Port Survey for Introduced Marine Species – Sydney Harbour
Final Report

Australian Museum Business Services

for

Sydney Ports Corporation

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Australian Museum divers working at Gore Cove.

Summary

The Sydney Ports Corporation, with support from the NSW Department of Transport and the Royal Australian Navy, commissioned Australian Museum Business Services to collect baseline data on the occurrence of exotic marine species in the port of Sydney Harbour. The Ballast Water Decision Support System (BWDSS) to be introduced in July 2001 by the Australian Quarantine Inspection Service (AQIS) requires knowledge of introduced species living in the port. The survey of introduced species was carried out according to the protocol as established by Australian Association of Ports and Marine Authorities (AAPMA) and the CSIRO Centre for Research on Introduced Marine Pests (Hewitt and Martin, 1996).

The protocol of Hewitt and Martin (1996) adopts a targeted approach with introduced species ranked in three categories.

Schedule 1 - ABWMAC (Australian Ballast Water Management Advisory Council) target introduced pests.

Schedule 2 – marine pest species that pose a threat to Australia.

Schedule 3 – known or likely exotic marine species in Australian waters

Sampling was conducted at 57 sites in Sydney Harbour from 30 March to 6 June 2001. A total of 184 dives were performed for visual surveys, epifaunal scrapings, fish poison stations and dinoflagellate sampling. Grab samples, beam trawl and environmental data were conducted over four boat days. A trapping program and shore sampling were also carried out.

The aim of this report is to document species from Schedules 1,2 or 3 which are living in Sydney Harbour.

The only species on Schedule 1 that were found in the survey were dinoflagellate cysts. The majority of the cysts were dead. The cysts could not be germinated, therefore, it was not possible to determine whether they were from the species *Alexandrium catenella* or *Alexandrium tamarense*. *Gymnodinium* spp. cysts could not also be germinated, and as a result it could not be determined if the cysts were of the introduced species *Gymnodinium catenatum*. The non-viability of the dinoflagellate cysts implies that the introduction of *Alexandrium catenella/tamarense* was not recent and these cysts will not cause toxic algal blooms.

The only species from Schedule 2 that was found was the blue mussel *Mytilus galloprovincialis*. This species is well established in southern Australia and its introduction may predate European arrival. It is abundant in Sydney Harbour on wharf piles, rocks, and cement facings of wharves, but it is not known whether it has displaced endemic species in establishing its dominance of hard sublittoral surfaces.

Seventeen species of plants and animals from Schedule 3 were found in the survey. In addition, another ten species listed on Schedule 3 are recorded from Sydney Harbour in the Australian Museum Faunal Database but were not found in this survey. The impact of these species has not been studied but all appear to be well established species in Sydney Harbour and have been living there for many years. Most are widespread and it is unclear whether they have displaced endemic species.

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1 Introduction and Aims

Introduced marine pest species are now recognised as a major problem in ports and coastal waters around the world. Shipping is an important vector for marine introductions, and shipping and quarantine authorities are trying to reduce the risk of further introductions.

The first step in controlling the spread of introduced marine pest species in Australian waters is knowledge of the current distribution and abundance of exotic species in Australian ports. Recognition of the need for baseline studies has led the Australian Association of Ports and Marine Authorities (AAPMA) and the CSIRO Centre for Research on Introduced Marine Pests (CRIMP) to initiate a program to survey Australian ports for introduced species.

The Sydney Ports Corporation, with support from the NSW Department of Transport and the Royal Australian Navy, commissioned Australian Museum Business Services to collect baseline data with the aim of documenting the occurrence of exotic species in the port of Sydney Harbour. The Ballast Water Decision Support System (BWDSS), introduced in July 2001, requires baseline knowledge of introduced species living in the port.

The aim of this study is to collect baseline data on the occurrence of exotic species in the port of Sydney Harbour utilising the protocol established by AAPMA and CRIMP (Hewitt and Martin, 1996). This adopts a targeted approach with introduced species ranked in three categories (Appendix 1).

Schedule 1 - ABWMAC (Australian Ballast Water Management Advisory Council) target introduced pests.

Schedule 2 – marine pest species that pose a threat to Australia.

Schedule 3 – known or likely exotic marine species in Australian waters

It was agreed that the first priority of the study was to determine if species in Schedules 1 & 2 are established in Sydney Harbour. This was the aim of the Interim Report which was completed before the introduction of the BWDSS in July 2001. The findings of the Interim Report are incorporated in the Final Report.

Since commencing the contract an updated protocol (Hewitt and Martin, 2001) was published. However, it was agreed by Sydney Ports Corporation that this survey follow the protocol of Hewitt and Martin (1996).

2 Review of Existing Biological Information

2.1 Fauna and flora of Sydney Harbour

The marine fauna of Sydney Harbour has been studied by scientists since the 19th century (eg. Haswell, 1879a; Haswell, 1881; Haswell, 1884; Haswell, 1885; Haswell, 1886; Herdman, 1899; McCulloch, 1913) and Thomas Whitelegge compiled a checklist of the invertebrate fauna in 1889 (Whitelegge, 1889). Whitelegge's checklist includes many species of Ascidiacea, Bryozoa, Coelenterata, Crustacea, Echinodermata, Hydrozoa, Mollusca, Polychaeta and Porifera. Two species from Schedule 3 were recorded in Whitelegge (1889), the polychaete worm *Hydroides elegans* and the bryozoan *Bugula neritina*. These species have, therefore, been established in the harbour at least since 1889. This is the last comprehensive study of the fauna of Sydney Harbour to be published. W.A. Herdman (1899) recorded 70 species of ascidians from Sydney Harbour, 63 of which were new species. A.R. McCulloch made regular use of local fishing trawlers to collect fish and crustaceans from the harbour between 1905 and 1921. F.A. McNeill made large crustacean collections from the harbour from 1922-1930. There has been no comprehensive study of fish from Sydney Harbour.

There have been no comprehensive fauna or flora surveys or scientific work done in Sydney Harbour in the last century. Many parts of the harbour have undergone development in the last 20-30 years (ie. several pier redevelopments, port upgrades and the Sydney Harbour tunnel (NSW Department of Environment and Planning, 1987)), however, most of these did not survey the fauna or flora as part of their environmental reports. An environmental impact statement of Berrys Bay (Sinclair Knight & Partners, 1990) has a marine flora and fauna component which does not record any introduced species of fauna or flora.

It has been found that the building of urban and port structures creates new habitats for marine organisms, which are quite unlike natural surfaces. The types and numbers of organisms on natural reefs and shorelines are similar to each other, but very different and less numerous compared to those found on urban structures (Connell and Glasby, 1999). This is backed up by Connell (1999) noting that assemblages of plants and animals on vertical urban surfaces were distinctly different to those on natural horizontal surfaces. Therefore, urban structures increase the abundance and diversity of organisms, especially in ports which are exposed to introductions because these urban structures are not habitats strongly utilised by native organisms.

The collections of the Australian Museum were established in the 19th century and those of the Royal Botanic Gardens in 1901, and their development is ongoing. These collections and their associated databases provide a specimen based record of fauna and flora including that of Sydney Harbour. The Australian Museum collections (Australian Museum Faunal Database) contain records of 3632 species of animals from Sydney Harbour. Similar collections at the Royal Botanic Gardens contain records and specimens of 55 species of marine plants from Sydney Harbour (Appendix 18).

As Sydney has been an active port receiving international shipping for over 200 years it is not surprising that there are records of introduced species present in the databases of the Australian Museum and the Royal Botanic Gardens from the 19th century. There are no records of species from Schedule 1 and the only species known from Schedule 2 is *Mytilus galloprovincialis* which was recorded in Sydney Harbour before 1888. Twenty-two species of animals from Schedule 3 are recorded in the Australian Museum Faunal Database. One species of plant from Schedule 3 is recorded in the Royal Botanic Gardens database (Appendix 17).

2.2 Ballast water and species introductions

Marine species have been introduced to new locations through human activities such as hull fouling, dry ballast and aquaculture, and by natural processes such as drifting logs and seaweed. With the advent of container shipping in the 1960's, and general increases in shipping (which now moves over 80% of the world's commodities), an important vector for marine introductions was created. Larval, juvenile and adult stages of marine organisms can be introduced to new areas by ballast water from ships (Carlton, 1985). These organisms are taken on board when ballast water is used to maintain ship stability. As Australia is a net exporter of raw materials such as iron ore, coal, grain and wood chips, large volumes of ballast water are discharged in Australian ports as cargo is loaded. Although water has been used for ship stability since the late 1870's, the volume being discharged increased dramatically from the late 1960's with the advent of bulk carriers that carry cargo in one direction. The majority of ships come into Australian ports in ballast with approximately half originating in Japan. Over 10,000 ship visits bring around 160 million tonnes of ballast water to be discharged annually into Australian ports (Kerr, 1994). Some of this water has been shown to contain marine organisms and some of these species have subsequently become established in Australia (Pollard and Hutchings, 1990a; 1990b; Hallegraeff and Bolch, 1991; Hewitt et al., 1999; Wilson et al., 1998).

During the past two decades there has been increased awareness of the threat of exotic species being introduced by ballast water. Some of these species, such as the Pacific sea star *Asterias amurensis* in the Derwent River in Tasmania (Grannum et al., 1996) and in Port Phillip Bay (Thresher, 1999), have become a major pest. Consequently considerable amounts of effort and resources have been directed to controlling or minimising the risk of such introductions. However, the recent incident of a large scale mollusc invasion into the Port of Darwin by the Caribbean black striped false mussel *Mytilopsis sallei*, probably introduced by a cruising yacht (Willan et al., 2000), illustrates that introductions by hull fouling organisms are also a real problem and need to be addressed as well as ballast water introductions.

3 Description of the Port

3.1 General features

The boundaries of Sydney Harbour are defined in the Ports Corporatisation and Waterways Management Regulation 1997. These are waters of Sydney Harbour and of all tidal bays, rivers and their tributaries connected or leading thereto bounded by mean high water mark together with that part of the South Pacific Ocean below mean high water mark enclosed by the arc of a circle of radius 4 sea miles having as its centre the navigation light at Hornby Lighthouse, South Head. For the purposes of this study we sampled areas inside Sydney Heads as far east as Bottle and Glass Rocks and extending west to Rozelle Bay (see Fig. 1). Sydney Harbour is a well flushed, open and relatively deep (up to 35m) temperate estuary. It has a surface temperature ranging from 15-22°C, and average salinity of 36 ppt (Hyder Consulting, 1997). The shoreline has many inlets and bays, the largest being Darling Harbour. Shipping facilities stretch from Chowder Bay in the east to Gore Cove and Rozelle Bay in the west.

Sydney Harbour has been an international port since the arrival of Europeans in Sydney Cove in January 1788. The history of port management in Sydney Harbour dates back as far as 1811 when the first harbour master was appointed to control the Port of Sydney. In 1901 the Sydney

Harbour Trust was formed to take over and develop the privately owned wharves of Sydney following a period of ramshackle development that contributed to the Bubonic Plague outbreak of the previous year. These arrangements continued until 1936 when the Maritime Services Board was established to co-ordinate port and navigation services under one authority. By 1939 facilities for the coal trade had been relocated at White Bay and wharf facilities for coastal shipping had been improved. During the 1960's the MSB embarked on a ten year plan to redevelop Darling Harbour. In June 1995 the MSB was abolished and replaced by the Sydney Ports Corporation (Sydney Ports Corporation, 2001)

Sydney Harbour handles a wide range of commercial, naval and recreational vessels. Cargoes include dry bulk, crude oil and general cargo, containers and motor vehicles. Sydney is also a leading destination for cruise shipping with two facilities for cruise vessels. The Port of Sydney, unlike Melbourne and Hobart, is considered an import port. As a result, the majority of cargo vessels entering Sydney Harbour do not discharge ballast water, but take up ballast water and discharge it elsewhere.

3.2 Shipping movement summary for 2000

Sydney Harbour received 1171 ship visits in 2000 - 882 from domestic and 289 from international last ports of call (Appendix 4).

3.2.1 Major imports and exports in Sydney Harbour

The major export commodities for the port (containerised cargo only) include: cereals, non-ferrous metals, chemicals, cotton, meat, iron and steel, manufactures, animal foods, food preparations and wool.

The major import commodities through the port include: oil products, motor vehicles, containerised cargo (manufactures, chemicals, paper and paper products, machinery, food preparations, beverages, non metallic minerals, iron and steel, timber, textiles), dry bulk cargo, cement, gypsum, timber, soda ash, salt, sugar and general cargo (predominantly steel).

3.2.2 Summary of ballast discharge patterns

In 2000, 1171 ships visited Sydney Harbour, of which 327 vessels discharged ballast water in the port from a total of 627 tanks. The discharge of ballast water occurs primarily at the berth, and for this reason all the past and present international berths were sampled in this study. Using data made available by the ships and supplied to Sydney Ports by AQIS, the attached Appendix 4 (charts 1–3) show the number of ballast water tanks discharged in Sydney Harbour over the calendar year 2000 as follows:

Chart 1 - from all ports by country

Chart 2 - from domestic (Australian) ports by ID/name

Chart 3 - by vessel type.

The locations of the ballast water discharged into Sydney Harbour are contained in Appendix 3 with the berth details.

3.2.3 Port development and port maintenance activities

Appendix 3 provides details of port facilities on a berth by berth basis, details of current configurations, date of original placement (and preceding structures if any), and recent construction/renovation activities.

Major dredging has not been undertaken in Sydney Harbour by Sydney Ports Corporation in the past ten years.

4 Survey Methods

4.1 Scope of the survey

The sampling program followed the protocol of CRIMP as specified in Hewitt and Martin (1996) and concentrated on the following areas:

Commercial and naval shipping facilities -

- active berths
- inactive and disused wharves
- rock jetties, breakwaters, groynes etc.,
- known deballasting areas
- uncompacted fine sediment in deep areas

Areas adjacent to shipping areas –

- rocky reef
- soft sediment

The following 11 berths (1-11) and two areas (12-13) outside the port facilities were nominated by the Sydney Ports Corporation for the Sydney Harbour survey:

1. White Bay berths 1-6
2. Glebe Island berths 1,2,7,8.
3. Darling Harbour berths 3-10
4. Sydney Cove Passenger Terminal
5. Gore Cove berths
6. Berrys Bay berth
7. Balls Head Bay berth
8. Rozelle Bay berth

9. Blackwattle Bay berth
10. Garden Island berths
11. Chowder Bay berth
12. Clarke Island
13. Bottle and Glass Rocks

Sampling was conducted at 57 sites in Sydney Harbour from 30 March to 6 June 2001 (Table 1, and Figs 1-6). A total of 184 dives were performed for visual surveys, epifaunal scrapings, fish poison stations and dinoflagellate sampling. Grab samples, beam trawl and environmental data were conducted over four boat days. A trapping program and shore sampling were also carried out. At each site a GPS reading was taken to record latitude and longitude, maximum depth was recorded and a photograph was taken from the boat.

Table 1. Sampling sites in Sydney Harbour for Introduced Species Survey

Key: **BT** - Beam Trawl, **CT** - Crab Trap, **DC** - Dinoflagellate Cores, **F** - Fish Poison Station, **G** - Van Veen Grab, **Sh** - Shore Collecting, **S** - Scrapings, **V** - Visual Transect, **WQ** - Water Quality

Site No.	Site Name	Site Description	Max Depth (m)	Sampling Methods
1	Balls Head Bay north	wooden piles	6.2	F, G, S, V, WQ
2	Balls Head Bay north	jetty with shallow rocky bottom	5	CT
3	Balls Head Bay north	fine sediment	12	BT, DC, G, WQ
4	Balls Head Bay south	rocky reef	5	F, S, V
5	Balls Head Bay south	fine sediment	13	BT
6	Berrys Bay north	cement piles	9.3	F, G, S, V
7	Berrys Bay west	jetty with shallow rocky bottom	3	CT
8	Berrys Bay north	fine sediment	11	BT
9	Berrys Bay south	fine sediment	15	DC
10	Blackwattle Bay	wooden piles	6	F, G, S, V, WQ
11	Blackwattle Bay	fine sediment	8.3	BT, DC
12	Bottle and Glass Rocks	rocky reef	10	F, S, V
13	Bottle and Glass Rocks	sand	13.9	BT, DC, G, WQ
14	Chowder Bay	cement piles	12	F, S, V
15	Chowder Bay	sand	13.9	BT, DC, G, WQ
16	Chowder Bay	intertidal rock platform	0	Sh
17	Clarke Island north	rocky reef	10	F
18	Clarke Island north	sand	12	DC
19	Clarke Island south	sand	8	BT, G, WQ
20	Clarke Island south	rocky reef	7	S, V
21	Darling Harbour north	cement facing	12	F, G, S, V, WQ
22	Darling Harbour north	fine sediment	13.5	DC
23	Darling Harbour south	cement facing	11	CT, F, G, S, V, WQ
24	Darling Harbour south	fine sediment	11.5	DC
25	Darling Harbour south-west	fine sediment	12	BT
26	Dawes Point	fine sediment	17.7	DC
27	Farm Cove	fine sediment	9	DC
28	Garden Island east	metal struts	10	F, G, S, V, WQ
29	Garden Island east	shallow rocky bottom	3	CT
30	Garden Island east	fine sediment	12	BT
31	Garden Island north-east	shallow rocky bottom	3	CT

Key: **BT** - Beam Trawl, **CT** - Crab Trap, **DC** - Dinoflagellate Cores, **F** - Fish Poison Station, **G** - Van Veen Grab, **Sh** - Shore Collecting, **S** - Scrapings, **V** - Visual Transect, **WQ** - Water Quality

Site No.	Site Name	Site Description	Max Depth (m)	Sampling Methods
32	Garden Island north	rocky reef	4	F, G, S, V, WQ
33	Garden Island north	jetty with shallow rocky bottom	2	CT
34	Garden Island south	fine sediment	12.9	DC
35	Garden Island west	wooden piles	8	F, G, S, V, WQ
36	Garden Island west	fine sediment	12	BT
37	Glebe Island east	cement facing	12	F, G, S, V, WQ
38	Glebe Island east	jetty with shallow rocky bottom	3	CT
39	Glebe Island east	fine sediment	14.9	BT, DC
40	Glebe Island west	wooden piles	9	V
41	Gore Cove north	rocky reef	9.7	CT, F, S, V
42	Gore Cove north	fine sediment	5	BT, G, WQ
43	Gore Cove south	cement piles	13.8	CT, F, G, S, V, WQ
44	Gore Cove south	fine sediment	18	BT, DC
45	Rozelle Bay	fine sediment	7.5	BT, DC, F, G, WQ
46	Rozelle Bay	jetty with shallow rocky bottom	2	CT
47	Shell Cove	intertidal rock platform	0	Sh
48	Sydney Cove	cement facing	10.4	F, G, S, V, WQ
49	Sydney Cove	shallow rocky bottom	5	CT
50	Sydney Cove	fine sediment	13	BT
51	White Bay east	cement facing	11	F, G, S, V, WQ
52	White Bay east	jetty with shallow rocky bottom	3	CT
53	White Bay east	fine sediment	14	BT, DC
54	White Bay west	wooden piles	9.8	F, G, S, WQ
55	White Bay west	fine sediment	15	BT, DC
56	Woolloomooloo Bay north	fine sediment	9	BT
57	Woolloomooloo Bay south	fine sediment	12	DC

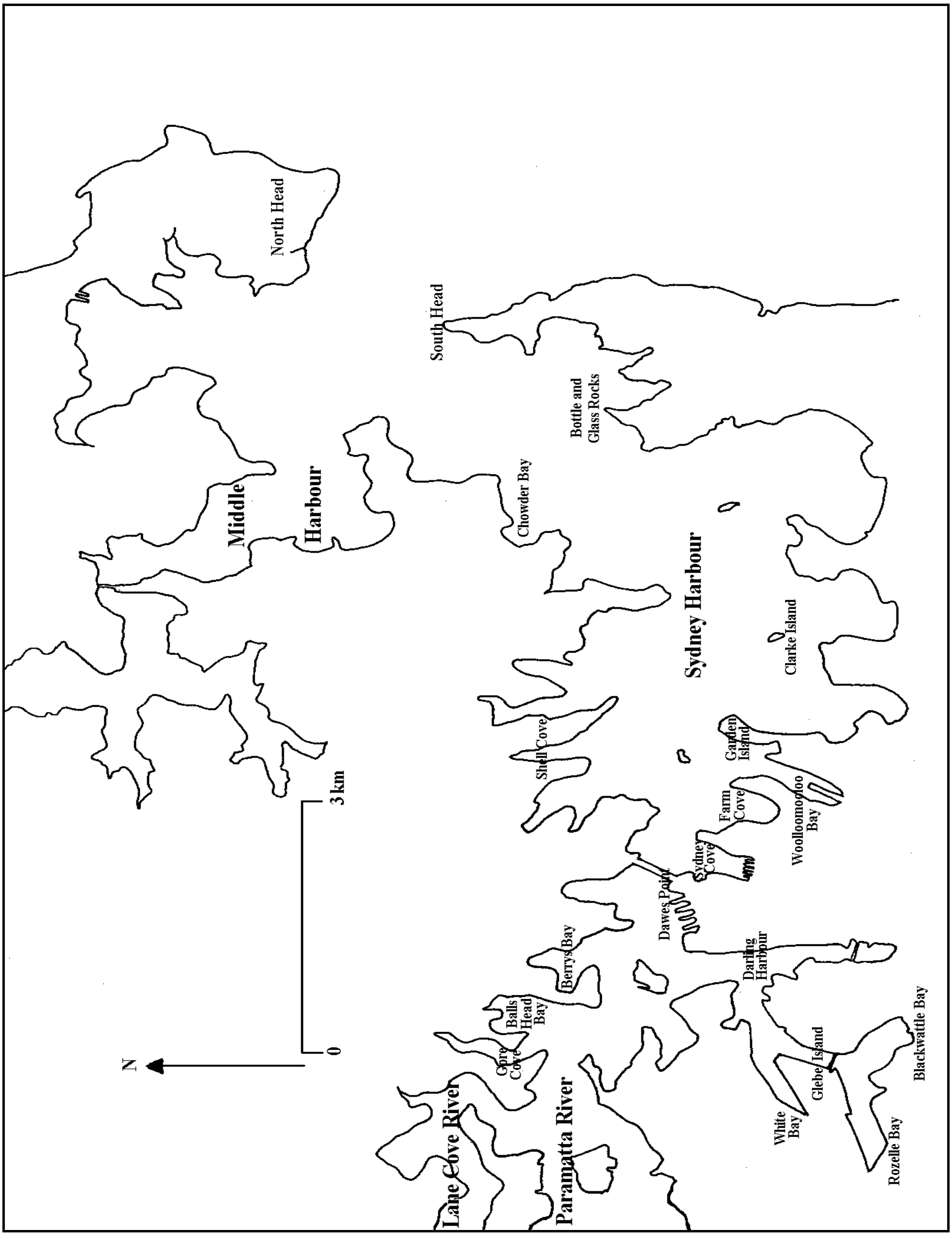


Fig. 1 - Locations in Sydney Harbour sampled in this survey (see Table 1 and Figs 2-6 for more detail)

Fig. 2 - Sampling locations for Rozelle Bay, Blackwattle Bay, Glebe Island and White Bay (see Table 1 for site information)

Fig. 3 - Sampling locations for Darling Harbour, Dawes Point and Sydney Cove (see Table 1 for site information)

Fig. 4 - Sampling locations for Gore Cove, Balls Head Bay and Berrys Bay (see Table 1 for site information)

Fig. 5 - Sampling locations for Farm Cove, Woolloomooloo Bay, Garden Island and Clarke Island (see Table 1 for site information)

Fig. 6 - Sampling locations for Bottle and Glass Rocks, Shell Cove and Chowder Bay (see Table 1 for site information)

4.2 Sampling methods for Schedule 1 species

4.2.1 *Alexandrium* spp. and *Gymnodinium catenatum* - toxic dinoflagellates

Sediment cores were taken from locations in Sydney Harbour where uncompacted fine sediment naturally accumulates. The selected locations were adjacent to berth areas in deep undisturbed areas where dinoflagellate cysts were most likely to occur (Table 1 and Figs 1-6).

Coring was carried out by divers using 50cm long clear perspex tubes with a 46 mm internal diameter and enclosed with rubber bungs at each end. Coring procedures were as specified in Hewitt and Martin (1996). The cores were packed upright in insulated boxes and sent to Associate Professor Gustaaf Hallegraeff at University of Tasmania for analysis and culture.

Plankton samples were collected at the same sites as diver-held cores to check for the presence of dinoflagellates in the water column. A vertical and horizontal tow was made using a 20 µm plankton net following the procedures specified in Hewitt and Martin (1996). The samples were preserved in 1% gluteraldehyde and sent to Associate Professor Gustaaf Hallegraeff at University of Tasmania for analysis.

4.2.2 *Carcinus maenas* – European shore crab

Crab traps, as specified by Hewitt and Martin (1996), were set overnight at wharf piles, facings and jetties. The traps were set at shallow depths (mainly 2-5 m depth) against the piles and facings sitting atop rocks and boulders (Table 1 and Figs 1-6).

The traps were Californian ‘Fathom Plus Crab Traps’ (0.9 m x 0.35 m x 0.7 m) which have been used extensively for Australian Museum research. The traps were baited with pilchards and a small trap (31 cm long x 11 cm diameter) was attached inside the large trap.

Underwater visual searches were conducted at most sites (Table 1 and Figs 1-6) as specified in Hewitt and Martin (1996). Based on the experience of Australian Museum scientists and Grosholz and Ruiz (1995), we considered that trap sampling should be augmented with shore collecting to sample *Carcinus maenas*. The most likely sites to find this crab are the lower reaches of the harbour as it only penetrates slightly into estuaries, and under rocks from high water mark to a couple of metres depth (Zeidler, 1978; Ahyong, pers. com.). Consequently shore collecting was carried out at Shell Cove and Chowder Bay. Shore collecting was also carried out for the Mourilyan Harbour and Abbot Point introduced species surveys (Hoedt et al. 2001).

4.2.3 *Asterias amurensis, Undaria pinnatifida* and *Sabella spallanzanii*

The sampling protocol of Hewitt and Martin (1996) specifies visual searches by divers, epifaunal scrapings and the beam trawl as the appropriate techniques for sampling *Asterias amurensis* (northern Pacific sea star), *Undaria pinnatifida* (Japanese seaweed) and *Sabella spallanzanii* (European fan worm). In addition soft bottom sampling is recommended for *Sabella spallanzanii.*

Visual diver searches, epifaunal scraping and beam trawls were carried out at all berth areas, and at Clarke Island and Bottle and Glass Rocks (Table1 and Figs 1-6).

Soft bottom sampling was performed using a Van Veen grab at sites adjacent to the berths where visual diver searches and epifaunal scraping were carried out (Table1 and Figs 1-6). In our proposal to Sydney Ports Corporation we considered that a Smith McIntyre grab would be used for soft bottom sampling, however, it was found that the Van Veen grab was more effective in the soft sediment of Sydney Harbour. The Van Veen grab sampled a surface area of 0.05 m^2 and the samples were placed in 1 mm mesh bags, labelled, preserved in 7% buffered formalin and later transferred to 70% ethanol. At each berth to be sampled, grab samples were taken adjacent to the berth and at the end of a 50 metre transect perpendicular to the berth.

4.3 Sampling methods for Schedule 2 & 3 species

4.3.1 Hard substrata invertebrates

Sessile and cryptic invertebrates were sampled at depths of 0.5 metres, 3 metres and 7 metres on wharf piles, cement facings and rocky bottoms in the port and adjacent areas (Table 1 and Figs 1-6). Sampling protocol was to scrape the fauna and flora from replicate 0.10 m^2 quadrats and carry out visual diver searches at the same depths, as specified in Hewitt and Martin (1996). Scrape samples tend to produce poor quality specimens of some animals or fragments so additional collections were made of the larger sessile invertebrates such as sponges, hydrozoans and bryozoans, which also provide habitat for smaller animals.

4.3.2 Soft substrata epibenthos

A lightweight beam trawl was used to sample mobile epibenthos over soft sediment areas, as specified in Hewitt and Martin (1996). Trawl samples were taken at all berths, and at Clarke Island and Bottle and Glass Rocks (Table 1 and Figs 1-6). The trawl was towed for 100 m over flat soft-bottom areas as close as practical to the berths where the visual diver searches and epifaunal scrapings were carried out. The beam trawl had a mouth opening of 1.0 x 0.5 metres and was fitted with a 10 mm mesh net.

4.3.3 Benthic infauna

Benthic infauna sampling was performed using a Van Veen grab at sites adjacent to the berths where visual diver searches and epifaunal scraping were carried out (Table1 and Figs 1-6) as outlined in section 4.2.3. A grab was considered to be a more suitable sampling device than diver-held cores as specified in Hewitt and Martin (1996). A grab was also used in the Mourilyan Harbour and Abbot Point introduced species surveys (Hoedt et al. 2001).

4.3.4 Fish poison stations

Rotenone was used to sample fishes as specified in Hewitt and Martin (1996) at all berths, and at Clarke Island and Bottle and Glass Rocks (Table 1 and Figs 1-6). At each site rotenone was spread from the surface down to the bottom, and the fish were then collected by four divers and a snorkeller with hand nets. All fish specimens were fixed in 10% formalin.

4.3.5 Environmental data

A Yeokal 612 submersible data logger (SDL) was used at all berths, and at Clarke Island and Bottle and Glass Rocks at the same place as the grab sample site 50 m off the berth (Table 1). It was equipped to measure pressure, conductivity, temperature, salinity, dissolved oxygen, pH, oxygen reduction potential and turbidity at 1 metre increments. The measurements were taken on 22-23 May 2001 (Appendix 16). Turbidity readings were unsuccessful due to equipment failure and, therefore, appear as zero.

4.3.6 Sediment analysis

Sediment samples of 100 g were taken at all berths, and at Clarke Island and Bottle and Glass Rocks at the same place as the grab locations. The samples were collected and stored in sealed plastic containers until analysis. Particle size analysis was done by Adam Gillis, University of Sydney (Appendix 15).

5 Public Awareness Program

A Sydney-wide public awareness program was undertaken prior to the commencement of fieldwork. Groups or individuals were encouraged to contact the Australian Museum or Sydney Ports Corporation with any observations or information they felt would assist in this study of exotic species in Sydney Harbour. A press release (Appendix 5) was issued on 29th March 2001 and was reported in several newspapers and radio stations. The press release was also placed on the Sydney Ports website. Letters were sent to government agencies and various non-government organisations to notify them of the survey. E-mails and notices were sent to fishing clubs and dive clubs requesting their input.

Responses received from members of public: John Olsen (UTS Dive), Michael McFadyen (St George SCUBA), one Central Coast and two Sydney residents all reporting observations of what they believed were potentially exotic animals. The Australian Museum spoke to all respondents, but none of their observations provided additional data.

6 Survey Results for Schedule 1 species – ABWMAC target pest species

6.1 *Alexandrium* spp. and *Gymnodinium catenatum* - toxic dinoflagellates

Schedule 1 lists four species of dinoflagellates *Alexandrium catenella, Alexandrium minutum, Alexandrium tamarense* and *Gymnodinium catenatum*.

Cysts of the dinoflagellate genus *Alexandrium* were abundant in the samples collected in this study. In most cores the majority of cysts were dead as indicated by discolouration or the absence of the accumulation body. The cysts could not be germinated but can be assigned to either *Alexandrium catenella* or *Alexandrium tamarense* (it is not possible to differentiate species of *Alexandrium catenella* and *A. tamarense* from each other by the cysts alone) and *Alexandrium affine*. The dominant taxon is *Alexandrium catenella/tamarense*, which occurred at 16 of the 17 sites (Appendix 6).

Alexandrium catenella was found in Sydney Harbour in the early 1990's in short episodes of two to four weeks (Hallegraeff et al. 1991). The blooms ("red tides") produce potent neurotoxins which are accumulated by filter-feeders and shellfish rendering them toxic to humans (Furlani, 1996). However, once a bloom subsides the cells form cysts, and these seem to need an environmental trigger (usually in the form of colder water temperatures less than 16°C) in order to germinate. If a cyst stays unhatched for more than a four to five years, particularly in warmer temperatures, the cyst dies. It may be possible that because Sydney Harbour is warmer than the natural range of *Alexandrium catenella* it is not conducive to cyst survival. *Alexandrium tamarense* has not been recorded in New South Wales, but is known from South Australia, Victoria and Tasmania.

Cysts of *Alexandrium affine* were found at 11 sites, but this species is not toxic (de Salas, pers. com.). *Alexandrium minutum* is known from South Australia, Victoria, Western Australia and Shoalhaven in New South Wales but was not found in this survey.

Cysts of the genus *Gymnodinium* were present in the samples but also could not be germinated, and as a result the species could not be determined.

6.2 *Carcinus maenas* (Linnaeus 1758) – European shore crab

Carcinus maenas was not found in the survey of Sydney Harbour by visual diver searches, scrapings, beam trawls or traps. This species is found under stones and crevices (Williams, 1984) in shallow water or intertidally, but was not collected by shore collecting during this survey.

Carcinus maenas is a swimming crab (family Portunidae) which was introduced from Europe to Victoria in the late 19th century (Fulton and Grant, 1900). Fulton and Grant (1902) further speculated that the crab was most likely introduced during the 1850's from dry ballast when old ships unloaded goldfield passengers in Port Phillip Bay. It is also found in USA, Brazil, Panama, Hawaii, Ceylon, and South Africa (Furlani, 1996). In Australia this temperate species is found in Western Australia, South Australia, Victoria, Tasmania and New South Wales (Zeidler, 1978). The most northern specimen-based records in the Australian Museum Faunal Database are Twofold Bay (Hutchings et al. 1989, found it to be abundant), Brou Lake and Narooma, although there are unconfirmed sightings from Botany Bay (Ahyong, pers. com.).

6.3 *Asterias amurensis* Lutken, 1871 - northern Pacific sea star

Asterias amurensis was not found in the survey of Sydney Harbour by visual diver searches, shore collecting, scrapings, beam trawls or traps.

Asterias amurensis has not been recorded from New South Wales and the only records for mainland Australia are in Port Phillip Bay (Thresher, 1999). It's native range is China, Japan, Korea and Russia, and it is thought to have been introduced to Australia in south-east Tasmania in the 1980's, in ballast water from a ship from Japan or Korea (Buttermore et al., 1994). In Tasmania the species is known to occur on various substrata including mud, sand and rock, and in water depths from littoral to 30 metres (Morrice, 1993).

6.4 *Undaria pinnatifida* (Harvey) Suringer – Japanese seaweed

Undaria pinnatifida was not found in the survey of Sydney Harbour by visual diver searches, shore collecting, scrapings or beam trawl.

Undaria pinnatifida was initially reported from the Tasmanian east coast in 1988. In 1996 it was found in the Geelong Arm of Port Phillip Bay, Victoria, but it has not been reported from New South Wales. This species of laminarian or kelp, is cultivated for food in Japan (known as "Wakame") and is native to China, Korea and Japan (Furlani, 1996).

6.5 *Sabella spallanzanii* (Gmelin, 1791) - European fan worm

Sabella spallanzanii was not found in the survey of Sydney Harbour by visual diver searches, scrapings, beam trawls or grabs. There are no records of this species from Sydney Harbour in the Australian Museum Faunal Database.

Sabella spallanzanii was probably introduced from the Mediterranean to Australia in Victoria in the 1980's and is now found in Victoria, Tasmania and the southern coast of Western Australia (Carey and Watson, 1992). It was first recorded from New South Wales in low densities from Snug Cove, Twofold Bay in 1996 (CSIRO Marine Research, 1997). This New South Wales record has since been confirmed by polychaete experts at the Australian Museum (AM registration numbers W27989-W27990). There have been unconfirmed sightings of the species from Jervis Bay but no specimens are available for species confirmation. When present in large numbers it is the visually dominant organism of the muddy bottom habitats, with colonies growing to a height of about 30 cm above the substratum (Carey and Watson, 1992).

7 Survey Results for Schedule 2 species

7.1 Mnemiopsis leidyi - Atlantic comb jelly

Mnemiopsis leidyi was not found in the survey of Sydney Harbour by visual diver searches. This species has not been recorded in Australia (Furlani, 1996). It is native to the east coast of North America and has been introduced to many other northern hemisphere world ports. Its introduction to the Black Sea in the early 1980's has caused major declines in zooplankton biomass and commercial fish catches, with jellyfish outbreaks reaching levels as high as hundreds of million of tonnes (95% of the biomass) in the Black Sea (GESAMP, 1997).

7.2 *Mytilus galloprovincialis* Lamarck, 1819 - Blue mussel

Mytilus galloprovincialis was found to be abundant in Sydney Harbour, occurring at 17 of the 18 scraping sites. This species forms a conspicuous zone subtidally at most of the sites sampled, and also provided a habitat for many other organisms both on the shell itself and in the spaces within mussel clumps.

The taxonomy of the genus *Mytilus* is in need of revision in the southern hemisphere and this species has been previously known under the names *M. edulis, M. planulatus* and *M. edulis planulatus*. *Mytilus galloprovincialis* is a northern hemisphere species that is now widespread in southern Australia and may predate the arrival of Europeans (Ponder et al., 2000).

The collections from this survey of Sydney Harbour are provisionally identified as *Mytilus galloprovincialis*. Identification is provisional because the genus *Mytilus* includes several cryptic species. For example, *Mytilus edulis,* a morphologically similar northern Hemisphere species that co-exists with *Mytilus galloprovincialis* in Europe, may also be present in Australia. It is possible that one or more cryptic species of *Mytilus* (one or more perhaps being endemic to Australasia) will be shown to co-exist with (or be replaced by) *Mytilus galloprovincialis* (Ponder, pers. com.).

The assumption that *Mytilus galloprovincialis* is an introduced species is questionable given that midden and Pleistocene mytilids, that predate the arrival of Europeans, have been found in New Zealand and Australia. *Mytilus* is also common in remote locations in southern Australia, and sub-Antarctic islands. The only reliable way to test all the above possibilities is using molecular data. At present there are no reliable data that would disprove any of the above scenarios (Ponder, pers. com.).

7.3 Potamocorbula amurensis (Schrenck, 1867) - Chinese clam

Potamocorbula amurensis was not found in the survey of Sydney Harbour by beam trawl or grab sampling. This species has not been recorded in Australia (Furlani, 1996). It is native to China, Japan and Korea, and has been introduced to San Francisco Bay where it now occurs in large numbers.

7.4 Philine auriformis **Suter, 1909 - sea slug**

Philine auriformis was not found in the survey of Sydney Harbour by visual diver searches or beam trawl. This species has not been recorded in Australia (Furlani, 1996). It is native to New Zealand and was recently considered to have invaded California, but this appears to have been a mistaken identification (Rudman, 1998).

7.5 Codium fragile tomentosoides **(Sur.) Hariot subsp. (Van Goor) Silva - green alga**

Codium fragile tomentosoides was not found in the survey of Sydney Harbour by visual diver searches, scrapings or beam trawl. This species has not been recorded in Australia. It is native to Japan and the northwest Pacific and has spread to numerous localities in North America, Europe and New Zealand (Furlani, 1996).

8 Survey Results for Schedule 3 species

The survey of Sydney Harbour made extensive collections of marine plants and animals. In preparing this report a targeted approach has been taken to establish the presence or absence of species listed on Schedule 3 (Hewitt and Martin, 1996). For some animal and plant groups, all specimens have been identified to species but in other groups the collections were too numerous or diverse to identify all specimens within the scope of the contract. However, the specimens have been deposited in the collections of the Australian Museum and the Royal Botanical Gardens and will be available for future study. Many specimens will be of immediate interest to taxonomists and all will be registered in the Australian Museum and Royal Botanical Gardens databases. A reference collection of introduced species will also be deposited with CSIRO Division of Fisheries as specified by Hewitt and Martin (1996).

8.1 Phylum Annelida

Introduced annelids from Schedules 1 and 3 are from three polychaete families only - Sabellidae, Serpulidae and Spionidae. Therefore, polychaete identifications were targeted so that only specimens from these families were identified, and then only to species in the seven introduced genera on Schedules 1 and 3. Furthermore, due to the large number of specimens collected by scraping, one depth replicate was identified from each of these sites. Specimens of the seven target genera were identified from all the trawl and grab sites.

This survey of Sydney Harbour found three of the six introduced polychaetes listed on Schedule 3 (*Euchone limnicola, Hydroides elegans* and *Pseudopolydora paucibranchiata*), and three other species which we believe to be introduced (Appendices 2 and 7).

Euchone limnicola was found in grabs and trawls from 10 of 21 sites. This sabellid lives in muddy sediments, and therefore was not found in scrapings. It was originally described from California in 1960 and first reported in Australia from Port Phillip Bay in 1984 (Cohen et al. 2001). It has since been found from Portland, Victoria, Botany Bay and Sydney Harbour. These are the first records from the lower reaches of Sydney Harbour, as previously it was only known from Homebush Bay and Parramatta River in the 1990's (Australian Museum Faunal Database, Appendix 17). Due to its absence from scrapings, it is possible that this species is a ballast water introduction, not a hull fouling introduction.

Hydroides elegans was the most commonly found polychaete from the Schedules, as it was found in scrapings, grabs and trawls from every site. This serpulid was described from Sydney

Harbour in 1883 and is now found almost worldwide. It is one of the most common fouling organisms in tropical and subtropical ports. It is possible that it is a native Australian species that has spread via hull fouling to other parts of the world, or alternatively, it may have been transported to Sydney Harbour prior to 1883 before being found and described. However, because of its current widespread distribution it would be difficult to determine its original native distribution. ten Hove (1974) suggested that this species may be transported by ballast water, but only on short voyages as the larval planktonic stage lasts about a week.

One specimen of *Pseudopolydora paucibranchiata* was found in one grab sample from Clarke Island. This spionid is native to Japan and is widely distributed around Pacific bays. It was first recorded in Australia from Sydney Harbour in 1972 (Australian Museum Faunal Database) and has since been recorded in south-eastern Australia from South Australia to New South Wales, and Western Australia (Furlani, 1996).

Ficopomatus enigmaticus (incorrectly listed in Schedule 3 as *Mercierella enigmatica),* has been recorded in Sydney Harbour (Appendix 17) from Glebe Island in 1972. However, no specimens of this species were found in this survey.

Three other introduced species of polychaetes were found in the survey which are not currently on Schedule 3. We believe *Boccardia chilensis, Hydroides diramphus* and *Hydroides ezoensis* should be included on Schedule 3.

The spionid *Boccardia chilensis* was found in one scraping from Gore Cove south. This species is native to Chile, and was first recorded in Australia from both Sydney Harbour (Iron Cove) and Minnie Waters, northern New South Wales in 1971. It has subsequently been found in South Australia and Western Australia.

The serpulid *Hydroides ezoensis* was found in scrapings at 13 sites in this survey. This Japanese species has only previously been recorded from Australia in Sydney Harbour (Glebe Island) in 1998.

The other serpulid, *Hydroides diramphus,* was found in scrapings at five sites in this survey. This species probably originates from tropical American seas. Records from around the world are from harbours and ships' hulls which ten Hove (unpublished data) suggests are indicative of a species transported by hull fouling. It has been recorded from Queensland and New South Wales, and this is the first record from Sydney Harbour.

We suspect that some records of the serpulids and the spionids on Schedule 3 may be misidentifications, as the species within genera of these families are particularly cryptic. Complete worms are necessary for identification and several groups of chaetae need to be examined under high magnification. Additionally, some spionids, especially members of the genera *Boccardia*, *Polydora* and *Pseudopolydora,* bore into oysters which have been moved up and down the east coast of Australia by aquaculture activities. In some cases oysters have been transported internationally and with them many boring polychaetes. As a result it is difficult to determine the native distribution of such species. Similarly many species on Schedule 3 are found as encrusting organisms on any hard substrata including hulls, drift algae, floating logs or other debris and these organisms have been transported by such means for centuries. Therefore, it may again be really difficult to establish the original distribution of these species and they may not be introductions into Australia.

8.2 Phylum Arthropoda

8.2.1 Order Amphipoda

The only species of amphipod on Schedule 3 is a caprellid amphipod, so identifications were targeted for caprellid amphipods which are a distinctive group. Six species of caprellids were found in this survey of Sydney Harbour from scrapings, grabs and trawls but did not include the species on Schedule 3 (*Caprella acanthogaster*). One species is believed to be introduced (*Caprella californica*) and is a new record for Australia. The other five species have been recorded from Sydney Harbour for over a century (Appendix 8).

Caprella acanthogaster is native to either China or South America, and is known from Russia, Sea of Japan and Japan (McCain and Steinberg, 1970; Arimoto, 1976). However, it has never been recorded from Australia or any adjacent areas, and was not found in this survey.

Caprella californica was found in scrapings, grabs and trawls from 8 of 21 sites. It is thought to be native to California, and is known from the Pacific coast of North America, Mexico, Chile, Japan, Hong Kong and South Africa (Arimoto, 1976). Until this survey it had never been recorded from Australia. This species is reported to have been introduced to other areas from California, and has been documented to raft on kelp (Morris et al., 1980). Given its known distribution we believe it has been introduced and hull fouling is the most likely introduction vector.

Paradeutella echinata was found in scrapings at two sites, one of which is a non-port site (Bottle and Glass Rocks) and the other a minimal use port (Chowder Bay). It is an endemic species described by Haswell (1879b) from Sydney Harbour, and only known from New South Wales. This endemic species may be restricted to relatively undisturbed habitats in the harbour's lower reaches, or may be out-competed in the port areas.

The other four species found (*Caprella danilevskii, Caprella equilibra, Caprella penantis* and *Caprella scaura*) are all cosmopolitan species (McCain and Steinberg, 1970; Arimoto, 1976). The Australian Museum Faunal Database has records of all these species in Sydney Harbour from at least 100 years ago. Even though these species are regarded as cosmopolitan and their native ranges unresolved, it is apparent that they are not recent introductions to Sydney Harbour.

A number of amphipod families, including the Ampithoidae, Aoridae, Cheluridae, Corophiidae, Dexaminidae and Lysianassidae, contain species that are likely to be spread by hull fouling or ballast water and these should be investigated as candidates for Schedule 3.

8.2.2 Class Copepoda

Mytilicola orientalis was not found in this survey of Sydney Harbour. This copepod parasitizes the intestine of bivalves, particularly mussels, causing what is known as *Mytilicola* disease or red worm. It is native to Japan, and has been introduced via seed oysters to the west coast of North America and recently to France (Bower, 1996). It has never been recorded from Australia or adjacent areas.

8.2.3 Class Cirripedia

All barnacle specimens were identified, and nine species were found from scrapings in this survey of Sydney Harbour including one introduced species from Schedule 3 (*Megabalanus rosa*) and eight native species (Appendix 8).

Megabalanus rosa was found at four of 19 scraping sites in this survey. It is native to Japan, China and Taiwan (Furlani, 1996) and was first recorded in Australia from northern and central

Western Australia in 1981, with hull fouling the most likely introduction vector (Pollard and Pethebridge, 2000). It has since been recorded from off Wollongong in 1990 (Australian Museum Faunal Database) and is a new record for Sydney Harbour.

Notomegabalanus algicola, listed on Schedule 3, was not found in this survey. It is native to South Africa and was first recorded in Australia from the Sydney region in 1943, and the Australian Museum Faunal Database records it from Sydney Harbour in 1945. Allen (1953) recorded it from Eden to Port Stephens and suggested that it was transported to Australia via hull fouling. Ten years after its first sighting, Allen reported it as one of the most common sublittoral barnacles on the open coast. However, the harbour being an estuary is a different environment to the open coast, and as a result it is not entirely surprising that *Notomegabalanus algicola* was not collected in the port of Sydney Harbour.

The eight native species (*Austrobalanus imperator, Balanus amphitrite, Balanus trigonus, Balanus variegatus, Chthamalus antennatus, Elminius covertus, Hexaminius popeiana* and *Tesseropora rosea*) are all relatively common southern Australian barnacles, and all have been recorded from Sydney Harbour or the Sydney coastline previously.

8.2.4 Order Decapoda

A targeted approach was taken in identifying the decapods by concentrating on the families listed in Schedule 3. None of the five species of decapods on Schedule 3 was found in this survey of Sydney Harbour. *Halicarcinus innominatus* and *Petrolisthes elongatus* are only known from Tasmania; *Cancer novaezelandiae* is known from Tasmania and Port Phillip Bay; *Pyromaia tuberculata* from Port Phillip Bay and Western Australia; *Palaemon macrodactylus* from estuaries in northern New South Wales and South Australia; and *Rhithropanopeus harisii* has never been recorded from Australia. As none of these species has been recorded from marine environments in New South Wales previously (Furlani, 1996), these nil results are not surprising.

8.2.5 Order Isopoda

Four of the eleven isopods from Schedule 3 were found in this survey - *Cirolana harfordi, Eurylana arcuata, Paracerceis sculpta, Sphaeroma walkeri* (Appendix 8). All four of these species have been recorded from Sydney Harbour previously, and seem to be associated with hull fouling communities. A targeted approach was taken in identifying the isopods by concentrating on the families listed in Schedule 3. It is estimated that approximately 35 additional species of isopods were found.

Cirolana harfordi was found in scrapings and traps from five of 21 sites. This scavenging isopod is native to California, and is known from the Pacific coast of North America, far east Russia, Japan and Hong Kong. It was first recorded in Australia from Berrys Bay, Sydney Harbour in 1972, and it is now recorded from Fremantle, Western Australia and Lorne, Victoria (Bruce, 1986).

Eurylana arcuata was found in one trap from Shell Cove. This scavenging isopod has a native range of New Zealand or Chile (Bowman et al. 1981). It is known from San Francisco, and was first recorded in Australia from Sydney Harbour prior to 1925. It's distribution in Australia ranges from Tweed Heads, northern New South Wales to Port Willunga, South Australia. Bowman et al. (1981) suggest that it was introduced to San Francisco Bay either by hull fouling or via ballast water.

Paracerceis sculpta was found in scrapings and trawls from 9 of 21 sites. It is native to the Pacific coast of North America, from California to Mexico, and is known from the Atlantic coast of North America, Hawaii, Hong Kong, Tunisia and Spain. It is transported in hull fouling animal and plant growth, and was most likely introduced to Australia from California (Pollard and Pethebridge, 2000). It was first recorded in Australia from Townsville in 1975 (Harrison and Holdich, 1982), and is now known from Port Phillip Bay, Botany Bay and Sydney Harbour (Australian Museum Faunal Database). The first record of its presence in Sydney Harbour is from Store Beach, Middle Harbour in 1984 (Australian Museum Faunal Database).

Sphaeroma walkeri was found in scrapings from five of 21 sites. It is native to the Northern Indian Ocean, and is believed to have spread via hull fouling to Hawaii, California, Florida, Puerto Rico, Brazil, South and East Africa, Middle East, northern Egypt, Israel, Sri Lanka, India, Hong Kong and Spain. It was first recorded in Australia from Sydney Harbour in 1927 (Australian Museum Faunal Database), and is now known from Cairns, Townsville and Moreton Bay in Queensland.

Schedule 3 also lists the isopods *Limnoria lignorum, L. quadripunctata and L .tripunctata*. None of these species was found in the survey, however, the usual habitat of these species (bored wood) was not sampled in this study. The only species of *Limnoria* collected in this survey was *L. rugosissima* (Appendix 8), an algal borer previously known from Sydney Harbour, South Australia, Victoria, Tasmania and The Snares (New Zealand subantarctic islands) (Cookson, 1991; 1997).

The Australian Museum Faunal Database records all three Schedule 3 species of *Limnoria* from Sydney Harbour (Appendix 17). Cookson (1991; 1997) recorded *Limnoria quadripunctata* and *L. tripunctata* from Australia and both are widespread species from around the world. However, the status of *L. lignorum* on Schedule 3 is questionable. Cookson (1991; 1997) has studied vast amounts of Australian material of *Limnoria* (including many samples from Sydney Harbour), and specifically excludes *L. lignorum* from Australia. Cookson (1991) records the distribution of this species as temperate and boreal northern hemisphere. The records of *L. lignorum* in the Australian Museum Faunal Database need to be checked by an expert taxonomist.

Due to their ability to bore wood and other substrata, species of *Limnoria* are candidates for widespread dispersal via shipping (particularly in previous centuries) and (more naturally) via drifting wood or algae. The most recent work on this taxon in Australia (Cookson, 1991, 1997), however, makes no comment on the distribution of the species listed in schedule 3 in regard to their status as possible or probable introductions to Australia.

The status of *Sydnidotea laevidorsalis* on Schedule 3 is questionable. Poore (1996) analysed specimens of *S. laevidorsalis* and found that the Australian specimens differ from native Japanese specimens, and for this reason believes that *Sydnidotea laevidorsalis* is not an introduction to Australia as proposed by Chapman and Carlton (1991; 1994). The Australian specimens were found to be native species *Synidotea grisea* (Victoria) and *S. keablei* (New South Wales), and *S. laevidorsalis* has a restricted range in the northwestern Pacific.

The collecting techniques specified by the CRIMP protocol (Hewitt and Martin, 1996) for several of the Schedule 3 isopod species could be improved (Keable, pers. com.). *Cirolana harfordi* and *Eurylana arcuata* are predominantly intertidal, they can be associated with fouling organisms or found under rocks lying on sand. They can be most easily surveyed using small baited traps left in the intertidal zone overnight (as demonstrated in this study) and are unlikely to be readily collected in cores or beam trawls as outlined in the CRIMP protocol. *Cirolana* *harfordi* was also collected in quadrat scrapings, although the CRIMP protocol does not specify this sampling technique for this isopod. *Ligia* species are intertidal and unlikely to be collected in beam trawls as specified in the CRIMP protocol, although it also specifies more appropriate methods such as quadrat scrapings. *Paracerceis sculpta* and *Sphaeroma serratum* are cryptic species often associated with fouling species and/or wood boring, they are more likely to be found in quadrat scrapings (as shown in this study for *Paracerceis sculpta*) than in cores and beam trawl sampling as specified in the CRIMP protocol. Bored wood should be investigated for the *Limnoria* and *Sphaeroma* species on Schedule 3.

8.2.6 Order Mysidacea

All specimens of mysids were identified and two species were found. The only mysid species on Schedule 3 (*Neomysis japonica)* was not found in this survey. Two native species were identified (*Heteromysis* cf. *brucei* and *Rhopalophthalmus brisbanensis*), both of which have previously been found in the Sydney region.

8.2.7 Order Stomatopoda

All specimens of stomatopods were identified and one species found. There are no stomatopods listed on Schedule 3. *Oratosquilla oratoria* was found in trawls and grabs from three sites (Blackwattle Bay, Glebe Island and Gore Cove north; Appendix 8). It is native to Japan and China, and is known from southern Russia, Hong Kong, Korea, Taiwan and Vietnam (Ahyong, 2001). Ahyong (2001) suggests that *Oratosquilla oratoria* was first introduced to Australia in Sydney Harbour in the mid-1980's, and is now known from other estuaries in the Sydney region and the Gippsland Lakes, Victoria. It is now a commercially trawled species in Sydney.

8.2.8 Order Tanaidacea

All specimens of tanaids were identified and neither of the two species of tanaids on Schedule 3 (*Lepotochelia dubia* and *Tanais dulongi*) were found. Five native species were identified (*Bathytanaia juergeni, Leptochelia ignota, Paratanais linearis*, *Tanais tenuicornis* and *Paratanais* sp.), all of which have previously been found in Sydney Harbour or the Sydney region.

Tanais dulongi was reported by Jones (1991) to have well established populations in the Spencer Gulf of South Australia, but there are no other records of this species occurring elsewhere in Australia. *Lepotochelia dubia* is believed to be native to Brazil, but has never been recorded from Australia or any adjacent areas.

8.3 Phylum Chordata

8.3.1 Class Ascidiacea

All specimens of ascidians were identified and ten species were identified. Two of these are listed on Schedule 3 - *Botrylloides leachi* and *Styela plicata* (Appendix 9). Herdman (1899) recorded 70 species of ascidians from Sydney Harbour, including two species from Schedule 3 - *Botrylloides leachi* and *Ciona intestinalis.*

Botrylloides leachi is a colonial ascidian which was found at 11 of the 19 scraping sites. This species has a native range of the European Atlantic, but now appears to have a broad range from north-eastern Atlantic to the Mediterranean, and from the Red Sea to the tropical Indo-west Pacific and temperate waters of southern Australia (Kott, 1985). This species was first recorded in Australia by Herdman in Sydney Harbour in 1899, and the Australian Museum Faunal Database has specimens collected from before 1905 in Sydney Harbour. At present it has an

Australian distribution from northern Queensland to southern Australia and northern Western Australia.

Styela plicata is a solitary ascidian which was the most abundant species in this survey, was found in large numbers at all 19 scraping sites. This species is native to the east coast of America, and is known from the temperate Atlantic, the Mediterranean, Japan, West Indies and Australia (Kott, 1985). This species was first recorded in Australia by Heller (1878) in Sydney Harbour and in Port Stephens by Herdman (1899), and the Australian Museum Faunal Database has specimens collected from 1887 in Sydney Harbour. At present it has an Australian distribution from northern Queensland to Victoria, South Australia and Western Australia. *Styela plicata* is now widely distributed in sheltered waters along southern Australia, but its absence from the Indo-west Pacific led Kott (1985) to consider it an introduction. *Styela plicata* is commonly found in shallow protected habitats, and is able to accommodate a degree of pollution and reduced salinity (Kott, 1972; Kott, 1985). A rapid growth pattern and reproductive rate allows large populations to colonise suitable substrata quickly and densely (Morris et al., 1980). These factors probably explain why this species is the dominant ascidian in the port area of Sydney Harbour.

The remaining six species on Schedule 3 were not found in Sydney Harbour during this survey. *Ascidiella aspersa, Botrylloides violaceus, Botryllus schlosseri, Molgula manhattensis* and S*tyela clava* have not been recorded from Sydney Harbour.

Ciona intestinalis has been recorded from Sydney Harbour as long ago as 1899 by Herdman, but was not found in this survey and the most recent specimen in the Australian Museum Faunal Database is from 1909. The known Australian distribution is from southern Queensland to South Australia, Tasmania and southern Western Australia. Kott (1990) notes that the Australian populations of *Ciona intestinalis* are in decline, with no recent records since the late 1970's, however, eight specimens were found in Geelong in 1997 (Currie et al., 1998). In harbours where it had large populations in the 1950-60's, it appears to be disappearing. Kott (1990) suggests that this may be because it is adapted for a habitat on under surfaces of ships, but not port habitats.

Botryllus schlosseri has been recorded once from Middle Harbour and Port Hacking in Sydney (Australian Museum Faunal Database). This species has a widespread distribution in Australia, occurring in every state except Northern Territory (Furlani, 1996).

The remaining eight endemic species identified (Appendix 9) have all been recorded from Sydney Harbour previously (Kott, 1985), with the exception of *Cnemidocarpa floccosa. Cnemidocarpa floccosa* generally has a tropical range, but is well represented in Moreton Bay. Its occurrence in Sydney Harbour may possibly represent a refuge at the southern end of its range (Kott, pers. com.).

From her identifications of the collections from this survey Kott states that the species diversity of ascidians in Sydney Harbour appears to be depleted, with only 10 species found in this survey compared with 70 species by Herdman in 1899. Most of the ascidians in this survey are opportunistic species, known to have a wide geographic range and able to adapt to the most diverse habitats (ie. cement facings, wooden piles, rocky reefs or rocky bottoms). Whereas, the least opportunistic species, *Pyura stolonifera* and *Cnemidocarpa radicosa*, commonly found from coastal locations, were usually found on natural rocky reefs and rocky bottoms.

8.3.2 Class Pisces

All fishes from this survey of Sydney Harbour were identified to species, and 86 species were recorded (Appendix 10). One species from Schedule 3 was found, *Tridentiger trigonocephalus* (Japanese Goby).

Tridentiger trigonocephalus has a native range of Korea, China and Japan. It is believed to have been introduced to Australia in the ballast water of ships coming from Japan or Taiwan (Hoese, 1973). It has been recorded in Sydney Harbour since 1971 and has since been found in Perth (1976) and Melbourne (1977) (Gomon, 1994). *Tridentiger trigonocephalus* was found at seven sites sampled by rotenone - Blackwattle Bay, Darling Harbour south, Glebe Island east, Gore Cove north, Rozelle Bay, White Bay east and White Bay west. It appears to be a well established species, however, little is known of its impact on other fishes in Sydney Harbour. It was commonly found in silty, muddy habitats during the survey, but it is found more commonly on sand in seagrass beds in Korea, China and Japan (Gomon, 1994).

One other species of goby, *Acentrogobius pflaumi,* identified in the harbour is introduced but is not listed on Schedule 3. *Acentrogobius pflaumi* has a native range of Japan and Korea in sandy and muddy coastal waters. It is believed to have been introduced into Melbourne between 1990-1994, and is now established in Port Phillip Bay (Lockett and Gomon, 2001). It had not previously been found in Sydney Harbour, and it is not known how it was introduced into Sydney waters. *Acentrogobius pflaumi* was found at four fish poison sites (site no's 23, 37, 51 and 54), ten beam trawl sites (site no's 3, 8, 12, 36, 42, 44, 50, 53, 55 and 56) and two Van Veen grab sites (site no's 6 and 28).

Of the remaining eight species on Schedule 3, we believe four species should not be listed as known or likely exotic marine species in Australian waters - *Oreochromis mossambicus, Salmo salar, Salmo trutta* and *Triso dermopterus*.

Oreochromis mossambicus (Mozambique Mouthbrooder) is presently known from Brisbane and Western Australia. *Oreochromis mossambicus* was first recorded in south eastern Queensland in 1977 and in Carnarvon, Western Australia in 1981 (McDowell, 1996). Although considered to be a pest in Australian waters, it is a freshwater species and thus poses no threat to marine species.

Salmo salar (Atlantic Salmon) is presently known from New South Wales, Victoria and Tasmania. It occurs naturally in cool or cold water in the North Atlantic from northern Spain, through eastern Europe, Iceland, Greenland and along the coast of North America. Between 1864 and 1870 attempts to stock *Salmo salar* in Tasmania met with little success (McDowell, 1996). Most stocks known in Australia are maintained by annual stocking (Burrinjuck Dam and Lake Jindabyne) and are reared in government and private freshwater hatcheries. Tasmania has a well established aquaculture industry and any populations established are escapees from such facilities. Young *Salmo salar* live in freshwater and migrate to sea after a period of approximately three years. There are currently no self sustaining sea-running populations in Australia (McDowell, 1996) and it is not considered to be a threat to marine species.

Salmo trutta (Brown Trout) is presently known from New South Wales, Victoria, South Australia and Tasmania. It occurs naturally in cool or cold waters of Europe, Iceland, Scandinavia, Spain, northern Africa and continues east to the Black and Caspian Seas. *Salmo trutta* was introduced in the 1860's from southern England and has spread throughout the freshwaters of Australia by establishing small self-sustaining populations in streams, lakes and reservoirs. The Adelaide population is primarily maintained by stocking (McDowell, 1996). While it is possible for *Salmo trutta* to exist in estuarine waters, it is primarily considered to be a freshwater species in Australia and thus poses no threat to marine species.

Triso dermopterus (grouper) was first collected in Australia in 1950 and was described as the species *Altiserranus woorei* by Whitley in 1951. The specimen was collected off Laurieton, New South Wales and other specimens have since been collected along the New South Wales coast and in Western Australia. It is considered to be an anti-tropical species with populations found in Korea, Japan, Taiwan, Hong Kong, the Fujian Province in China as well as Australia (Heemstra and Randall, 1993). In a recent review of this genus, the holotype of *Altiserranus woorei* was synonymised into the genus *Triso* (Randall et al., 1989). The species *Altiserranus woorei* is considered to be identical to the northern hemisphere *Triso dermopterus*. This species is not considered an exotic marine pest, but rather a naturally occurring species in Australian waters (Paxton et al., 1989).

The CRIMP sampling protocols are not considered to be completely appropriate for one species listed on Schedule 3. *Acanthogobius flavimanus* (Yellowfin Goby) is a known introduced marine species (Hoese, 1973), however, no specimens of this fish were collected due to the constraints on the areas collected for this survey. This species of fish is generally found in the upper estuarine regions of Parramatta River and Lane Cove River, outside the reaches of the port of Sydney Harbour. As these areas were not targeted within this survey, there was no examination of the extent of the population within the Sydney Harbour region.

8.4 Phylum Cnidaria

8.4.1 Class Anthozoa

The only anthozoan species on Schedule 3, *Diadumene lineata* (orange-striped anemone), was not found in this survey of Sydney Harbour. It has only been inferred to occur in Australia at Port Adelaide, South Australia. It is native to Japan, and has been introduced to Europe, the Atlantic and Pacific coasts of USA and the Suez Canal mainly via oyster shipments (Furlani, 1996).

8.4.2 Class Hydrozoa

All specimens of hydrozoans were identified and 13 species were recorded (Appendix 11). None of these was listed on Schedule 3. Most are potential or actual hull-fouling organisms that could have been introduced to Australia in the past. One or two species (eg. *Obelia angulosa*) may have been exported from Australia to other countries (Watson, pers. com.).

With the exception of *Eudendrium carneum,* none of the species found is a surprising record for the geographical area sampled, all being previously known from southern Australia or extending their range from southern Queensland. *Eudendrium carneum* was the most abundant and largest species in this survey being found in scrapings from six of the 19 sites. It has a distribution of the Atlantic and Pacific coasts of North America, southern Africa and tropical east Pacific (Watson, 1985), and has been recorded from ship hulls in South Africa (Millard, 1966). This is the first record of the species from the Australian east coast, although it has been present in Fremantle for at least 40 years (Watson, 1985) and recorded from north-western Australia (Watson, pers. com.). Its origin is not known, but it is well documented as a common hull fouling hydrozoan, and is present in many shipping ports worldwide. The genus *Eudendrium* tends to favour habitats of low light intensity and avoid exposed coasts where there is wave action (Watson, 1985), and these factors may explain the dominance of *Eudendrium carneum* in Sydney Harbour.

The only hydrozoan found in the survey of the same genus as any on Schedule 3 was *Bougainvillia muscus.* This species was found from scrapings at six sites has been positively identified to species by Watson. It is not the introduced *Bougainvillia ramosa.* However, Briggs (1931) recorded *Bougainvillia muscus* as *Bougainvillia ramosa* from several localities in Sydney Harbour.

8.5 Phylum Echinodermata

The only class of Echinodermata on Schedule 3 is the Asteroidea or sea stars and all specimens were identified to species. Three species of asteroids were found in the survey (*Coscinasterias calamaria, Patiriella exigua* and *Astropecten vappa*) and none of these species is listed on Schedule 3. The two species listed on Schedule 3 (*Patiriella regularis* and *Astrostole scaber*) were not found in the survey of Sydney Harbour.

Patiriella regularis and *Astrostole scaber* are common species in New Zealand (Morton and Miller, 1968; Rowe and Gates, 1995) and south east Tasmania (Dartnall, 1969). *Patiriella regularis* was not found in Tasmania before 1930 and Dartnall (1969) concluded that both species of sea star were probably introduced to Tasmania from New Zealand with oysters in the 1930's.

Patiriella mimica was described from a single specimen from Newcastle Bight, New South Wales by Livingstone in 1933 but this species has been synonymised with *Patiriella regularis* (Dartnall, 1970). This specimen is the only record of *Patiriella regularis* from New South Wales (Australian Museum Faunal Database).

In Australia, *Astrostole scaber* (incorrectly listed in Schedule 3 as *Astrostole scabra*) has not been found outside Tasmania (Rowe and Gates, 1995).

8.6 Phylum Ectoprocta

All specimens of bryozoans were identified and 17 species were recorded (Appendix 11). Seven species are believed to be introduced (which includes four species from Schedule 3 - *Bugula flabellata, Bugula neritina, Conopeum tenuissimum* and *Schizoporella unicornis*), two species are cryptogenic, and the remaining eight species are endemic.

Bugula flabellata was found at 16 of 21 sites from scrapings, grabs and trawls. It is known from the Atlantic coasts of Europe and America, California, Mediterranean and Brazil (Ferguson Wood and Allen, 1958). It was introduced to New South Wales and South Australia from southern Britain before the 1940's, and is now distributed from New South Wales to Western Australia (Pollard and Pethebridge, 2000). The Australian Museum Faunal Database has specimens collected in Sydney Harbour from 1933. *Bugula flabellata* prefers vertical, shaded, sublittoral areas, and in particular areas where hydrological conditions approximate the open sea (Furlani, 1996). This would explain why it was found at nearly all the sites in the lower reaches of the harbour.

Bugula neritina was found at 10 of 21 sites from scrapings, grabs and trawls, but was not as common as *Bugula flabellata.* It is a cosmopolitan species found commonly in tropical ports and harbours, it is also a very common fouling organism (Shepherd and Thomas, 1982). It was first found in Australia from Victoria in the 1880's, Waters (1887a) reports it as common from Balls Head, Sydney Harbour, and the Australian Museum Faunal Database has specimens collected in

Sydney Harbour from earlier than 1905. Therefore, it has been established in southern Australia for over a century. At present it occurs in many ports from New South Wales to South Australia (Pollard and Pethebridge, 2000). It has a short larval life and usually settles on hard substrata within two hours, it also displays rapid growth patterns and colonies can attain heights of up to 7 cm within two months (Gordon and Mawatari, 1992).

Conopeum tenuissimum was found at two scraping sites, both in the upper reaches of the port (Blackwattle Bay and White Bay west). It is originally described from the Gulf of Mexico, and is now a common estuarine species along the east and west coasts of USA, and is one of three species which are truly estuarine bryozoans (Winston, 1982). It is not known when this species was introduced into Australia, with no records of this species from Australia in the Australian Museum Faunal Database.

Schizoporella unicornis was found at 15 of 21 sites from scrapings, grabs and trawls. It was observed in the field to be the dominant species of bryozoan in the port, and formed at times very large, purple, encrusting colonies on facings and piles. It is native to Japan and is widely distributed throughout temperate and tropical seas, especially in the northern hemisphere (Ferguson Wood and Allen, 1958). It was first introduced to Australia via hull fouling or oyster mariculture to Sydney Harbour in the 1940's and has since spread to South Australia and Fremantle, Western Australia.

Tricellaria occidentalis was found at 12 of 21 sites from scrapings, grabs and trawls. This species is not on Schedule 3, but is believed to be introduced. It is native to California, and is found from British Columbia to Baja California, China, Japan, Italy and New Zealand (Pollard and Pethebridge, 2000). It has been recorded in Australia from New South Wales, Victoria and South Australia.

Watersipora subtorquata was found at 20 of 21 sites from scrapings, grabs and trawls. This species is not on Schedule 3, but is believed to be introduced. The type locality is given as Rio de Janeiro, Brazil but its native range is currently unresolved. It has a wide global distribution of Brazil, Japan, West Indies and Australia (Gordon and Mawatari, 1992). *Watersipora subtorquata* has been recorded in Australia from Torres Strait, Townsville, Victoria (Currie et al., 1998) and Twofold Bay (Australian Museum Faunal Database).

Bowerbankia sp. was found at two scraping sites (Garden Island east and Glebe Island east). Dr Nair was unable to identify these specimens to species but believes the genus to be introduced. The genus *Bowerbankia* was first recorded from Australia in the 1970's and was most probably introduced via hull fouling (Pollard and Pethebridge, 2000).

Bugula sp. was found at one scraping site (Garden Island east). Dr Nair was unable to identify this single specimen to species but believes it to be cryptogenic (Nair, pers. com.).

Fenestrulina malusii was found at 14 of 21 sites from scrapings and grabs. This cryptogenic species is cosmopolitan and was described from the Red Sea by Audouin in 1826, but its native range is unresolved. Waters (1887b) reports it from Bottle and Glass Rocks, the Australian Museum Faunal Database has many records of this species from Sydney Harbour in the late 19th century, and from Victoria and Queensland in the early 20th century. Therefore, *Fenestrulina malusii* has been present in Sydney Harbour for over 115 years.

The remaining eight endemic species have all been recorded from Sydney Harbour or New South Wales, and as such do not represent new distributions.

8.7 Phylum Entoprocta

The single introduced kamptozoan species on Schedule 3, *Barentsia benedeni*, was not found in this survey of Sydney Harbour. This species is native to Europe and has spread across the northern hemisphere via hull fouling. There are no records of this species occurring in Australia.

8.8 Phylum Mollusca

All specimens of molluscs were identified and 87 species and genera were identified - 25 Bivalvia, 59 Gastropoda, one Cephalopoda, one Polyplacophora and one Scaphopoda (Appendix 12). One species from Schedule 3 (*Theora lubrica)* was found in this survey.

Theora lubrica (Asian clam) was found at eight of 18 trawl sites. It is native to the Western Pacific, and is common in muddy sediments in bays throughout Japan where it can reach very high densities (Currie et al. 1998). *Theora lubrica* was first identified in Australia from the Swan Estuary, Western Australia in 1971 (Chalmer et al. 1976) and from Port Phillip Bay since at least 1969 (Poore and Rainer, 1974 - as *Theora fragilis*). It is thought to have been introduced to Australia via ballast water in commercial shipping (Hutchings et al. 1987). At present it is known from Devonport in Tasmania, Westernport in Victoria and Botany Bay in New South Wales (Cohen et al. 2001). This is the first time *Theora lubrica* has been recorded from Sydney Harbour. The nomenclature of this species has been somewhat unstable in the past, it has commonly been confused with *Theora fragilis* Adams, 1855 - type locality Moreton Bay, Queensland (Hewitt et al. 1999). Work done by Climo (1976) confirmed that *Theora lubrica* and *Theora fragilis* are indeed distinct species.

The oysters as a group (Family Ostreidae) are morphologically similar and identifications based solely on shell characters can be unreliable (Ponder, pers. com.). The collections in this survey appear to be mainly *Saccostrea glomerata* (Sydney rock oyster) but the possibility of juvenile *Crassostrea* being present could not be reliably excluded. The taxon identified as "*Ostrea*" is possibly more than one species and its relationships with foreign oysters unknown. Currently, New South Wales oysters in general are being reviewed by an expert in Japan.

Three species from Schedule 3, *Polycera hedgpethi, Terodo navalis* and *Zeacumantus subcarinatus,* have been recorded from Sydney Harbour (Australian Museum Faunal Database - Appendix 17) but were not found in this survey. *Terodo navalis* is a wood boring bivalve, a habitat not sampled in the survey. *Zeacumantus subcarinatus* is a gastropod typically found in mangroves and mud flats, also a habitat not sampled in this survey.

8.9 Phylum Porifera

All specimens of sponges were identified and 38 species were identified (Appendix 13). There are no sponges listed on Schedule 3 but sponges would be likely species to be spread by hull fouling as they are found as fouling organisms on hard surfaces including mussel shells.

8.10 Plantae

All specimens of marine plants were identified and 127 species were found. Associate Professor Gustaaf Hallegraeff and Miguel de Salas (University of Tasmania) identified 57 species of dinoflagellates. Dr Alan Millar and Nick Yee (Royal Botanic Gardens, Sydney) identified eight species of green algae (Chlorophyta), 10 species of brown algae (Phaeophyta), 51 species of red algae (Rhodophyta) and one species of diatom (Bacillariophyta). One of the 13 species (*Caulerpa filiformis*) from Schedule 3 was found.

8.10.1 Chlorophyta

Eight species of green algae were recorded from this survey of Sydney Harbour (Appendix 14). Seven species have south-eastern Australian distribution ranges (Millar and Yee, pers. com.) and one species, *Caulerpa filiformis*, is listed on Schedule 3.

Caulerpa filiformis was thought to have been introduced from South Africa to Australia in Botany Bay and Port Jackson in 1923 (May, 1976). Since then it has proliferated and now covers extensive areas of the lower eulittoral zone on rock platforms from Wollongong to Port Stephens, New South Wales (Clayton and King, 1990). However, recent genetic work by Pillman et al. (1997) has shown that the Australian *Caulerpa filiformis* differs from the South African form. Alan Millar (Royal Botanic Gardens, pers com.) believes that the species is native to both countries, and the two different populations are probably remnants of Gondwanan populations.

8.10.2 Dinophyta

In addition to the two dinoflagellate species found from ABWMAC Schedule 1 (see section 6.1 above), 26 species of cysts from the sediment cores and 29 species of plankton cells from the plankton nets were identified in this survey from Sydney Harbour (Appendix 6), but none is listed in Schedule 3.

8.10.3 Phaeophyta

Ten species of brown algae were recorded from this survey of Sydney Harbour (Appendix 14). None of these is introduced species, and all have south-eastern Australian distribution ranges (Millar and Yee, pers. com.).

8.10.4 Rhodophyta

Fifty one species of red algae were recorded from this survey of Sydney Harbour (Appendix 14). None of these is introduced species, and all have south-eastern Australian distribution ranges (Millar and Yee, pers. com.).

9 Distribution and impacts of introduced species in Sydney Harbour

Sydney Harbour has been an international port since European settlement, receiving ships from many overseas ports. Initially most of the trade was from northern Europe but more recently also from Asia. Sydney Harbour is also a busy harbour for recreational boating, fishing, defence activities and domestic shipping. Therefore, for over 200 years Sydney Harbour may have been receiving exotic species. Initially these would be primarily hull fouling organisms and more recently from ballast water. However, the Port of Sydney is considered an import port, and as a result, the majority of cargo vessels do not discharge ballast water in Sydney Harbour. This is an important factor, as it decreases the risk of Sydney Harbour being exposed to frequent new inoculations from high volumes of ballast water discharge.

The sampling conducted for this project represents only fauna and flora at selected sites in Sydney Harbour during autumn 2001. A large part of the harbour has not been sampled and additional species on Schedules 1, 2 and 3 may be present in other parts of the harbour, at different times of year, or may be new introductions at any time.

9.1 Schedule 1 species - ABWMAC target pest species

The only species from Schedule 1 that were found in Sydney Harbour were dinoflagellate cysts. The dominant taxon was *Alexandrium catenella/tamarense*, which occurred at 16 of the 17 sites. The cysts were not viable and are therefore not considered to pose a risk of causing a toxic algal bloom, although there have been blooms in Sydney Harbour in the early 1990's.

9.2 Schedule 2 species - marine species that pose a threat to Australia

The only species found from Schedule 2 was *Mytilus galloprovincialis*. This species is abundant in Sydney Harbour on wharf piles, rocks, and cement facings of wharves. The taxonomy is confused and there may be a cryptic endemic species in Australia. The impact of *Mytilus galloprovincialis* on the endemic fauna and flora is not known. *Mytilus galloprovincialis* may have displaced endemic species in establishing its dominance of hard sublittoral surfaces. Clumps of *Mytilus galloprovincialis* provide a habitat for cryptic and encrusting animals and plants.

9.3 Schedule 3 species - known or likely exotic marine species in Australian waters

Seventeen species of plants and animals from Schedule 3 were found in the survey of Sydney Harbour. In addition, another ten species listed on Schedule 3 are recorded from Sydney Harbour in the Australian Museum Faunal Database but were not found in this survey (Appendix 1). The majority of the species found are hull fouling (ie. barnacles, ascidians and bryozoans) or wood boring organisms (isopods and molluscs) and have been living in Sydney Harbour for many years (Appendix 17). An additional nine species were found in the survey which may be introduced and these species should be assessed for inclusion on Schedule 3 (Appendix 2).

The impact of these species has not been studied but all appear to be well established species in Sydney Harbour and have been living there for many years (Appendix 17). Most are widespread and it is unclear whether they have displaced endemic species.

10 Origin and possible vectors for the introduction of exotic species in Sydney Harbour

The exotic species found in this baseline survey of the port of Sydney Harbour were probably introduced directly to the port by hull fouling and ballast water, or by domestic translocation by commercial fishing and recreational vessels. Some exotic species found in Sydney Harbour may be the result of natural range expansions of species introduced to other domestic ports.

The determination of the origins of a species can be a very complex issue. For example, the first place from which a species is discovered (the type locality) does not necessarily define its native range. The type locality of a species may be the result of an introduction. Detailed biogeographical and molecular studies may be necessary to determine the geographical origin of a species.

The study of marine species introductions is further complicated by taxonomic problems. Many marine groups include species which appear to have wide geographical ranges, so called “cosmopolitan species”. Often upon detailed examination these cosmopolitan species have been found to contain a whole suite of sibling species. The separation of these species may require experts to distinguish subtle differences, make detailed examinations and depend on mature complete individuals. Many introduced species in Schedule 3 are cosmopolitan, and until extensive research is done on these species, one cannot be sure whether a species is introduced or is a suite of species within their native ranges. Sections 6, 7 and 8 give detailed discussion of these issues for species found in Sydney Harbour.

These problems can be resolved by detailed taxonomic studies and highlight the need for material collected during introduced species baseline surveys to be deposited in a recognised institution and available for subsequent comparative studies. Such collections will also facilitate studies to document the changes in distribution and abundance of introduced and native species and to assess the impact of introduced species on native fauna and flora.

11 Influences of the port environment and port practices on colonisation and survival of introduced species

Sydney Harbour is an estuary with seawater replenished by tidal exchange at the seaward end, and freshwater inputs from Parramatta River and terrestrial runoff. There are numerous habitats (be they natural or urban) supporting very diverse and complex assemblages of species (Underwood and Chapman, 1998). Ecological relationships of animals and plants from place to place in the harbour are variable and complex due to the diverse habitats being connected by water-flow which changes direction and character.

The fauna and flora of the port of Sydney Harbour is indicative of a marine-dominated estuarine environment. Of the introduced species found in this survey, the majority are not restricted to estuarine environments, and therefore, some species may be capable of extending their ranges beyond the confines of Sydney Harbour.

The port of Sydney Harbour handles more imports than exports, and as a result the number of ships discharging ballast water is relatively low for a port of its size. From figures supplied to Sydney Ports Corporation from AQIS for 2000, 28% of all ships entering the port (domestic and international) discharge ballast water, with an average discharge of less than two ballast tanks each (Appendix 4).

Hull fouling in Sydney Harbour may have significant influences on the inoculation and establishment of introduced species. In-water hull cleaning of all commercial vessels is prohibited, and commercial vessels less than 25 metres long can only carry out hull cleaning activities above the tidal zone over appropriate drop sheets (ANZECC, 1997). The NSW Waterways Authority has regulations for hull cleaning of fishing and recreational vessels which require that the vessels be removed from the water, when possible, and debris be captured and disposed of properly. Therefore, in the future, introductions as a result of hull cleaning activities should be reduced. However, in-water hull cleaning was a common practice in the past, and some recreational boats are still cleaned on their moorings or at pontoons with the scrapings falling directly into the harbour and potentially releasing species to settle onto the substrata. Many hull fouling organisms can spread in the harbour without actually being cleaned off hulls, as they release pelagic larvae into the water column which then disperse and settle on suitable substrata. In a study by Floerl (2001) of introduced marine pests in Port Phillip Bay, New Zealand, Hawaii and Elkhorn Slough, USA, he suggests that between 69-74% of the introduced species arrived via hull fouling rather than ballast water. Floerl believes that hull fouling is a much more important introduction vector than previously realised.

Many introduced species appear to require some form of disturbance, such as dredging, in order to enter an existing native community, however, dredging has not occurred in Sydney Harbour in the last ten years.

During this survey sampling was restricted to the Port of Sydney. However, it must be noted that much shipping occurs outside the port, both upstream and downstream of the port area. Detailed figures are not available as to the amount of such shipping and boating activities in Sydney Harbour but it may be a cause for concern in regard to the introduction of marine species.

12 Assessment of the risk of new introductions to the port

Domestic and international shipping pose an ongoing risk for new introductions to Sydney Harbour from hull fouling, ballast discharge and accidental introductions. Carlton (2001) stresses that "the invasion picture is dynamic and ever changing" and that the absence of pest species from a port does not guarantee that the port will be immune from future introductions. The survival of introduced organisms depends on their environmental tolerance and the environmental conditions of the port, and the most important conditions are temperature and habitat (Hutchings et al. 2002).

From figures supplied by Sydney Ports Corporation for 2000, 75% of incoming ships have a domestic port as their last port of call. Brisbane is the most common 'last port of call' for domestic shipping arriving in Sydney (36%). The higher water temperatures of the Port of Brisbane indicate a low risk factor, however, the results of the port survey for introduced species in the Port of Brisbane are not available at the time of writing this report. The risk factor will need to be reconsidered when the results of the survey of the Port of Brisbane are available.

Cohen et al (2001) in the survey of the Port of Melbourne found six of the eight Schedule 1 ABWMAC target species. In 2000, 25% of our domestic shipping came from Port of Melbourne, combined with 4% from Geelong, which means almost 30% of Sydney Harbour's annual domestic shipping arrives from the Melbourne area. This high proportion of shipping from Melbourne, combined with the presence of many ABWMAC target species, places domestic shipping from Melbourne as the highest risk factor for new introductions to Sydney Harbour.

Hobart also has six of the eight Schedule 1 ABWMAC target species present, and even though less than 1% of Sydney Harbour's domestic shipping has Hobart as a last port of call, Hobart should also be considered a high risk factor.

The large cruise ships which come into Sydney Harbour may come from the South Pacific or other tropical regions, and represent additional shipping routes to those employed by cargo and container ships. The recent introduction of the black striped false mussel, *Mytilopsis sallei,* in the Port of Darwin was via hull fouling on an itinerant fishing vessel and an international cruising yacht (Willan et al. 2000). This highlights the risk of introductions from non-commercial vessels which may not be as diligent in their hull cleaning as commercial shipping (Hutchings et al. 2002). Over 950 yachts arrive in Australia from overseas every year (Floerl, 2001), in addition to thousands of yacht passages within Australian waters.

12.1 Risk of introduction of Schedule 1 species - ABWMAC target species

Although Sydney Harbour does not have any viable ABWMAC target species, the risk of future introductions cannot be ignored. The cysts of the dinoflagellate *Alexandrium* *catenella/tamarense,* which are present in the sediment of Sydney Harbour may remain viable for four to five years, but those collected in the survey were old or damaged (Hallegraeff and de Salas, pers. com.). These cysts may be from earlier blooms of *Alexandrium catenella* ("red tides") in Sydney Harbour in the early 1990's. There is the potential for new introductions of dinoflagellates and under the right conditions (ie. oxygen supply, water temperature, light, nutrients and dredging), for "blooms" to occur, giving rise to serious human health problems. The risk of dinoflagellate introductions could be reduced by exchanging ballast water in transit in the open ocean when leaving a port where a recent dinoflagellate bloom has occurred.

Since being introduced into Tasmanian waters, *Asterias amurensis* has become the dominant invertebrate predator of benthic communities in the Derwent River estuary (Grannum et al., 1996) and is found in large numbers in Port Phillip Bay (Hutchings, 1999; Thresher, 1999). *Asterias amurensis* is a cold-temperate species, inhabiting waters ranging from 7-10°C in its natural habitat (Turner, 1992) and from 15.5-18.2°C in the Derwent River estuary. The temperature ranges tolerated by *Asterias amurensis* would inhibit its colonisation of most parts of the east coast of the Australian mainland (AMBS, 1997). Sydney Harbour's annual temperature range of 15-22°C indicates that the survival of both adults and larvae would be limited in the harbour and surrounds. This species is dioecious (separate sexes) and each female may spawn up to 19 million eggs annually (Kim, 1968), therefore, with favourable environmental factors as in Tasmania the populations can increase rapidly. The larvae could be transported in ballast water, and adults by accidental introductions, such as attached to fishing gear.

Despite *Sabella spallanzanii* being a common species in Europe, there is a dearth of information about its biology, such that the temperature range for the successful introduction of this species is not well understood. In Australia *S. spallanzanii* is usually found attached to submerged objects such as rocks, piles, buoys, channel markers and jetties. They have also been found embedded in sand and mud, and prefer quieter, less exposed conditions (Carey and Watson, 1992). Sydney Harbour includes many areas suitable for colonisation by *S. spallanzanii.* When present in large numbers it can significantly alter subtidal communities by changing the micro-currents and completely filtering the water column, leaving no food for other organisms present. *Sabella spallanzanii* is more likely to be transported around Australia via hull fouling and scallop dredges, but could also be transported in ballast water (AMBS, 1997). Because of its drastic effect on benthic communities and the availability of suitable habitat, the introduction of *S. spallanzanii* to Sydney Harbour could have serious consequences.

Although *Carcinus maenas* is not found in Sydney Harbour, the short larval stage of 17-80 days (Cohen et al., 1995) suggests that there is potential for larvae to be transported in ballast water from New Zealand or by domestic shipping. As *Carcinus maenas* has been present in Australia for over one hundred years, its potential for further distribution may be limited. It may already occur in all potential habitats in Australia (AMBS, 1997).

Undaria pinnatifida is a northern hemisphere temperate water species found sub-tidally from 1-15 m depth, with a preference for sheltered areas. This species has never been found in New South Wales but has been introduced to Tasmania and Victoria. It could be introduced to Sydney Harbour by hull fouling or ballast water. The greatest risk of introduction of *Undaria pinnatifida* is from Victoria because almost 30% of domestic shipping originates from Melbourne. Zoospores (the motile asexual spore of the algae) could be transported by ballast water, however, gametophytes (the gamete-producing second stage in the algae's life cycle), are limited in their potential for transport by ballast water due to the fact they are usually attached to the substratum and ballast tanks lack light for photosynthesis (Peters and Breeman, 1992). The introduction of *Undaria pinnatifida* via zoospores is far more likely than via gametophytes, unless sand is taken up with the water for the ballast tanks and the ship's journey is relatively short. The mature sporophyte is unable to be transported in ballast water due to their size and need for light, but could also be transported by hull fouling. The preferred temperature for zoospore settlement is less than 20°C (Saito, 1975). The preferred temperature for sporophyte growth is 15-17°C, and growth of thalli decreases above 20°C (Saito, 1975). The temperature tolerance of different life stages of *Undaria pinnatifida* suggest that it could survive in Sydney Harbour.

13 Assessment of the risk of translocation of introduced species found in Sydney Harbour

An assessment of risks of translocation of introduced species from Sydney Harbour to other ports involves similar considerations to those in section 12 above.

Any ships taking up ballast water in Sydney Harbour run the risk of potentially discharging exotic species to other ports in Australia or overseas. The likelihood of successful transport and establishment of exotic species in other ports depends on the distance and temperature change of the journey, as well as suitable environmental factors at the port where the ballast water is discharged. Dinoflagellate cysts taken up in ballast water need to be viable to cause blooms in other ports. As none of the toxic dinoflagellate cysts found in this survey were viable there is no cause for concern in their spread from Sydney Harbour, unless viable cysts are re-introduced in the future.

The risk of translocation of exotic species by hull fouling is relatively high, as the majority of the introduced species in this survey are hull foulers (barnacles, bryozoans and ascidians) (Floerl, 2001). The fact that many ports within south-eastern Australia have environments similar to Sydney Harbour increases this risk.

14 Recommendations

14.1 Recommendations for Sydney Ports Corporation

1. It is recommend that ongoing monitoring for introduced species be undertaken every three to five years. This recommendation is also made by Hewitt and Martin (2001). It is suggested that the intensity of sampling in wharf areas be reduced, but additional areas outside the port area should be included in the sampling program.
2. If ongoing monitoring for toxic dinoflagellates were to be considered, it is recommended that plankton sampling would be more appropriate than sediment sampling. The existing non-viable cysts will not cause any blooms, and therefore there is no reason for further sediment sampling. However, any viable cysts which may be introduced via ballast water in the future only require favourable environmental conditions to germinate and form a bloom. Plankton sampling of the water column would detect blooms and would also allow the dinoflagellates to be positively identified to species to determine whether the bloom was toxic. Monitoring would aid in determining the environmental conditions that trigger a bloom for the toxic dinoflagellate species of *Alexandrium* and *Gymnodinium* (Hallegraeff, pers. com.). It is recommended that the design of any monitoring program be discussed with Assoc. Prof. Gustaaf Hallegraeff, University of Tasmania.
3. It is suggested that the results from the survey of the Port of Brisbane be reviewed when available because of the high volume of shipping from Brisbane to Sydney.

14.2 Recommendations for Regulatory Bodies

1. It is recommended that the potential for introductions by the commercial fishing fleet, recreational shipping and the aquaculture industry be considered.
2. It is recommended that the uptake of ballast water from Port Phillip Bay be prohibited during the spawning season of ABWMAC pest species.
3. A program should be maintained to alert the public to the potential for marine introductions. The public should be encouraged to seek expert identifications. The Australian Museum provides a free identification service by expert taxonomists for public enquiries.
4. It is recommended that the schedules of introduced species (Hewitt and Martin, 1996) need to be reviewed and the criteria discussed and accepted by the scientific community. Hewitt and Martin (2001) only include Schedule 1, but it is essential to establish which species are introduced even if not ABWMAC pest species. Before future surveys are carried out it would be beneficial for all parties who have conducted port surveys around Australia to meet in a workshop to review sampling protocols, lists of introduced species and recommendations.

14.3 Recommendations by the Australian Museum for future studies

1. Any future monitoring program should include additional habitats which are known to be suitable for introduced species, such as wooden structures containing boring species, intertidal mud flats and rocky shores.
2. In future surveys, a selection of material should be preserved in 100% ethanol for molecular analyses which may facilitate the determination of the native range of species and ascertain which species are introduced and which are native.
3. Ecological studies should be encouraged to assess the impact of introduced species in Sydney Harbour. Student scholarships could be offered to study this topic.

15 References

Ahyong, S.T., 2001. Revision of the Australian Stomatopod Crustacea. *Records of the Australian Museum, Supplement* **26**. 326pp.

Allen, F.E., 1953. Distribution of marine invertebrates by ships. *Australian Journal of Marine and Freshwater Research* **4**(2): 307-316.

ANZECC, Australian and New Zealand Environment and Conservation Council, 1997. Code Of Practice for Antifouling and In-water Hull Cleaning and Maintenance. 12pp.

Arimoto, I., 1976. Taxonomic studies of caprellids (Crustacea, Amphipoda, Caprellidae) found in the Japanese and adjacent waters. Nippon Printing & Publishing Co., Ltd., Osaka, Japan. 229pp.

Australian Museum Business Services (AMBS), 1997. Ability of Target Organisms to Survive in Ballast Water. Report for AQIS.

Bower, S.M., 1996. Synopsis of Infectious Diseases and Parasites of Commercially Exploited Shellfish: *Mytilicola orientalis* (Red Worm) of Oysters. URL: http://www-sci.pac.dfo-mpo.gc.ca/sealane/aquac/pages/morwoy.htm

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

Briggs, E.A., 1931. Notes on Australian Athecate Hydroids. *Records of the Australian Museum* **18**: 279-282.

Bruce, N.L., 1986. Cirolanidae (Crustacea: Isopoda) of Australia. *Records of the Australian Museum, Supplement* **6**. 239pp.

Buttermore, R.E., Turner, E., and Morrice, M.G., 1994. The introduced northern Pacific seastar *Asterias amurensis* in Tasmania. *Memoirs of the Queensland Museum* **36**(1): 21-26.

Carey, J.M., and Watson, J.E., 1992. Benthos of the muddy bottom habitat of the Geelong Arm of Port Phillip Bay, Victoria, Australia. *Victorian Naturalist* **109**(6): 196-202.

Carlton, J.T., 1985. Transoceanic and interoceanic dispersal of coastal marine organisms: the biology of ballast water. *Oceanography and Marine Biology Annual Review* **23**: 313-371.

Carlton, J.T., 2001. Introduced Species in U.S. Coastal Waters. Prepared for the Pew Oceans Commission. 28pp.

Chalmer, P.N., Hodgkin, E.P., and Kendrick, P.W., 1976. Benthic faunal changes in a seasonal estuary of south-east Australia. *Records of the Western Australian Museum* **4**(4): 383-410.

Chapman, J.W., and Carlton, J.T., 1991. A test of criteria for introduced species: the global invasion by the isopod *Synidotea laevidorsalis* (Miers, 1881). *Journal of Crustacean Biology* **11**: 386-400.

Chapman, J.W., and Carlton, J.T., 1994. Predicted discoveries of the introduced isopod *Synidotea laevidorsalis* (Miers, 1881). *Journal of Crustacean Biology* **14**: 700-714.

Clayton, M.N., and King, R.J. (Eds), 1990. Biology of Marine Plants. Longman Cheshire, Melbourne, Australia. 501pp.

Climo, F.M., 1976. The occurrence of *Theora (Endopleura) lubrica* Gould, 1861 (Mollusca: Bivalvia: Semelidae) in New Zealand. *Auckland Institute and Museum Conchology Section Bulletin* **1**: 11-16.

Connell, S.D., 1999. Effects of surface orientation on the cover of epibiota. *Biofouling* **14**: 219-226.

Connell, S.D., and Glasby, T.M., 1999. Do urban structures influence local abundance and diversity of subtidal epibiota? A case study from Sydney Harbour, Australia. *Marine Environmental Research* **47**: 373-387.

Cohen, A.N., Carlton, J.Y., and Fountain, M.C., 1995. Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California. *Marine Biology* **122**: 225-237.

Cohen, B.F., McArthur, M.A., and Parry, G.D., 2001. Exotic Marine Pests in the Port of Melbourne, Victoria. Marine and Freshwater Resources Institute, Report No.25. 69pp.

Cookson, L.J., 1991. Australasian species of Limnoriidae (Crustacea: Isopoda*). Memoirs of the Museum of Victoria* **52**(2):137-262.

Cookson,L.J., 1997. Additions to the taxonomy of the Limnoriidae (Crustacea: Isopoda). *Memoirs of the Museum of Victoria* **56**(1):129-143.

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

Currie, D.R., McArthur, M.A., and Cohen, B.F., 1998. Exotic Marine Pests in the Port of Geelong, Victoria. Marine and Freshwater Resources Institute, Report No.8. 72pp.

Dartnall, A.J., 1969. New Zealand Sea Stars in Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **103**: 53-55.

Dartnall, A.J., 1970. The Asterinid Sea Stars of Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **104**: 73-77.

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

Floerl, O., 2001. Loopholes For Marine Invaders. *Waves, The Marine & Coastal Community Network* **8**(3): 1-2.

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

Fulton, S.W., and Grant, F.E., 1902. Some little known Victorian Decapod Crsuatcea with description of a new species. *Proceedings of the Royal Society of Victoria* **14**(2): 55-64.

Furlani, D.M., 1996. A guide to the introduced marine species in Australian waters. *CRIMP Technical Report No.* **5**. CSIRO Division of Fisheries, Hobart.

GESAMP (IMO/FAO/UNESCO-IOC/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection), 1997. Opportunistic settlers and the problem of the ctenophore *Mnemiopsis leidyi* invasion in the Black Sea. Rep. Stud. GESAMP, **58**: 84pp.

Gomon, M.F., Glover, J.C.M., and Kuiter, R.H. (eds), 1994. The fishes of Australia's south coast. Flora and Fauna of South Australia Handbooks Committee. State Printer, Adelaide. 1-992.

Gordon, D.P., and Mawatari, S.F., 1992. Atlas of marine fouling Bryozoa of New Zealand ports and harbours. *New Zealand Oceanographic Institue, Miscellaneous Publications* **107**:1-52.

Grannum, K., Murfet, N.B., Ritz, D.A., and Turner, E., 1996. The distribution and impact of the exotic seastar *Asteria amurensis* (Lütken), in Tasmania. Pp. *in* The introduced Northern Pacific Seastar, *Asterias amurensis* in Tasmania Australian Nature Conservation Agency, Canberra.

Grosholz, E.D. and Ruiz, G.M., 1995. Spread and potential impact of the recently introduced European green crab, *Carcinus maenas,* in central California. *Marine Biology* **122**: 239-247.

Hallegraeff, G.M., and Bolch, C.J., 1991. Transport of toxic dinoflagellate cysts via ships' ballast water. *Marine Pollution Bulletin* **22**(1): 27-30.

Hallegraeff, G.M., Bolch, C.J., Blackburn, S.I., and Oshima, Y., 1991. Species of the toxigenic dinoflagellate genus *Alexandrium* in southeastern Australaian waters. *Botanica Marina* **34**: 575-587.

Harrison, K., and Holdich, D.M., 1982. New eubranchiate sphaeromatid isopods from Queensland waters. *Memoirs of the Queensland Museum* **20**(3): 421-446.

Haswell, W.A., 1879a. On Australian Amphipoda. *Proceedings of the Linnean Society of New South Wales* **4**(3): 245–279.

Haswell, W.A., 1879b. On some additional new genera and species of amphipodous crustacaeans. *Proceedings of the Linnean Society of New South Wales* **4**(3): 319-351.

Haswell, W.A., 1881. On some new amphipods from Australia and Tasmania. *Proceedings of the Linnean Society of New South Wales* **5**(1): 97–105.

Haswell, W.A., 1884. The marine annelids of the order Serpulea. Some observations on their anatomy, with the characteristics of the Australian species. *Proceedings of the Linnean Society of New South Wales* **9**: 649–675.

Haswell, W.A., 1885. Notes on the Australian. *Proceedings of the Linnean Society of New South Wales* **10**(1): 95–114.

Haswell, W.A., 1886. Observations on some Australian Polychaeta. Part I. *Proceedings of the Linean Society of New South Wales* **10**: 733–756.

Heemstra, P.C., and Randall, J.E., 1993. Groupers of the World (Family Serranidae, Subfamily Epinephelinae); an annotated and illustrated catalogue of the grouper, rockcod, hind, coral grouper and lyretail species known to date. *FAO Species Catalog* **16**. Rome. i-viii, 1-382.

Heller, C. 1878. Beitrage zur nahern Kenntnis der Tunicaten. *Sber. Akad. Wiss. Wien* **77**(1): 2-28.

Herdman, W.A., 1899. Descriptive Catalogue of the Tunicata in the Australian Museum, Sydney, N.S.W. *Australian Museum, Sydney, Catalogue* **17**:1-139.

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

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

Hewitt, C.L., and Martin, R.B., 2001. Revised protocols for baseline port surveys for introduced marine species: survey design, sampling protocols and specimen handling. *CRIMP Technical Report No.* **22**, CSIRO Division of Fisheries, Hobart.

Hoedt, F.E., Choat, J.H., Cruz, J.J., and Collins, J.D., 2001. Sample collection methods and practical comnsiderations for introduced species' surveys at tropical ports. CRC Reef Research Centre, Technical Report No. 35. Townsville. 41pp.

Hoese, D.F., 1973. The introduction of the gobiid fishes, *Acanthogobius flavimanus* and *Tridentiger trigonocephalus*, into Australia. *Koolewong* **2**(3):3-5.

Hutchings, P., 1999. The limits to our knowledge of introduced marine invertebrates. Other 99% Conference. *Transactions of the Royal Zoological Society of New South Wales*: 26-29.

Hutchings, P.A., van der Velde, J.T., and Keable, S.J., 1987. Guidelines for the conduct of surveys for detecting introductions of non-indigenous marine species by ballast water and other vectors - and a review of marine introductions to Australia. *Occasional Reports of the Australian Museum* **3**: 147pp.

Hutchings, P.A., van der Velde, J.T., and Keable, S.J., 1989. Baseline survey of Twofold Bay NSW with a discussion of the marine species introduced into the Bay. *Proceedings of the Linnean Society of New South Wales* **110**(4): 339-367.

Hutchings, P.A., Hilliard, R.W., and Coles, S.L., 2002. Species Introductions and Potential for Marine Pest Invasions into Tropical Marine Communities, with Special Reference to the Indo-Pacific. *Pacific Science* **56**(2): 223-233.

Hyder Consulting, 1997. Port Environment Comparisons. Draft report to AQIS, Strategic Ballast Water Research Program, Project 4.

Jones, M.M., 1991. Marine organisms transported in ballast water. A review of the Australian scientific position. *Bureau of Rural Resources Bulletin* **11**: 1-45.

Kerr, S., 1994. Ballast Water Ports and Shipping Study. *AQIS Ballast Water Research Series Report No.* **5**, Australian Government Publishing Service, Canberra, ACT, Australia.

Kim, Y.S., 1968. Histological observations of the annual change in the gonad of the starfish, *Asterias amurensis* Lütken. *Bulletin of the Faculty of Fisheries Hokkaido University* **19**: 97-108.

Kott, P. 1972. Notes on some ascidians from Port Jackson, Botany Bay and Port Hacking, NSW. *Proceedings of the Linnean Society of New South Wales* **97**(4): 241-257.

Kott, P. 1985. The Australian Ascidiacea Pt 1, Phleobranchia and Stolidobranchia. *Memoirs of the Queensland Museum* **23**: 1-440.

Kott, P. 1990. The Australian Ascidiacea Pt 2, Aplousobranchia (1). *Memoirs of the Queensland Museum* **29**(1): 1-298.

Lockett, M.M., and Gomon, M.F., 2001. Ship mediated fish invasions in Australia: two new introductions and a consideration of two previous invasions. *Biological Invasions* (in press).

May, V., 1976. Changing dominance of an algal species (*Caulerpa filiformis* (Suhr) Hering). *Telopea* **1**(2): 136-138

McCain, J.C., and Steinberg, J.E., 1970. Part 2. Amphipoda I Caprellidea I Fam. Caprellidae pp1-78 in Gruner, H.E., and Holthuis, L.B. (eds) *Crustaceorum Catalogus.* Den Haag: Dr. W. Junk N.V.

McCulloch, A.R., 1913. Studies in Australian Crustacea No.3. *Records of the Australian Museum* **9**(3): 321-358.

McDowell, R.M., 1996. Freshwater fishes of south-eastern Australia. Reed Books. 247pp.

Millard, N.A.H., 1966. The Hydrozoa of the south and west coasts of South Africa. 3. The Gymnoblastea and small families of Calyptoblastea. *Annals of the South African Museum* **48**(18): 427-497.

Morrice, M.G., 1993. The distribution and ecology of the introduced northern Pacific seastar, *Asterias amurensis* (Lutken) in south-eastern Tasmania. Unpublished progress report, Australian Nature Conservation Agency, Canberra.

Morris, R,H., Abbott, D.P., and Haderlie, E.C., 1980. Intertidal Invertebrates of California. Stanford University Press. Stanford, CA. 690 pp.

Morton, J., and Miller, M., 1968. The New Zealand Sea Shore. Collins. 638pp.

New South Wales Department of Environment and Planning, 1987. Proposed Sydney Harbour tunnel environmental impact assessment. 103pp.

Paxton, J.R., Hoese, D.F., Allen, G.R., and Hanley, J.E., 1989. Zoological Catalogue of Australia. Volume 7. Pisces. Petromyzontidae to Carangidae. Australian Government Publishing Service, Canberra. v. 7: i-xii + 1-665.

Peters, A.F., and Breeman, A.M., 1992. Temperature responses of disjunct temperate brown algae indicate long-distance dispersal of microthalli across the tropics. *Journal of Phycology* **28**: 428-438.

Pillman, A., Woolcott, G.W., Olsen, J.L., Stam, W.T., and King, J., 1997. Inter- and intraspecific genetic variation in *Caulerpa* (Chlorophyta) based on nuclear rDNA ITS sequences. *European Journal of Phycology* **32**: 379-386.

Pollard, D.A., and Hutchings, P.A., 1990a A review of exotic marine organisms introduced to the Australian region. 1. Fishes *Asian Fisheries Science* **3**: 205-221.

Pollard, D.A., and Hutchings, P. A. 1990b. A review of exotic marine organisms introduced to the Australian region. II. Invertebrates and algae. *Asian Fisheries Science* **3**: 223-250.

Pollard, D.A., and Pethebridge, R.L., 2000. Report of Port Botany Bay Introduced Marine Pests Species Survey for Sydney Ports Corporation. New South Wales Fisheries Office of Conservation, 49pp

Ponder, W.F., Clark. S.A., and Dallwitz, M.J., 2000. Freshwater and Estuarine Molluscs: An Interactive, Illustrated Key for New South Wales. CD-ROM. CSIRO Publishing, Melbourne.

Poore, G.C.B., 1996. Species differentiation in *Synidotea* (Isopoda: Idoteidae) and recognition of introduced marine species: a reply to Chapman and Carlton. *Journal of Crustacean Biology* **16**(2): 384-394.

Poore, G.C.B., and Rainer, S., 1974. Distribution and abundance of soft bottom molluscs in Port Phillip Bay, Victoria. *Australian Journal of Marine and Freshwater Research* **29**: 371-411.

Randall, J.E., Johnson, G.D., and Lowe, G.R., 1989. *Triso*, a new generic name for the serranid fish previously known as *Trisotropis dermaterus*, with comments on its relationships. *Japanese Journal of Ichthyology* **35**(4): 414-420.

Rowe, F.W.E., and Gates, J., 1995. Echinodermata. *In* Wells, A. (ed.) *Zoological Catalogue of Australia.* **33**. Melbourne: CSIRO Australia. 510pp.

Rudman, W.B., 1998. Comment on *Philine auriformis*. URL: http://www.seaslugforum.net

Saito,Y., 1975. *Undaria*. In Tokida, J. (ed.) *Advances of Phycology in Japan.* The Hague. pp 304-320.

Shepherd, S.A., and Thomas, I.M. (Eds), 1982. Marine Invertebrates of Southern Australia, Part 1. J.D. Woolman, Government Printers, South Australia. 491pp.

Sinclair Knight & Partners, 1990. Rehabilitation of Boat Maintenance Facility, Berrys Bay. Environmental Impact Statement. Launches and Realty Pty Ltd, a divison of the Stannard Bros. Group.

Sydney Ports Corporation, 2001. URL: http://www.sydneyports.com.au/AboutUs

ten Hove, H.A., 1974. Notes on *Hydroides elegans* (Haswell, 1883) and *Mercierella enigmatica* Fauvel, 1923, alien serpulid polychaetes introduced into the Netherlands. *Bulletin Zoologisch Museum Universiteit van Amsterdam* **4**(6): 45-51.

Thresher, R.E., 1999. Diversity, Impacts and Options for Managing Invasive Marine Species in Australian Waters. *Australian Journal of Environmental Management* **16**: 137-148.

Turner, E., 1992. A northern Pacific seastar *Asterias amurensis,* in Tasmania. *Australian Marine Science Association Bulletin* **120**: 18-19.

Underwood, A.J., and Chapman, M.G., 1998. The Environment, An ideas paper on environmental issues for DUAP's Forum 'Sydney's Harbour Planning Strategy'. Report to NSW Department of Urban Affairs and Planning.

Waters, A.W., 1887a. Bryozoa from New South Wales, North Australia, &c. Part 1. *Annals and Magazine of Natural History* **20**: 81-95.

Waters, A.W., 1887b. Bryozoa from New South Wales, North Australia, &c. Part 2. *Annals and Magazine of Natural History* **20**: 181-203.

Watson, J.E., 1985. The genus *Eudendrium* (Hydrozoa, Hydroida) from Australia. *Proceedings of the Royal Society of Victoria* **97** 179-221.

Whitelegge, T.H., 1889. List of the marine and fresh-water invertebrate fauna of Port Jackson and the neighbourhood. *Royal Society of N.S.W.* 161pp.

Willan, R.C., Russell, B.C., Murfet, N.B., Moore, K.L., McEnnulty, F., Horner, S.K., Hewitt, C.L., Dally, G.M., Campbell, M.L., and Bourke, S.T., 2000. Outbreak of *Mytilopsis sallei* (Récluz, 1849) (Bivalvia: Dreissenidae) in Australia. *Molluscan Research* **20**(2): 25-30.

Williams, A.B., 1984. Shrimps, lobsters, and crabs of the Atlantic coast of the eastern United States, Maine to Florida. Smithsonian Institution Press, Washington D.C. i-xviii + 1-550.

Wilson, R.S., Heislers, S., and Poore, G.C.B., 1998. Changes in benthic communities of Port Phillip Bay, Australia, between 1969 and 1995. *Marine and Freshwater Research* **49**: 847-861.

Winston, J.E., 1982. Marine bryozoans (Ectoprocta) of the Indian River Area (Florida). *Bulletin of American Museum of Natural History* **173**(2): 100-176.

Zeidler, W., 1978. Note on the occurrence of the European shore crab *Carcinus meanas* (Linn., 1758) in Australia. *South Australian Naturalist* **53**(1): 11-12.

Appendix 1 - List of target species in Schedules 1, 2 & 3 (Hewitt and Martin, 1996)

Phylum	Class/Order	Genus & Species	Recorded in this survey (*)	Recorded by AM and RBG Databases in Sydney Harbour (*)
Schedule 1				
ABWMAC target introduced pest species				
Annelida	Polychaeta	*Sabella spallanzanii*		
Arthropoda	Decapoda	*Carcinus maenas*		
Echinodermata	Asteroidea	*Asterias amurensis*		
Phycophyta	Dinophyceae	*Alexandrium catenella*	*	
		Alexandrium minutum		
		Alexandrium tamarense	*	
		Gymnodinium catenatum		
Phaeophyta	Laminariales	*Undaria pinnatifida*		
Schedule 2				
Marine species that pose a threat to Australia				
Ctenophora	Lobata	*Mnemiopsis leidyi*		
Mollusca	Bivalvia	*Mytilus galloprovincialis*	*	*
		Potamocorbula amurensis		
	Gastropoda	*Philine auriformis*		
Chlorophyta	Codialea	*Codium fragile tomentosoides*		
Schedule 3				
Known or likely exotic marine species in Australian waters				
Annelida	Polychaeta	*Boccardia proboscidea*		
		Euchone limnicola	*	*
		Hydroides elegans	*	*
		Ficopomatus enigmaticus		*
		Polydora ciliata		
		Pseudopolydora paucibranchiata	*	*
Arthropoda	Amphipoda	*Caprella acanthogaster*		
	Cirripedia	*Balanus improvisus*		
		Megabalanus rosa	*	
		Megabalanus tintinnabulum		
		Notomegabalanus algicola		*

	Copepoda	*Mytilicola orientalis*		
	Decapoda	*Cancer novaezelandiae*		
		Halicarcinus innominatus		
		Palaemon macrodactylus		
		Petrolisthes elongatus		
		Pyromaia tuberculata		
		Rhithropanopeus harisii		
	Isopoda	*Cirolana harfordi*	*	*
		Eurylana arcuata	*	*
		Ligia oceanica		
		Limnoria lignorum		*
		Limnoria quadripunctata		*
		Limnoria tripunctata		*
		Paracerceis sculpta	*	*
		Paradella dianae		
		Sphaeroma serratum		
		Sphaeroma walkeri	*	*
		Synidotea laevidorsalis		
	Mysidacea	*Neomysis japonica*		
	Tanaidacea	*Leptochelia dubia*		
		Tanais dulongi		
Chordata	Ascidiacea	*Ascidiella aspersa*		
		Botrylloides leachi	*	*
		Botrylloides violaceus		
		Botryllus schlosseri		*
		Ciona intestinalis		*
		Molgula manhattensis		
		Styela clava		
		Styela plicata	*	*
	Pisces	*Acanthogobius flavimanus*		
		Forsterygion varium		
		Lateolabrax japonicus		
		Oreochromis mossambicus		
		Salmo salar		
		Salmo trutta		
		Sparidentex hasta		
		Tridentiger trigonocephalus	*	*
		Triso dermopterus		
Cnidaria	Anthozoa	*Diadumene lineata*		
	Hydrozoa	*Bougainvillia ramosa*		

		Cordylophora lacustris		
		Ectopleura crocea		
		Sarsia tubulosa		
Echinodermata	Asteroidea	*Astrostole scabra*		
		Patiriella regularis		
Ectoprocta	Cheilostomata	*Anguinella palmata*		
		Bugula flabellata	*	*
		Bugula neritina	*	*
		Conopeum tenuissimum	*	
		Conopeum tubigerum		
		Cryptosula pallasiana		
		Membranipora membranacea		
		Schizoporella unicornis	*	
		Watersipora arcuata		
Entoprocta	Barentsiidae	*Barentsia benedeni*		
Mollusca	Bivalvia	*Corbula gibba*		
		Crassostrea gigas		
		Ischadium demissum		
		Musculista senhousia		
		Perna canaliculus		
		Soletellina donacioides		
		Tapes japonica		
		Teredo navalis		*
		Theora lubrica	*	
		Venerupis largillierti		
	Gastropoda	*Aeolidiella indica*		
		Batillaria attramentaria		
		Bullia annulata		
		Ceratostoma inornatum		
		Corambe pacifica		
		Crepidula fornicata		
		Cymatium cutaceum africanum		
		Doridella steinbergae		
		Godiva quadricolor		
		Haliotis sanguinea		
		Illyanassa obsoleta		
		Janolus hyalinus		
		Maoricolpus roseus		
		Nassarius kraussianus		
		Okenia plana		

		Polycera capensis		
		Polycera hedgpethi		*
		Sakuraeolis enosimensis		
		Tenellia adspersa		
		Thecacera pennigera		
		Urosalpinx cinerea		
		Zeacumantus subcarinatus		*
	Polyplacophora	*Chiton glaucus*		
Chlorophyta	Caulerpales	*Caulerpa filiformis*	*	*
		Caulerpa geminata		
		Caulerpa racemosa		
		Caulerpa taxifolia		
Phaeophyta	Phaeophyceae	*Discosporangium mesarthrocarpum*		
		Sargassum muticum		
		Spacella subtilissima		
		Zosterocarpus sp.		
Rhodophyta	Rhodophyceae	*Antithamnionella spirographidis*		
		Arthrocladia villosa		
		Polysiphonia brodiaei		
		Polysiphonia pungens		
		Sperococcus compressus		

Appendix 2 - Species recorded from survey not listed on Schedule 3, which are believed to be introduced

Phylum	Class/Order	Genus & Species
Annelida	Polychaeta	*Boccardia chilensis*
		Hydroides diramphus
		Hydroides ezoensis
Arthropoda	Amphipoda	*Caprella californica*
	Stomatopoda	*Oratosquilla oratoria*
Chordata	Pisces	*Acentrogobius pflaumi*
Ectoprocta	Cheilostomata	*Bowerbankia* spp.
		Tricellaria unicornis
		Watersipora subtorquata

Appendix 3a – Details of port facilities for operating berths

Berth Name	Sydney Cove Passenger Terminal
Construction Date	1950's
Modification	Facility modernised in 2000-2001
Length	300 m
Nominal Depth	10.4 m
Main commodities handled	Passengers
Main Vessel Types	Cruise Vessels
Imports and Exports	-
Ballast is Discharged/Taken up	Small amounts discharged

Berth Name	Darling Harbour Passenger Terminal (Wharf 8)
Construction Date	Mid 1970's
Modification	This berth was formerly a container/bulk cargo berth, until modification in 2000. Cargo handled was formerly as for 3-7, and significant quantities of ballast was not discharged.
Length	335 m
Nominal Depth	9.8 m
Main commodities handled	Passengers
Main Vessel Types	Cruise Vessels
Imports and Exports	-
Ballast is Discharged/Taken up	Small amounts discharged

Berth Name	Darling Harbour Berths 3-7
Construction Date	Mid 1970's
Length	229, 287, 336, and 113 m respectively
Nominal Depth	11.2, 11.0, 10.5, and 9.9 m respectively
Main commodities handled	
Main Vessel Types	Container, Ro-Ro, and wet and dry bulk cargo vessels.
Imports and Exports	General, containerised and bulk cargo
Ballast is Discharged/Taken up	Container vessels generally have little need for ballast exchange because containers are generally exchanged on a one for one basis and any trim corrections are made by internal transfers within heeling tanks. Ro-Ro vessels seldom take on or discharge large volumes of ballast but small volumes (100-200 tonnes) may be loaded or discharged in port to achieve desired vessel trim. The bulk cargo is primarily imported at this berth therefore ballast water is primarily taken up here by bulk cargo vessels.

Berth Name	Glebe Island Berths 1 and 2
Construction Date	Early 1970's
Length	468 m
Nominal Depth	11.9 m
Main commodities handled	Glebe Island Berths 1 and 2 comprise a dedicated motor vehicle discharge facility.
Main Vessel Types	Vehicle Carrier
Imports	Motor Vehicles
Exports	-
Ballast is Discharged/Taken up	No ballast required to be taken up or discharged from car carriers.

Berth Name	Glebe Island Berth 7
Construction Date	Early 1970's
Length	229 m
Nominal Depth	11.4 m
Main commodities handled	A common user dry bulk cargo discharge facility.
Main Vessel Types	Self discharging vessels using manifold to pipelines, conveyors and adjacent storage silos.
Imports	The types of cargo discharged at the facility include bulk cement and bulk refined sugar. Cement is transported from Devonport, Tasmania.
Exports	-
Ballast is Discharged/Taken up	Taken Up

Berth Name	Glebe Island Berth 8
Construction Date	Early 1970's
Length	120 m
Nominal Depth	6.6-9.3 m
Main commodities handled	A dry bulk cargo discharge facility.
Main Vessel Types	
Imports	The principal commodity discharged at this berth is bulk soda ash. Bulk soda ash is shipped from Penrice's factory in Osborne, South Australia. It receives shipments of approximately 8,000 tonnes a month.
Exports	-
Ballast is Discharged/Taken up	Taken Up

Berth Name	White Bay Berths 1 and 2
Construction Date	Late 1960's - early 1970's
Length	336 m
Nominal Depth	9.8 m
Main commodities handled	Currently operates under short term lease for vehicle imports, a long term lease is being called for.
Main Vessel Types	Vehicle Carrier
Imports	Motor Vehicles
Exports	-
Ballast is Discharged/Taken up	No ballast required to be taken up or discharged from car carriers.

Berth Name	White Bay Berths 3- 6
Construction Date	Late 1960's - early 1970's
Length	279, 265, 203 and 203 m respectively
Nominal Depth	10.5, 10.9, 11.0 and 11.0 m respectively
Main commodities handled	Containers as well as general, break-bulk and Ro-Ro cargoes
Main Vessel Types	Container, Ro-Ro
Imports	
Exports	
Ballast is Discharged/Taken up	Container vessels generally have little need for ballast exchange because containers are generally exchanged on a one for one basis and any trim corrections are made by internal transfers within heeling tanks. Ro-Ro vessels seldom take on or discharge large volumes of ballast but small volumes (100-200 tonnes) may be loaded or discharged in port to achieve desired vessel trim.

Berth Name	Blackwattle Bay
Construction Date	
Length	120 m
Nominal Depth	5.0 m
Main commodities handled	Pioneer’s Blackwattle Bay berth is used for the discharge of bulk concrete aggregate.
Main Vessel Types	
Imports	Bulk concrete aggregate.
Exports	-
Ballast is Discharged/Taken up	Taken up

Berth Name	Gore Cove Terminal (Shell)
Construction Date	1901
Length	Wharf 1: 320 m, Wharf 2: 220 m
Nominal Depth	Wharf 1: 13.8 m, Wharf 2: 9.7 m
Main commodities handled	Oil products, crude and feedstocks
Main Vessel Types	Tanker
Imports and Exports	Approximately 4.5 million tonnes of crude oils, feedstocks and products are moved through the terminal each year.
Ballast is Discharged/Taken up	Primarily an import terminal therefore ballast water is generally taken up.

Appendix 3b – Details of naval facilities and former berths

Berth Name	Darling Harbour 9 and 10
Construction Date	Mid 1970's
Operation Dates	
Length	174 and 178 m respectively
Nominal Depth	9.9 and 9.4 m respectively
Main commodities handled	
Main Vessel Types	
Imports and Exports	
Ballast was Discharged/Taken up	

Berth Name	Berrys Bay Berth 2 (BP)
Construction Date	
Operation Dates	Closed in 1993
Length	183 m
Nominal Depth	9.3 m
Main commodities handled	Formerly oil
Main Vessel Types	Tanker
Imports and Exports	
Ballast was Discharged/Taken up	

Berth Name	Balls Head Bay Berth
Construction Date	
Operation Dates	1917-1992
Length	
Nominal Depth	6.2 m
Main commodities handled	Formerly coal
Main Vessel Types	Coal collier
Imports and Exports	
Ballast was Discharged/Taken up	Taken up

Berth Name	Rozelle Bay Berths
Construction Date	
Operation Dates	
Length	
Nominal Depth	
Main commodities handled	-
Main Vessel Types	Yachts
Imports and Exports	-
Ballast was Discharged/Taken up	-

Berth Name	Garden Island
Construction Date	
Operation Dates	Operational
Length	
Nominal Depth	
Main commodities handled	-
Main Vessel Types	Naval Vessels
Imports and Exports	-
Ballast was Discharged/Taken up	Not in significant quantities

Berth Name	Chowder Bay
Construction Date	
Operation Dates	Operational
Length	
Nominal Depth	
Main commodities handled	-
Main Vessel Types	Naval Vessels
Imports and Exports	-
Ballast was Discharged/Taken up	Not in significant quantities

Appendix 4 – Shipping movements in the port

Last Port (All) By Country	No. of Ships
Antarctica	1
Fiji	1
Hong Kong	1
Norfolk Island	1
Saudi Arabia	1
Solomon Islands	1
China	2
Guam	2
Tuvalu	2
Taiwan	3
Vietnam	3
Paupa New Guinea	4
East Timor	5
United States	5
Samoa	6
Brunei	7
Malaysia	7
United Arab Emirates	8
Japan	8
Korea	9
Indonesia	10
Singapore	16
Vanuatu	16
New Caledonia	35
New Zealand	135
Australia	882
Total	**1171**

Next Port (All) By Country	No. of Ships
United Arab Emirates	1
Argentina	1
Spain	1
Hong Kong	1
Indonesia	1
Panama	1
Peru	1
Philippines	1
Uruguay	1
Vietnam	1
Sri Lanka	2
East Timor	2
United States	2
Paupa New Guinea	3
Fiji	4
Japan	5
Norfolk Island	7
Vanuatu	21
Singapore	30
New Caledonia	34
New Zealand	128
Australia	923
total	**1171**

Last Port (Aus)	No. of Ships
George Town	1
Jabiru	1
Port Adelaide	1
Port Arthur	1
Port Bonython	1
Portland	1
Varanus Island	1
Bunbury	2
Burnie	2
Kurnell	2
Port Stanvac	2
Port Alma	2
Townsville	2
Bell Bay	4
Fremantle	4
Port Botany	4
Cossack Pioneer	5
Gladstone	5
Cairns	6
Hobart	7
Adelaide	8
Mackay	8
Botany Bay	13
Newcastle	15
Port Kembla	16
Thevenard	21
Sydney	28
Devonport	36
Geelong	36
Unknown (Aust)	106
Melbourne	224
Brisbane	317
total	**882**

Next Port (Aus)	No. of Ships
Darwin	1
Gladstone	1
Lord Howe Island	1
Portland	1
Westernport	1
Dampier	2
NEW	2
Yamba	2
Bell Bay	3
BUR	3
Cairns	3
Fremantle	3
Port Adelaide	3
Port Stanvac	3
Cossack Pioneer	4
Kurnell	5
Townsville	5
Port Botany	6
Hobart	7
Adelaide	11
Thevenard	12
Mackay	14
Port Kembla	22
Botany Bay	23
Sydney	31
Burnie	32
Devonport	33
Newcastle	38
Geelong	39
Unknown (Aust)	110
Melbourne	173
Brisbane	329
total	**923**

Chart 1 - Number of Ballast Water Tank Discharges in Sydney by Uptake Port over Year 2000

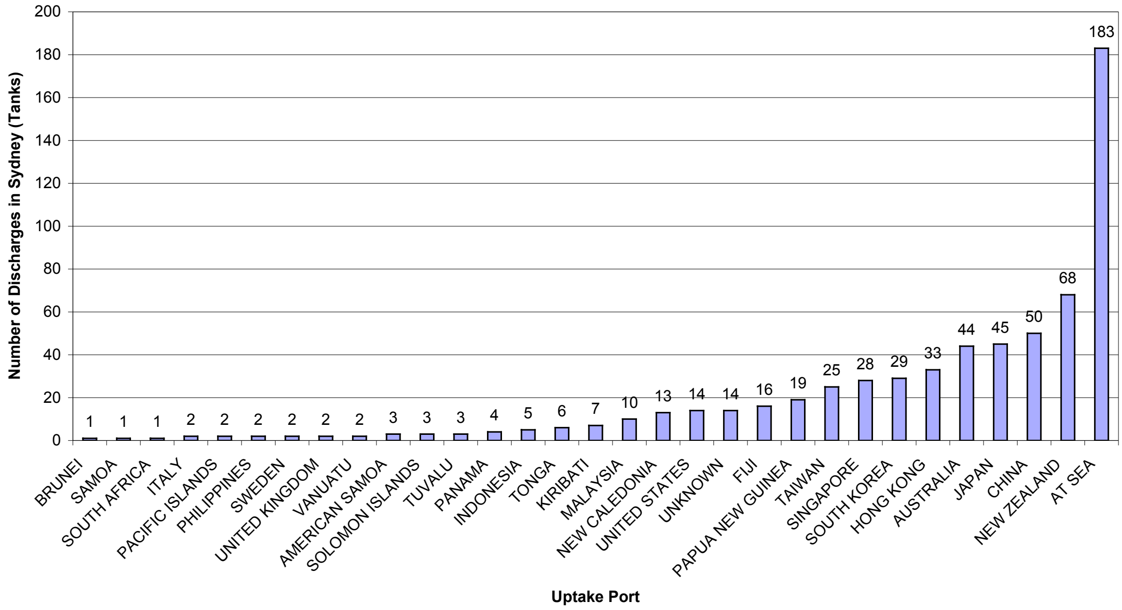


Chart 2 - Number of Ballast Water Tank Discharges in Sydney by Australian Uptake Ports

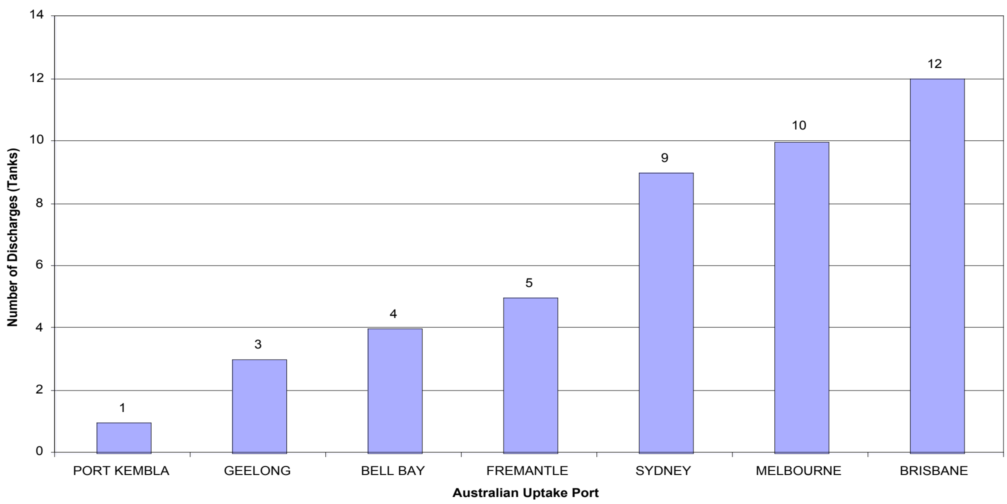
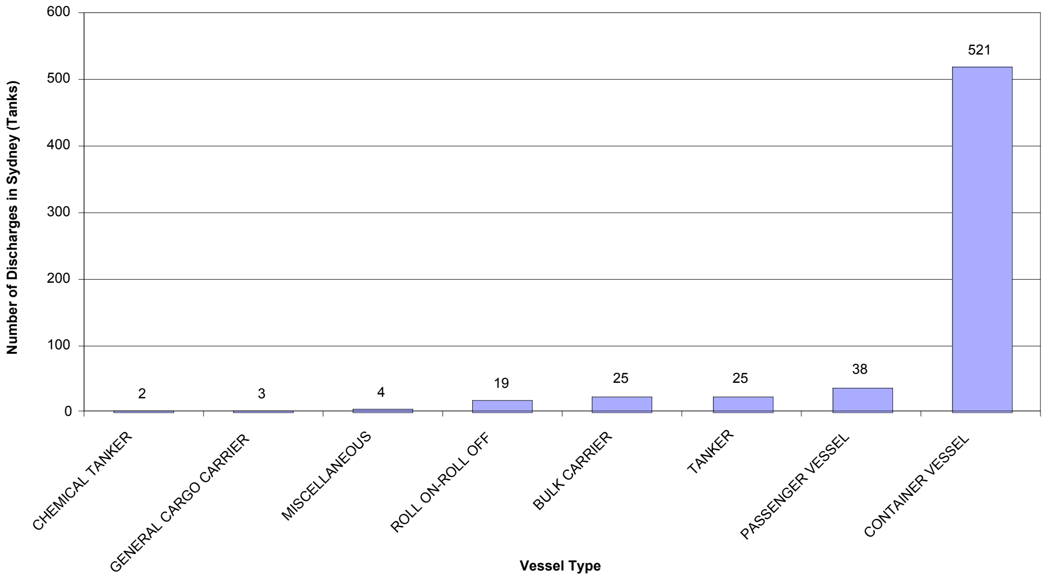


Chart 3 - Number of Ballast Water Tank Discharges by Vessel Type in Sydney Over Year 2000



Appendix 5 – Press release and notice sent to public

SYDNEY PORTS MEDIA RELEASE

Sydney Ports Corporation protecting the Harbour
Thursday, 29 March 2001

Sydney Ports Corporation has commissioned the Australian Museum to carry out a survey of Sydney Harbour to determine the presence, type and abundance of introduced marine pests.

The survey will use the resources of the local community, which is being asked to report sightings of any new or unusual marine animals or plants in the harbour.

The survey is to be carried out as a result of the Federal Government's commitment to better manage ballast water in Australian Ports and reduce the risk of further introductions.

Australian Quarantine Inspection Services (AQIS) will implement new ballast water management arrangements in July 2001, by means of a newly developed Decision Support System (DSS). For this system to work effectively a baseline study of Sydney Harbour must be undertaken to determine the current condition of the port environment.

"The DSS will regulate the discharging of ballast water by vessels coming into Australian Ports and in turn help reduce the number of harmful introduced marine organisms being transferred from other coastal environments" said Murray Fox, General Manager, Navigation and Environment, at Sydney Ports Corporation.

Mr Fox said "The Sydney Harbour Introduced Marine Pest Survey will commence this week. The survey will cover 11 separate sites in the Harbour where it is expected that ballast water discharges have occurred in the past".

Sydney Ports Corporation and the Museum are calling for members of the public, especially those working on and around the harbour such as fishermen, divers, wharf workers and shipping personnel, to contribute to the survey. Individuals with any observations of changes to marine species populations, or information relating to the identification of exotic species in Sydney Harbour are asked contact the Australian Museum on 02 9320 6202 or by email to sand@austmus.gov.au.

Media Contact:
Polly Bennett - Manager Corporate Communications, Sydney Ports Corporation
Phone: 9296 4661
For technical information please contact:
Duncan Wyllie, Publicist, Australian Museum
Phone: 02 9320 6216.

SYDNEY PORTS

SYDNEY HARBOUR
INTRODUCED MARINE PEST SPECIES SURVEY

What is going on?

A survey to determine the number and type of introduced marine pests will be carried out in Sydney Harbour over the next 3 months.

Why?

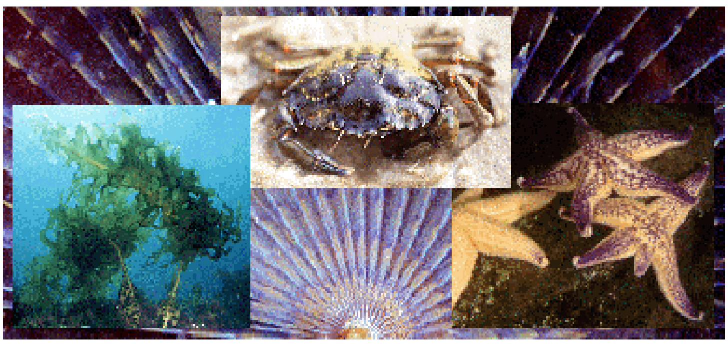
The survey is a result of the Federal Government's commitment to better management of ship's ballast water in Australian ports. The survey results will be used to reduce the risk of introductions of harmful marine pests into Australian ports.

Who is undertaking the survey?

The survey is being carried out by the Australian Museum on behalf of Sydney Ports. Divers, fishermen, workers and recreational users of the harbour are being asked to help.

What can I do?

Please contact the Australian Museum on 9320 6202 or email sand@austmus.gov.au and **report your observations** of new or unusual marine animals or plants in Sydney Harbour.



For further information about the survey please contact Sydney Ports Corporation on 9296 4999 (ph), 9296 4742 (fax), or at www.sydneyports.com.au.