

*Gymnodinium* & *Alexandrium* spp. (toxic dinoflagellates)
*Undaria pinnatifida* (Japanese seaweed)
*Sabella spallanzanii* (European fan worm)
*Carcinus maenas* (European shore crab)
*Maoricolpus roseus* (New Zealand screw shell)
*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 |
| *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) | N.W. Pacific | Vic, NSW |
| *Acentrogobius pflaumi* (goby) | Japan | Vic, NSW |
| *Tridentiger trigonocephalus* (goby) | N.W. Pacific | WA, Vic, NSW |
| *Forsterygion 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 | Tas, Vic |
| *Zosterocarpus* spp. (brown alga) | Mediterranean | SA |

# APPENDIX 2. DETAILS OF PORT FACILITIES[1]

## 2.1. Brotherson Dock

Berths 1, 1A, 2, 2A and 3 on the northern side and 4, 5, 5A and 6 on the southern side of Brotherson Dock were constructed in the late 1970s. These berths, which are used as container terminals, consist of reinforced concrete (counterfort) units that form a vertical wall. The total wharf lengths are 1006 m (northern side) and 936 m (southern side), with depths ranging between 12.6 m and 14.8 m. Container vessels have little need for ballast water exchange because containers are generally exchanged on a one for one basis and internal transfers within heeling tanks are used to make any trim corrections.

The cable berth at the eastern end of Brotherson Dock consists of three dolphins, which have reinforced concrete caps on steel piles. This berth is used for the export of submarine optical fibre cable. Cable laying vessels, due to their operations generally being offshore, discharge open oceanic water when loading cable.

## 2.2. Bulk Liquids Berth

The Bulk Liquids Berth is located near the entrance to Brotherson Dock and was constructed in the late 1970s, having a nominal depth of 18.3 m. This berth consists of a reinforced concrete deck on steel piles, forming an approach roadway, pipe support structure and “T” head mooring and berthing dolphins. A wide variety of mainly imported liquid chemical, LP gas and refined petroleum cargoes are handled. As this berth is primarily an import facility, ballast water is taken up rather than discharged there.

## 2.3. Caltex Marine Facilities

### *Kurnell Pier (Kurnell No. 1 and No. 2 Berths)*

The Kurnell Pier was constructed in the mid 1950s and consists of a one kilometre long finger jetty constructed of a reinforced concrete deck on steel piles, with two berths, Kurnell No. 1 and No. 2. The depths at Kurnell No. 1 and No. 2 are 10.3 m and 10.6 m, respectively. This facility is used for both the import and export of petroleum products. Exports from this facility which lead to the need to discharge ballast water are predominantly via vessels that have taken up ballast in the Australian ports of Brisbane, Hastings (Victoria) and Melbourne.

### *Multi-Buoy Mooring (Kurnell No. 3 Berth)*

This berth, towards the southern side of Botany Bay offshore from the Kurnell Pier, is located in a dredged basin of length 300 m, depth at least 13.1 m and breadth 120 m, and consists of five buoys for attachment to the aft end of the berthing vessel. The forward end of the vessel is moored by one swamp mooring on each side and the vessel is anchored. Crude oil is unloaded via hoses and a pipeline on the bed of the bay. As an import berth for crude oil for the Caltex Refinery at Kurnell, ballast water is taken up rather than being discharged at this locality.

[1] Information provided by Shane Hobday, Sydney Ports Corporation.

# APPENDIX 3. SAMPLING PROCEDURES

## 3.1. ABWMAC Target Species

### *3.1.1. Dinoflagellates*

#### *3.1.1.1. Sediment sampling for cyst-forming species*

Sediment cores are taken from locations within the estuary 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 triplicate sediment cores are taken by divers using 20 cm long tubes with a 2.5 cm internal diameter. Tubes are forced into the sediment and then capped at each end with a bung to provide an air-tight seal. Following sampling, cores are stored upright in the dark at 4°C prior to size fractionation, examination for dinoflagellate cysts, and subsequent cyst germination.

Sediment cores collected during the present study and sent for examination arrived in poor condition, and consequently only limited analysis was possible.

#### *3.1.1.2. Sediment preparation and cyst identification*

The top 6 cm of the 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 2-3 min (Bransonic sonicator) to dislodge detritus particles. The sample is then screened through a 100 µm sieve and collected onto a 20 µm sieve. 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 is counted in each sample. Identification of species follows Bolch and Hallegraeff (1990) and Sonnemann and Hill (1997). Cysts of suspected toxic species are photographed with a Zeiss Axioplan light microscope using bright field or phase contrast illumination.

All cysts examined from the Botany Bay sediment samples were in poor condition. Features of the *Alexandrium* cysts observed were not consistent with those found in healthy, viable cysts. No successful germinations were recorded in preliminary germination experiments undertaken on size fractionated material.

#### *3.1.1.3. Cyst germination*

Following sonication and size-fractionation of sediments, subsamples of the 20-100 µm fraction are added to 20 ml of growth medium in sterile polystyrene containers. All incubations are carried out at 20.0°C at a light intensity of 80 µE $m^{-2}$ $s^{-1}$ (12 h light: 12 h dark) and examined regularly for germination. Actively swimming dinoflagellate cells from incubations are isolated by micro pipette, washed in sterile growth medium and their identity determined where possible.

#### *3.1.1.4. Phytoplankton sampling and culture*

Phytoplankton samples are collected by vertical tows of a hand-deployed plankton net (25 cm diam. opening, 20 µm Nytal mesh, Swiss Screens, Melbourne, Vic.). The samples are sealed in plankton jars, placed in a cool container, and returned to the laboratory within 48 hours for light and fluorescent microscopic examination. In the laboratory, net samples are diluted 1:1 with growth medium. Germanium dioxide (10 mg· $l^{-1}$) is added to inhibit overgrowth by diatom species and these enrichment cultures incubated. Incubations are examined regularly by light microscopy, and single cells of suspected toxic species isolated by micro pipette for further culture and toxicity determination.

### *3.1.2. Carcinus maenas*

#### *3.1.2.1. Trapping*

The European shore crab *(Carcinus maenas)* and other crab (and some fish) species are 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 and deployed with surface buoys. Whenever possible, traps are deployed in the late afternoon and recovered early the next morning.

#### *3.1.2.2. 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 structures between the surface and the bottom, to provide a complete visual survey of the outer wharf. Surveys of beach wrack are made on beaches to collect crab exuviae (shedded shells).

### *3.1.3. Asterias amurensis, Sabella spallanzanii and Undaria pinnatifida*

#### *3.1.3.1. Visual searches*

Visual searches for the northern Pacific seastar *(Asterias amurensis),* the Japanese kelp *(Undaria pinnatifida)* and the European fan worm *(Sabella spallanzanii)* are carried out by divers in rocky reef and wharf areas, and over soft bottoms. Divers are free swimming. Diver searches in wharf areas and surveys for *Undaria* in beach wrack follow procedures described for *Carcinus* above.

## 3.2. Non Target Species

### *3.2.1. Hard substrate invertebrates*

#### *3.2.1.1. Wharf pile communities*

Piles or projecting steel facings are selected from wharves having different types of shipping activity. Three piles or facings are selected in series from near one end of each wharf, starting about 5 m from the end to reduce “edge” effects, with about 10 m distance separating each pile or facing. Three piles or facings are sampled from all wharves selected for study. The selected piles or facings are marked and their positions recorded and photographed. For each pile divers then take:

(i) video film of the outer surface of the pile/facing from approximately high-water level down to the deepest exposed part of the pile/facing using a Hi-8 video camera recorder (Sony CCD-TR3000E) in an underwater housing (Sony MPK-TRB Handycam Marine Pack). The housing is fitted with twin 20 W (Sony HVL-M20) underwater lights and a distance-measuring rod with a scale and a digital depth meter. The rod ensures that the camera is a constant distance (approx. 50 cm) from the pile or sea floor. The scale and depth meters are positioned so that they fall within the field of view of the camera and provide real-time depth information on the video recording;

(ii) 35 mm still photographs using a Nikonos V underwater camera with a 35 mm lens and a 1:6 overlens and single SB-102 flash to provide higher-resolution records of the fouling communities and selected species; and

(iii) representative quantitative ($0.1m^2$ quadrat) samples of the fouling communities present at three depths (0.5, 3.0 and 7.0 m) by scraping attached animals and algae as carefully as possible into plastic bags. These samples are first rough-sorted and then preserved in 5% buffered formalin or ethanol for subsequent sorting and identification in the laboratory.

*3.2.1.2. Breakwater communities*

Using equipment detailed in section 3.2.1.1 above, divers take video and still photographs, and collect representative samples of the attached plant and invertebrate communities on breakwater wall substrates.

### *3.2.2. Soft substrate invertebrates*

*3.2.2.1. Epibenthos*

Visual searches by divers to locate and collect non-target, soft-bottom, epibenthic species are carried out at selected sites as described for target species in sections 3.1.2 and 3.1.3 above. At each wharf sampled, if underwater visibility allows, divers video film a 50 m transect between one of the piles and the outer series of infaunal benthic cores (see section 3.2.2.2 below), along a weighted transect line marked at 1 m intervals.

*3.2.2.2. Benthic infauna*

Divers take infaunal samples using a tubular 0.025 $m^2$ (17.9 cm internal diameter) hand-held corer. The 40 cm deep corer has a pair of handles close to the upper end and is marked externally with grooves at 20 cm and 25 cm from the bottom to indicate the depth to which the core is taken. The upper end of the corer is closed except for a mesh-covered 8 mm diameter hole, which can be sealed with a rubber bung to aid retention of the infaunal sample when the corer is withdrawn from the sediment.

When sampling around wharves, a core is taken within 1 m of the bottom of each outer pile and facing sampled, and a second set of three cores 50 m directly out from the wharf. For each wharf area sampled this provides three samples close to the wharf ("inner" cores) and three 50 m from the wharf ("outer" cores). When sampling around channel markers or single pylons, three replicate cores are taken 1 m from the base of the pile. Each sample is transferred to a 1 mm mesh bag with drawstring mouth and then sieved underwater, either *in situ* or after the diver has returned to the surface. The retained material is then washed into a plastic bag and preserved in 5% buffered formalin for subsequent sorting and identification in the laboratory.

### *3.2.3. Fish*

#### *3.2.3.1. Netting surveys*

Seine nets are used to collect fish (and some mobile invertebrates) from sandy beaches. Seine netting is carried out using a 20 m seine with 10 mm mesh. All species taken with the seine nets are recorded.

## 3.3. Environmental Data

### *3.3.1. Temperature and salinity*

A temperature/salinity meter is used to record data on water temperature and salinity, usually at 1 m intervals from the surface to near the bottom. Water visibility (turbidity) is measured using a Secchi disk.

# APPENDIX 4. SHIPPING INFORMATION PROFORMA

## 4.1. Visiting vessels

1 Origin of vessel entering the port
- 1.1 international
  - 1.1.1 last international port
  - 1.1.2 last port of call (if any) within Australia
- 1.2 domestic
  - 1.2.1 last port of call
  - 1.2.2 other ports visited

2 Frequency of visits
- 2.1 regular service
  - 2.1.1 frequency
  - 2.1.2 duration of service
- 2.2 occasional visits
  - 2.2.1 frequency
  - 2.2.2 over what period

3 Ballasting
- 3.1 vessel in ballast during voyage to port
- 3.2 port where ballast loaded
- 3.3 ballast water exchanged at sea
- 3.4 reballasting in or near port
  - 3.4.1 ballast water discharged; estimated volume discharged
    - at berth
    - within port (not at berth)
    - outside port
  - 3.4.2 ballast water loaded; estimated volume loaded
    - at berth
    - within port
    - outside port
    - no reballasting in or near port

4 Hull condition
- 4.1 level and type of fouling
- 4.2 date when last slipped and cleaned
- 4.3 port where last slipped and cleaned

5 Location (berth) in port

6 Turn around time
- 6.1 average turn-around time
- 6.2 maximum time in port

### 4.2. Vessels in port for extended periods (dredges, barges, etc.)

1 Type/name of vessel

2 Previous location
- 2.1 name of port
- 2.2 duration of stay in that port

3 Duration of stay in port

4 Location (berth or area of operation) in port

5 Destination (if departed)

6 Hull condition
- 6.1 on arrival
  - 6.1.1 level and type of fouling
  - 6.1.2 date when last slipped and cleaned
  - 6.1.3 not cleaned
- 6.2 at departure
  - 6.2.1 level and type of fouling
  - 6.2.2 date when last slipped and cleaned
  - 6.2.3 not cleaned

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