

Marine and Freshwater Resources Institute

Report No. 45

Exotic species established in Western Port, including an assessment of the status of the exotic species *Corbula gibba*, *Alexandrium* spp, *Gymnodinium* spp and *Undaria pinnatifida*.

Gregory D. Parry and Brian F. Cohen

October 2001

Marine and Freshwater Resources Institute

Report No. 45

**Exotic species established in Western Port, including an
assessment of the status of the exotic species *Corbula gibba*,
Alexandrium spp, *Gymnodinium* spp and *Undaria*
pinnatifida.**

Gregory D. Parry and Brian F. Cohen

October 2001

**Marine and Freshwater Resources Institute
PO Box 114
Queenscliff 3225**

© The State of Victoria, Department of Natural Resources and Environment, 2001

This work is copyright. Apart from any use under the Copyright Act 1968, no part may be reproduced by any process without written permission.

ISSN: 1328-5548

ISBN: 0 7311 49637

Copies available from:

Librarian

Marine and Freshwater Resources Institute

PO Box 114

Queenscliff VIC 3225

Phone: (03) 5258 0259

Fax: (03) 5258 0270

Email: queenscliff.library@nre.vic.gov.au

Preferred way to cite this publication:

Parry, G.D. and Cohen, B.F. (2001). Exotic species established in Western Port, including an assessment of the status of the exotic species *Corbula gibba*, *Alexandrium* spp, *Gymnodinium* spp and *Undaria pinnatifida*. Marine and Freshwater Resources Institute Report No. 45. Marine and Freshwater Resources Institute: Queenscliff.

General disclaimer:

This publication may be of assistance to you but the State of Victoria and its employees do not guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaims all

liability for any error, loss or other consequence which may arise from you relying on any information in this publication.

Summary

There are 18 exotic species that have been recorded in Western Port. On the basis of criteria developed in this report, there is enough evidence to consider that only 12 of these species have unambiguously established self-sustaining populations in Western Port. These 12 species include eleven macroscopic species (the ascidians *Ascidiella aspersa*, *Ciona intestinalis*, *Styela clava*, *Styela plicata*, the bryozoans *Bugula neritina*, *Watersipora subtorquata*, the crab *Carcinus maenus*, the algae *Codium fragile tomentosoides*, *Ulva lactuca* and the bivalves *Musculista senhousia*, *Theora lubrica*) and the toxic dinoflagellate, *A. tamarense*. Single 'blooms' of a further two species of toxic dinoflagellates (*Alexandrium catenella* and *A. minutum*) have been recorded in Western Port. The status of these species is uncertain, but they are considered to have probably established self-sustaining populations in Western Port.

The remaining four exotic species in Western Port, that are not considered to have established self-sustaining populations, are the bivalves *Corbula gibba*, *Crassostrea gigas*, the polychaete, *Sabella spallanzanii*, and the kelp, *Undaria pinnatifida*.

Introduction

Biological surveys of exotic species in ports are necessary to understand the risk of translocating species between ports, and to assist management decisions intended to minimise these risks.

Currie and Crookes (1997) recorded seven exotic species in a survey of the Port of Hastings during 1997. However one of these species, the bivalve *Corbula gibba*, was only recorded as a single (dead) valve and another, the bryozoan *Bugula dentata*, is now considered to be a native species (Keough and Ross 1999). A further 4 exotic species were recorded by Cohen *et al.* (2000a) in a survey of conspicuous exotic species in Western Port during 2000.

This report was commissioned by the Department of Natural Resources & Environment and Environmental Protection Authority to determine the status of four exotic taxa (*Corbula gibba*, *Undaria pinnatifida*, *Alexandrium* spp and *Gymnodinium catenatum*) in Western Port. These four species are included on the Australian Ballast Water Management Advisory Council's (ABWMAC) marine target species list, but it was uncertain, despite earlier surveys, whether they had established self-sustaining populations in Western Port.

This report provides information on the abundance of *Corbula gibba*, *Alexandrium* spp, *Gymnodinium catenatum* and *Undaria pinnatifida* in Western Port as a result of field studies conducted between July and November 2000. The results of a survey and eradication program for *Undaria pinnatifida* undertaken at Flinders between January and May 2001 is also briefly described (Appendix 1). In addition, previously unpublished data on the abundance of *Alexandrium* and *Gymnodinium* spp at Flinders shellfish growing area in Western Port between September 1987 and December 1996 is summarised to enable a more comprehensive assessment of the status of these toxic algae.

Methods

Corbula gibba

Fifty 0.1m² Smith-McIntyre grab samples were taken at sites throughout sub-tidal regions of Western Port between 10-12 July 2000 (Table 1, Figure 1). Sites were selected to cover a large area of Western Port near shipping activities, and to include a wide range of sediment types. The closest sub-tidal muddy sediments to commercial shipping activity were targeted, but these occurred many kilometres from the shipping channel, in the east of the bay, north of Churchill Island near Rhyll (Marsden and Mallet 1975). Surface sub-samples (70 mL) of all grabs were taken and sediment analysed by wet sieving to determine percentage mud (<63 µm). All grab samples were analysed for *Corbula gibba* by sieving on board through a 5 mm sieve. This method was chosen to maximise the number of samples processed, although small *Corbula* may be missed.

Alexandrium and *Gymnodinium* spp

The abundance of dinoflagellate cysts was determined in 10 sediment samples collected by Smith-McIntyre grab on the 11 July 2000. Samples were collected near the Port of Hastings and near the anchorage north of Cowes where some deballasting occurred in the past (Table 1, Figure 1). A 70 mL sediment subsample was removed from the top of 10 grab samples and 2.5-10 mL of this sediment thoroughly mixed with filtered seawater, then filtered through a 100 µm sieve to remove large sediment particles and detritus. The remaining fraction, containing cysts and particulate material, was collected on a 20 µm sieve. After thorough rinsing with filtered seawater, this fraction was pipetted into a 10-mL tube, and the total volume made up to 10 mL with filtered seawater. Cysts in the 20-100 µm fraction were counted using a Sedgwick-Rafter counting chamber. Samples were examined using light and fluorescence microscopy.

The species composition of phytoplankton samples was determined on the day of collection (11 July 2000), at the same ten sites at which dinoflagellate cysts were collected. At each site a phytoplankton net sample (20 µm) and a 1 L water sample were collected. Dinoflagellates in the net tows were examined using bright-field, phase-contrast and fluorescence microscopy. For fluorescence microscopy samples were fixed with Lugol's iodine solution then stained with calcofluor white to enable detailed examination of the arrangement of thecal plates. A minimum of 500 dinoflagellates were examined from each net tow. Quantitative estimates of abundance of potentially toxic dinoflagellates were obtained using the 1 L water samples. Dinoflagellates in the 1 L water sample were enumerated using a Sedgwick-Rafter counting cell, after the sample was concentrated by continuous flow centrifugation to a final volume of 6 mL. The detection limit of the method was 100 cells/L (=1 cell recorded in the count) hence species of potentially toxic dinoflagellates that were recorded in the net tows, but not in the quantitative cell counts, were assigned a density of <100 cells/L.

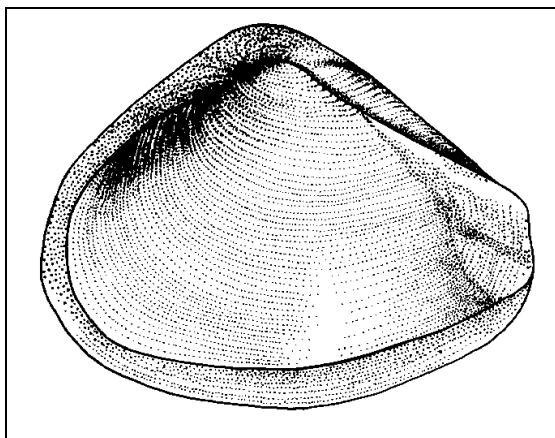
All phytoplankton and dinoflagellate cyst samples were analysed by Drs Steve Brett and David Hill (Brett Water Science).

Undaria pinnatifida

Visual searches for *Undaria pinnatifida* were conducted on the 15-16 November, 2000 at eight sites in Western Port; Flinders Aquaculture area, Flinders Pier, Tortoise Head, Tankerton and Stony Point Jetty, Crib Point and Steel Wharf, and Eagle Rock (Figure 2). During spring, *Undaria* is at its most conspicuous, as it is present as large (>1m) sporophytes, prior to a summer senescence. At this time, sporophytes of *Undaria* in Port Phillip Bay are visible from the surface in clear water. Broad scale, boat based visual surveys were conducted at each site. More detailed visual surveys were also conducted at each site by divers or snorklers (Table 2).

Results

Corbula gibba



No *Corbula gibba* were found in the >5mm fraction of the 50 grab samples collected during this survey of Western Port. Analyses of the sediments collected in the grabs indicate that a wide range of sediment types were sampled, although most sub-tidal sediments contained less than 10% mud (Table 1, Figure 3). Muddy sub-tidal sediments (>10% mud) in the east of the bay, north of Churchill Island and near Rhyll (Marsden and Mallett 1975) were sampled, but contained no

Corbula.

In Port Phillip Bay *Corbula gibba* is rarely encountered in sediments that contain less than 10% mud (<63 μm), and below 15% mud there is a strong relationship between the percentage mud and the abundance of *Corbula* ($r^2=0.71$, $P<0.0001$). Above 15% mud, *Corbula* is often abundant in Port Phillip Bay, although there is no significant relationship between abundance and percentage mud ($r^2=0.07$, $P>0.35$) (Figure 4). The lack of a relationship between abundance and percentage mud in the finer sediments, reflects the large temporal and spatial variation shown by this species in deeper regions of Port Phillip Bay (Talman 2000).

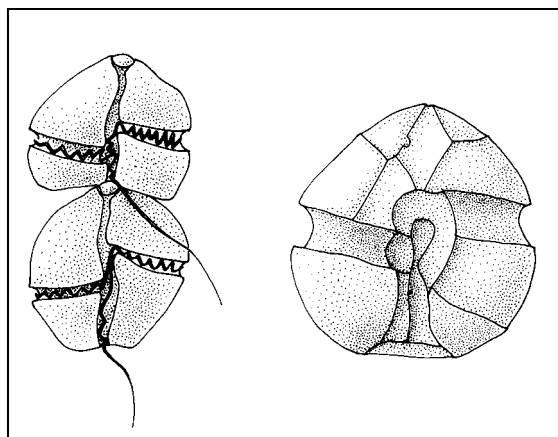
Most sediments in Western Port near the commercial shipping facilities had a low mud content, but isolated sites with muddy sediments occurred near Long Island (Hastings #3, Table 1), Crib Point (Crib #3, Table 1) and inside Westernport marina (Fig 1, Table 1). These muddy areas appear the most suitable habitats for the establishment of *Corbula*.

Western Port contains extensive muddy intertidal flats interspersed with channels containing coarse sandy sediments. There are few subtidal areas that contain sediments as muddy as the sediments in areas in Port Phillip Bay dominated by *Corbula gibba* (Fig 3). It appears likely that only limited areas in Western Port are suitable for the establishment of *Corbula*. The finding of a single small valve of *Corbula* during a 1997 survey at the Port of Hastings (Currie and Crookes 1997) shows that *Corbula* has been released in Western Port. However from the current survey, which sampled many sites and targeted suitable habitats, there is no evidence that a self-sustaining population of *Corbula* has established. Whether this is because most of Western Port does not provide a suitable habitat or because there have been minimal releases and stochastic factors have prevented their establishment is unknown.

If we make the reasonable assumption that *Corbula* shows a Poisson distribution throughout the area sampled then the power of the survey to detect at least one

Corbula is given by the formula $n = -(1/m) \cdot \log \beta$, where n = no of samples, m = density/sampling unit and power = $1 - \beta$. (Green and Young 1993). Thus there is a 95% probability that 50 samples will detect at least one *Corbula* if the density is at least 0.06/sampling unit or $0.006/m^2 = 1/167m^2$.

Alexandrium and *Gymnodinium*



Phytoplankton samples collected in Western Port contained low numbers of dinoflagellate cells, with fewer than 3000 cells L^{-1} (total dinoflagellates) recorded at all sites. Low levels of dinoflagellates are common during the less productive winter period. The dinoflagellate flora was dominated by gymnodinioid cells, and a range of *Protoperidinium* species. The potentially toxic (DSP producing) *Dinophysis acuminata* and *Dinophysis caudata* were observed at several sites, but cell numbers were below 100 cells L^{-1} , the

detection limit for cell counts.

Detailed examination of net tow material revealed the presence of *Alexandrium* spp, but these cells were generally in poor condition and abundances were extremely low, with fewer than 100 cells L^{-1} (total *Alexandrium* cells) recorded at all sites (Table 3). *A. minutum* was recorded in six net tow samples. The exotic *A. tamarense* was only recorded in two samples, one sample from near Crib Point and one from the anchorage north of Cowes. The exotic *A. catenella* was not recorded in any sample (Table 3). *Alexandrium peruvianum* was the most commonly observed *Alexandrium* species in samples, and was recorded from all sites. Note that the size of cells fits within that described for *A. peruvianum*, although there is current debate regarding the separation of this species from the morphologically similar *A. ostenfeldii*.

No cysts of *Alexandrium* or *Gymnodinium* sp. were found during this survey (Table 4). Densities of dinoflagellate cysts (0-48/mL, Table 4) were much lower than was found in the Port of Melbourne where cyst densities varied from 245-1030/mL (Mean 860/mL) and where *A. catenella* was present in 90% of samples and formed up to 7.9% (mean 3.5%) of the dinoflagellate cysts (Cohen *et al.* 2000b).

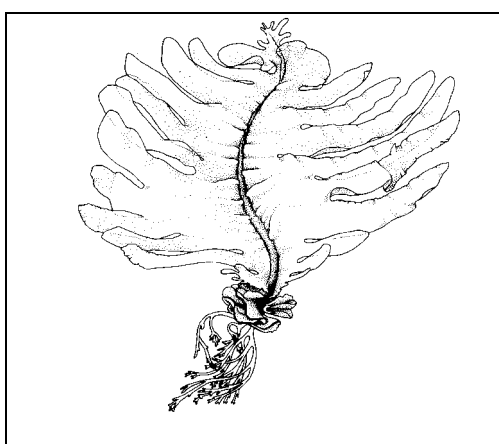
Phytoplankton sampling undertaken as part of surveys of the Flinders Bight shellfish growing area between Sept 1987 and December 1996 (Table 5) recorded *A. catenella* on only two occasions and *A. tamarense* on three occasions. On all occasions only a few cells were observed, concentrations were very low with the maximum concentration of 7.8×10^3 cells L^{-1} recorded for *A. tamarense* (Arnott *et al.* 2000). *Alexandrium margalefii*, *A. ostenfeldii* and *Gymnodinium mikimotoi* and *G. sanguineum* were also occasionally recorded at Flinders between September 1987 and December 1996 (Table 5).

Gymnodinium catenatum was not recorded during sanitary surveys conducted in Port Phillip Bay or Western Port between September 1987 and December 1996 (Table 5),

although this species has been recorded at Portland and Lakes Entrance (MAFRI Phytoplankton database).

A. ostenfeldii is known to be slightly toxic (S. Brett, *pers comm*), but it has been recorded only rarely (Table 5). The only strain of *A. margalefii* to be tested was non-toxic, but this species may be implicated in a toxic event in Tasmania (Hallegraeff *et al.* 1991). *Gymnodinium mikimotoi* is known to cause fish kills (Taylor *et al.* 1995), while *G. sanguineum* is not known to produce toxins but is recorded as a nuisance “red-tide” species (S. Brett, *pers comm*). There is insufficient evidence to consider *A. ostenfeldii*, *A. margalefii*, *G. mikimotoi* or *G. sanguineum* as exotic species in Western Port (Hallegraeff, G, Univ of Tasmania, *pers comm*).

Undaria pinnatifida



No specimens of *Undaria* were observed in Western Port during the November 2000 survey, despite stands of macro brown algae occurring at all sites surveyed (Table 2). The sites surveyed were all areas of hard substrate near the port (Tortoise Head, Tankerton and Stony Point Jetty, Cribb Point and Steel Wharf, and Eagle Rock) or on or near the mussel growing area at Flinders (Flinders Aquaculture area, Flinders Pier). While searches were conducted at the most likely areas for the establishment of *Undaria* (all

areas of hard substrate nearest shipping and mariculture activities) a small population of *Undaria*, occupying an area of only a few square metres, at any of these sites was unlikely to be detected.

On 21 December 2001, 8 immature *Undaria pinnatifida* sporophytes were discovered growing on abalone shells near Flinders pier (Appendix 1). All of these plants were removed immediately and a follow up survey on 28 December 2001 removed a further 4 immature sporophytes. No further sporophytes were found during surveys on 12 January 2001 or 22 May 2001 (Appendix 1).

Discussion

Two issues must be considered when using the results of surveys to assess the 'status' of exotic species in a given area :

An exotic species may be present but not recorded by the survey as the species

- is too rare to be detected given the sampling intensity of the survey
- is confined to an unsampled or an under-sampled habitat
- is only abundant occasionally, so the likelihood of recording it during a particular survey is low (e.g. phytoplankton)
- has a complex lifecycle involving seasonal alternation of growth forms and the species is in a cryptic form when the survey occurs.

A high sampling intensity in a wide range of habitats minimises the likelihood that species will not be recorded during a particular survey. But multiple surveys, during different seasons and years, will be required to record species that are abundant only periodically. Where species have complex lifecycles the survey must be timed so that the species is conspicuous at the time of the survey.

Surveys only record the abundance of exotic species rather than whether their populations are sustainable. An exotic species may be recorded in an area, although its population may not be self-sustaining. For exotic species that are abundant through time it is reasonable to assume that their populations are self-sustaining. However for exotic species that are recorded only rarely it is difficult to determine whether their populations are self-sustaining. These species may be rarely recorded because they exist at low, but self-sustaining, densities or because they are periodically imported from other areas. In the latter case their failure to establish a self-sustaining population may have been the result of chance events leading to localised extinction (suggesting that they would establish self-sustaining populations if invasions continued) or because the habitat of the area in question was unsuitable, for at least part of their lifecycle. In some instances the habitat provided by an area may be clearly unsuitable (eg. tropical species occasionally found in temperate areas), but in most instances the suitability of a habitat is difficult to determine. Experimental introductions which would determine whether habitats are suitable for particular exotic species are clearly unethical.

In order to make decisions on the risk of a pest being introduced to, or introduced from, Western Port it is necessary to identify those species that already have self-sustaining populations in the port. The following criteria have been used to determine whether a rare exotic species should or should not be regarded as having a sustainable population in a port:

Macroscopic exotic species where populations are not considered self-sustaining

- (1) There is evidence that a population may have been eradicated since it was recorded (eg. *Undaria*, *Sabella*).
- (2) The population density is much lower than (<5%) the density at which the exotic is typically found in infested areas (eg. *Crassostrea gigas*).
- (3) Only juveniles or dead adults (eg. *Corbula gibba*) have been found.

Self-sustaining populations of exotic dinoflagellates.

Dinoflagellates can exist at either (unmeasurably) low densities in the plankton or as cysts in the sediment until conditions are favourable, when very high planktonic densities can result quickly. Dinoflagellates may bloom only every few years, consequently a long time series of data may be required to record a species, and an even longer time series is required to record any seasonal or spatial pattern in their occurrence.

When only a single record exists for a particular dinoflagellate species this may have resulted from a recent discharge from a vessel or the species may have already

established a sustainable population in the region. These alternatives can only be distinguished by collecting information on the abundance of the species over a long time period, or possibly over a large area. As additional bloom events are recorded, and particularly if bloom events correlate with an environmental cue (season, salinity), it becomes increasingly likely that the species has established a sustainable population. Similarly, blooms that occur over large areas are more likely to be the result of an established sustainable population than of the effects of a recent local discharge. As there are few long term records of dinoflagellates in ports/bays in Australia, establishing the status of these species with certainty is currently not possible. In this report an exotic dinoflagellate species has been considered to have a self-sustaining population:

- (1) Where viable cysts of dinoflagellates were found in the sediment, even if the alga was not found in the plankton.
- (2) Where dinoflagellate cysts were not found, but the species was recorded in more than one bloom event, ie. it was recorded at least twice, in samples (preferably non-sequential) separated in time by at least 2 months. Cyst densities were presumed to be too low to be detected. A seasonal pattern of blooms provided additional evidence the species had established a self-sustaining population.
- (3) Where the species was distributed widely in the plankton, ie. found at sites 10s of km apart, on at least one occasion, so that hydrodynamic spread from a vessel discharge was unlikely.

Where dinoflagellate cysts were not found, and the species was recorded only once in the plankton, an exotic dinoflagellate species has been considered to **probably** have a self-sustaining population, where the failure to record this species more than once was considered more likely to be due to the low sampling intensity than because a self-sustaining population had not established.

The above criteria are first tested by applying them to the status of *Alexandrium catenella*, *A. tamarensense* and *A. minutum* in Port Phillip Bay, where an excellent time series of abundance data exists, and then applied to the status of these same species in Western Port, where a much more limited database exists.

On the basis of the above criteria *Alexandrium catenella*, *A. tamarensense* and *A. minutum* are considered to have self-sustaining populations in Port Phillip Bay. *A. catenella* cysts have been recorded in the bay (Cohen *et al.* 2000b; criteria 1), *A. catenella* was recorded in all years between 1987 and 1996 (Appendix Table A2-2, criteria 2), was highly seasonal in its occurrence, occurring only during summer and autumn (Tables A2-1, A2-2, A2-5, criteria 2) and was often widely distributed (criteria 3).

Alexandrium tamarensense cysts have not been germinated from Port Phillip Bay (Steve Brett, *pers comm*, criteria 1 not applicable), but *A. tamarensense* was found in the bay in every year between 1991-95 (Tables A2-3 & A2-6 criteria 2), blooms only occurred during summer and autumn (Table A2-1, criteria 2), and it was widespread in 1993, 1995 and 1996 (Table A2-6, criteria 3).

Alexandrium minutum cysts have not been germinated from Port Phillip Bay (Steve Brett, *pers comm*, criteria 1 not applicable), but *A. minutum* was found in the bay in 1988 and 1994 (Table A2-4, criteria 2), blooms only occurred during summer and spring (Tables A2-1 & A2-7, criteria 2), and it was widespread in 1994 (Table A2-4, criteria 3).

Samples taken at 16 sites at approximately fortnightly intervals over a ten year period in Port Phillip Bay recorded *Alexandrium catenella* at each site with a frequency of between 1 and 25% of sampling occasions, *A. tamarense* at each site with a frequency of between 1 and 17%, but *A. minutum* at each site with a frequency of only 0 to 2% (Table 5). The infrequency with which these exotic dinoflagellates were recorded in Western Port (Table 5) during the same period, probably reflects the limited sampling – with only one site (Flinders) sampled. However these data still confirm that *A. tamarense* has a self-sustaining population in Western Port as it was recorded in each of 3 years (Table A2-3, criteria 2). *A. catenella* was recorded at low density twice during summer 1995 (Table A2-2), but the sampling interval between records was only 14 days. *A. minutum* was not recorded at Flinders between 1987 and 1997 (Tables 5, A2-1), although it was recorded during the present study. Therefore, these latter species cannot be unambiguously considered to have established self-sustaining populations in Western Port. However the natural mixing of waters from Port Phillip Bay and Western Port, and the large volumes of Port Phillip Bay ballast discharged in Western Port historically (Walters 1996) suggest that *Alexandrium catenella* and *A. minutum* probably have sustainable populations in Western Port (criteria 3).

There are 18 exotic species that have been recorded in Western Port. On the basis of criteria developed in this report only 12 of these species are considered to have unambiguously established self-sustaining populations in Western Port (Table 6). These 12 species include eleven macroscopic species (the ascidians *Ascidiella aspersa*, *Ciona intestinalis* *Styela clava*, *Styela plicata*, the bryozoans *Bugula neritina*, *Watersipora subtorquata*, the crab *Carcinus maenus*, the algae *Codium fragile tomentosoides*, *Ulva lactuca* and the bivalves *Musculista senhousia*, *Theora lubrica*) and the toxic dinoflagellate *Alexandrium catenella*. A further two species of toxic dinoflagellate (*A. minutum* and *A. tamarense*) have been recorded during only single bloom events in Western Port, and therefore their status is uncertain, but they are considered to have probably established self-sustaining populations in Western Port. Included amongst the 14 species that have self-sustaining or probably self-sustaining populations are 5 species (*Alexandrium catenella*, *A. minutum*, *A. tamarense*, *Carcinus maenus* and *Musculista senhousia*) on the Australian Ballast Water Management Advisory Council (ABWMAC)'s marine target species list.

Four species on ABWMAC's marine target species list (*Corbula gibba*, *Crassostrea gigas*, *Sabella spallanzani* and *Undaria pinnatifida*) have been recorded in Western Port in the past, but there is no clear evidence that they have established self-sustaining populations in Western Port. A single (dead) *Corbula* valve was found in Western Port in 1997, but no live specimens have been found despite intensive sampling in the current study. Only a small number of *Crassostrea gigas* have been found in Western Port and the population of this species may not yet be self-sustaining, as its population density is much lower (<5%) than the density at which this exotic species is typically found in infested areas. *Sabella* has been recorded on mussel farms at Flinders, but there are no records of *Sabella* on mussel farms in the

past 12 months, and there is no evidence of their spread beyond mussel farms. *Undaria* was found recently at Flinders pier, but no specimens were found in the infested area during two recent surveys so current evidence indicates that this species has been eradicated in Western Port (Appendix 1).

Acknowledgements

All phytoplankton analyses were undertaken by Drs Steve Brett and David Hill (Brett Water Science). Brett Abbott, David Beyer, David Forbes, Trish Paradise, Mark and Graham Ferrier, Matt McArthur, David Forbes and Guy Werner assisted with field work. Sonia Talman (MAFRI and University of Melbourne) provided the data in Figure 4. Please note that data in Figure 4 must not be cited without Dr Talman's permission. We thank Sarah Walters, Don Hough and Dr Greg Jenkins for their comments on the manuscript.

We especially thank Dr Gustaaf Hallegraaf for several useful discussions on criteria for determining whether dinoflagellates had established self-sustaining populations.

References

- Arnott, G.A., Conron, S.D., Brand, G.W. and Reilly, D.J. (2000). Victorian shellfish quality assurance program 8. Sanitary survey of Flinders Bight shellfish growing area. Marine and Freshwater Resources Institute **23**, 1-52.
- Currie, D.R. and Crookes, D.P. (1997). Exotic marine pests in the Port of Hastings, Victoria. Marine and Freshwater Resources Institute, Report No. **4**, 1-45.
- Cohen, B.F., McArthur, M.A., and Parry, G.D. (2000a). Exotic marine pests in Westernport. Marine and Freshwater Resources Institute **22**, 1-15.
- Cohen, B.F., McArthur, M. A. and Parry, G.D. (2000b). Exotic marine pests in the Port of Melbourne. Marine and Freshwater Resources Institute Report No. **25**, 1-97.
- Green, R.H. and Young, R.C. (1993). Sampling to detect rare species. Ecological Applications **3**:351-356.
- Gunthorpe, L., Cohen, B.F., Werner, G.F. and Parry, G.D. (2001). Survey of Flinders Pier, Western Port for *Undaria* - December 2000-January 2001. Marine and Freshwater Resources Institute Internal Report No. **14** (In press).
- Hallegraaf, G.M. Bolch, C.I., Blackburn, S.I. and Oshima, Y. (1991). Species of the toxicogenic dinoflagellate genus *Alexandrium* in southeastern Australian waters. *Botanica Marina* **34**:575-587.
- Keough, M.J. and Ross, J. (1999). Introduced fouling species in Port Phillip Bay. Pp193-226. **In:** Hewitt, C.L., Campbell, M.L., Thresher, R.E. and Martin, R.B. (eds.) Marine biological invasions of Port Phillip Bay, Victoria. Centre for Research on Introduced Marine Pests. Technical Report No. **20**. CSIRO Marine research, Hobart. 344pp.

Marsden, M.A.H. and Mallet, C.W. (1975). Quaternary evolution, morphology, and sediment distribution, Westernport Bay, Victoria. *Proc Roy. Soc.* 87: 107-137.

Talman, S. G. (2000). The ecology and impacts of the introduced basket clam, *Corbula gibba*, in Port Phillip Bay, Australia. PhD Thesis. University of Melbourne.

Taylor, F.J.R., Succuyo, Y. and Larsen, J. (1995) Taxonomy of harmful dinoflagellates. **In:** Hallegraaf, G.M., Anderson, D.M. and Cembella, A.D. (Eds) *Manual on harmful microalgae*. I.O.C. Manuals and Guides No.33. UNESCO.

Walters, S. (1996) Ballast water, hull fouling and exotic marine organism introductions via ships - A Victorian study. Environment Protection Authority Publication No. 494.

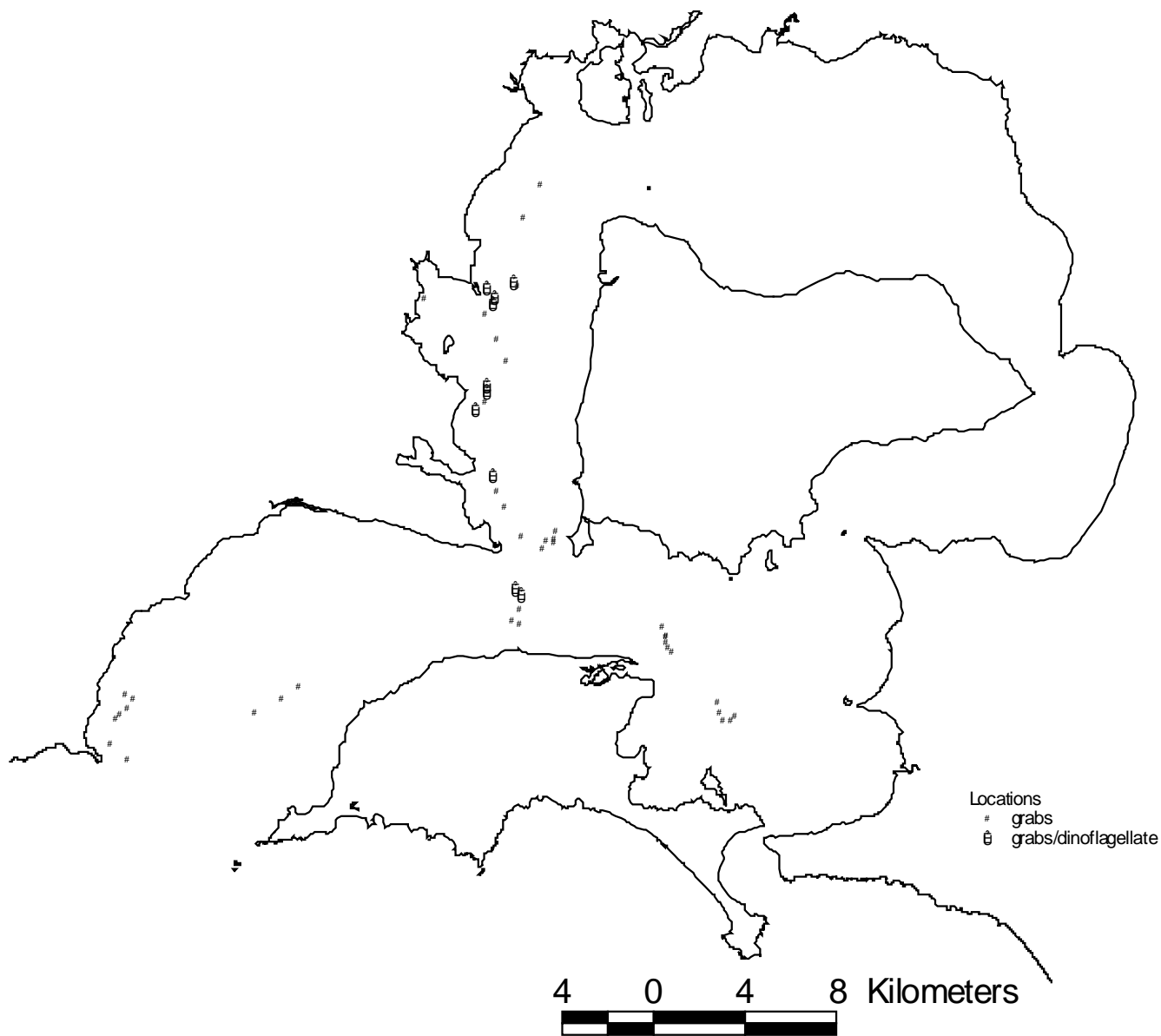


Figure 1: Stations sampled for *Corbula gibba* (● and ★) and the subset of stations sampled for motile dinoflagellates and dinoflagellate cysts (★).

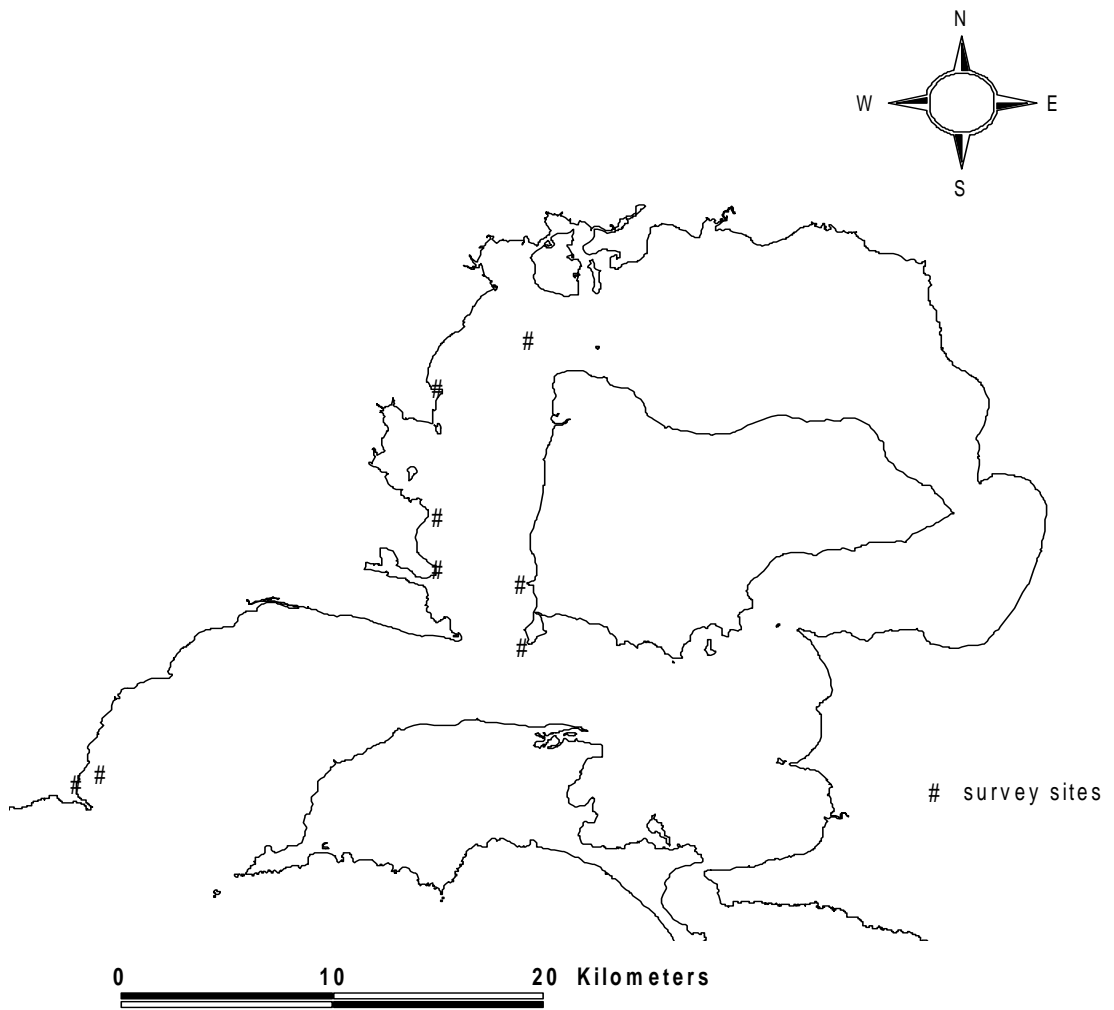
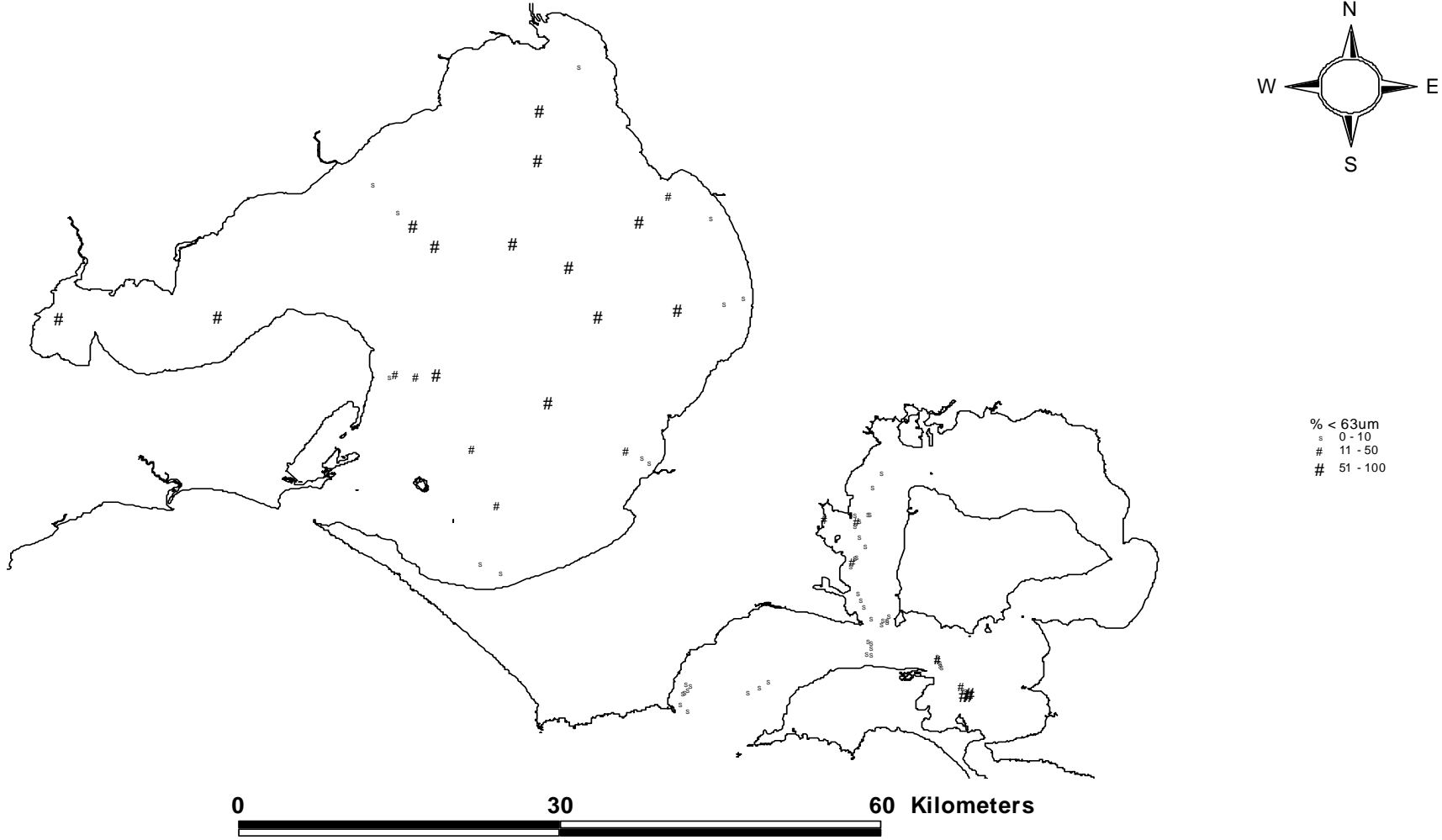


Figure 2. Sites surveyed for *Undaria pinnatifida* .

Figure 3: Sediment type (% mud) in Port Phillip Bay and Western Port. Data for Port Phillip Bay has been provided by Sonia Talman, University of Melbourne, and must not be cited elsewhere without her permission.



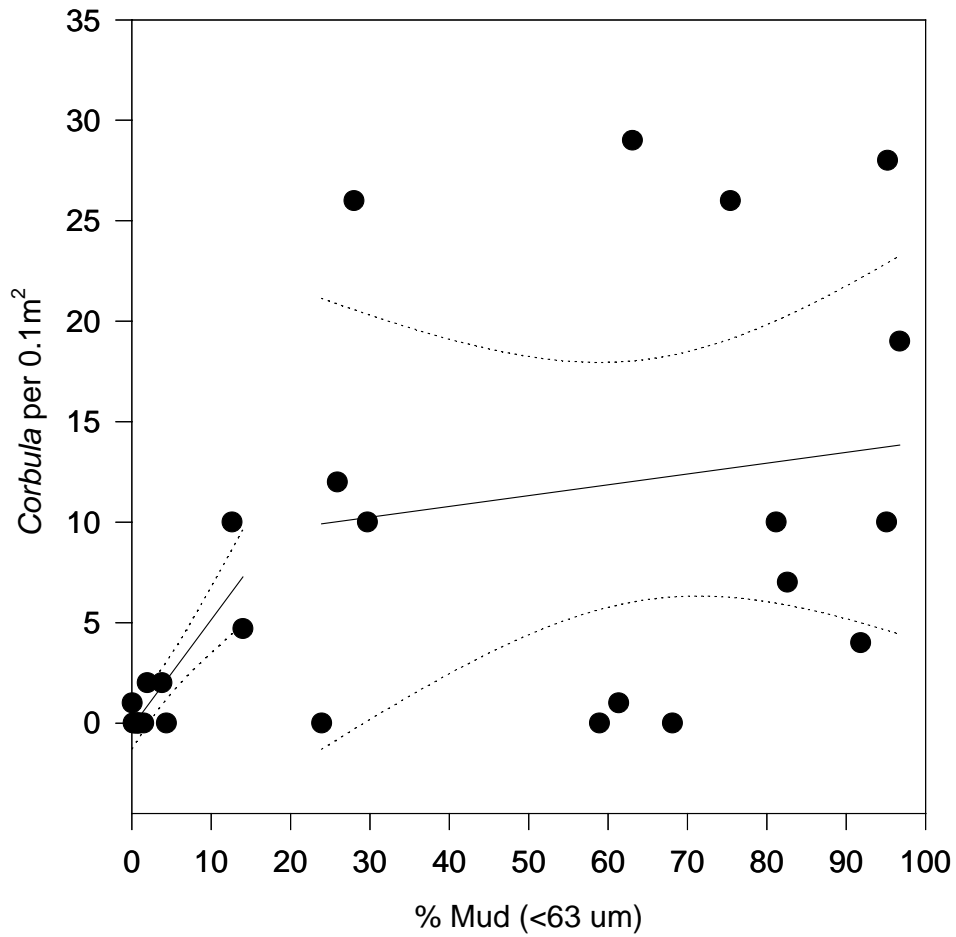


Figure 4: Relationship between abundance of *Corbula gibba* and sediment type (% mud) in Port Phillip Bay. This data has been provided by Sonia Talman, University of Melbourne, and must not be cited elsewhere without her permission.

Table 1. Sample locations and sediment characteristics of grab samples collected from Western Port between 10-12 July 2000.

Location	Easting	Northing	% sediment <63 μ m
Cowes #1	346416	5745430	7.601
Cowes #2	346666	5745214	0.751
Cowes #3	346572	5744676	2.708
Cowes #4	346280	5744165	1.751
Cowes #5	346599	5744020	0.296
Crib #1	345201	5754096	6.033
Crib #2	345179	5753863	5.503
Crib #3	345082	5753458	41.202
Crib #4	344734	5753069	5.372
Hann #1	345447	5750268	4.171
Hann #2	345635	5749661	1.239
Hann #3	345950	5748980	1.374
Hastings #1	345570	5757793	5.899
Hastings #2	345467	5757551	22.566
Hastings #3	345138	5757221	0.832
Hastings #4	329740	5740864	0.406
Hastings #5	345589	5756122	1.623
Hastings Marina	342466	5757884	42.12
Heads #1	329642	5788086	0.413
Heads #2	329632	5788036	0.754
Heads #3	336966	5741294	0.0997
Heads #4	336195	5740790	0.0881
Heads #5	335060	5740209	0.370
Long #1	345172	5758253	1.135
Long #2	346545	5758382	4.942
Mussel #1	329017	5740036	0.620
Mussel #2	329195	5740138	0.631
Mussel #3	329508	5740404	0.236
Mussel #4	355346	5740286	0.349
Mussel #5	329381	5740978	1.642
Reef #1	355986	5740074	79.578
Reef #2	355803	5739938	60.907
Reef #3	355449	5739925	61.988
Reef #4	352993	5743491	18.677
Reef #5	355227	5740659	12.64
Rhyll #1	353245	5742808	9.166
Rhyll #2	353037	5742984	4.116
Rhyll #3	353019	5743232	5.281
Rhyll #4	352993	5743491	11.54
Rhyll #5	352843	5743881	4.335
Steel #1	346351	5758487	7.716
Tortoise #1	347578	5747222	2.383
Tortoise #2	347762	5747543	3.827
Tortoise #3	348079	5747502	3.395
Tortoise #4	348220	5747995	0.546
Tortoise #5	348109	5747603	1.7
#22	347528	5762689	4.969
#23	346750	5761229	7.148
#24	346545	5758382	1.793
#25	346018	5755187	0.862
#29	346677	5747723	0.668

Table 2. Sites surveyed, survey techniques and survey times for native brown algae and *Undaria pinnatifida* in Western Port.

Site	Date	Survey techniques	Survey Duration (min)	Divers/ Observers*	Native brown algae present	<i>Undaria</i>
Tortoise Head	15/11/00	snorkel	90	B.C., G.W.	Yes	None detected
Tankerton Jetty	15/11/00	boat	5	B.C., G.W., D.F.	Yes	None detected
Stony Pt Jetty	15/11/00	boat & snorkel	20	B.C., G.W.	Yes	None detected
Cribb Pt Wharf	15/11/00	boat & snorkel	20	B.C., G.W.	Yes	None detected
Long Is Pt Wharf	15/11/00	no access, tanker loading				
Steel Wharf & rock wall	15/11/00	boat & snorkel	30	G.W.	Yes	None detected
Eagle Rock	15/11/00	dive	40	B.C., G.W.	Yes	None detected
Flinders	16/11/00	boat & dives	120	B.C., G.W., D.F.	Yes	None detected
Aquaculture Area						
Flinders Jetty	16/11/00	dive	40	B.C., G.W.	Yes	None detected

* B.C. Brian Cohen, G.W. Guy Werner, D.F. David Forbes

Table 3. Species composition and abundance of dinoflagellates in (20 m) plankton net and water samples collected in Western Port on 11 July 2000. Presence of dinoflagellates in net tows is shown (x). Cell densities of potentially toxic dinoflagellates based on analysis of 1 L water samples.

Genus	Species	Steel 1	Cowes 1	Cowes 2	Hanns 2	Crib 1	Crib 2	Crib 4	Lony	Hastings 1	Hastings 2
<i>Alexandrium</i>	spp. (total cells/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
<i>Alexandrium</i>	<i>minutum</i>	x	x	x	x			x			x
<i>Alexandrium</i>	<i>peruvianum</i>	x	x	x	x	x	x	x	x	x	x
<i>Alexandrium</i>	<i>tamarense</i>			x				x			
<i>Ceratium</i>	<i>furca</i>		x	x	x				x		
<i>Ceratium</i>	<i>fuscus</i>			x							x
<i>Ceratium</i>	<i>macroceros</i>				x						
<i>Dinophysis</i>	<i>acuminata</i>				<100	<100	<100		<100		
<i>Dinophysis</i>	<i>caudata</i>				<100						
<i>Gonyaulax</i>	<i>spinifera</i>	x							x		
<i>Gonyaulax</i>	spp.					x		x	x	x	
<i>Gymnodinium</i>	spp.	x	x	x	x	x	x	x	x	x	x
<i>Gyrodinium</i>	spp.				x	x				x	
<i>Heterocapsa</i>	sp.	x									
<i>Heterocapsa</i>	<i>rotundata</i>				x	x	x		x	x	
<i>Heterocapsa</i>	<i>triquetra</i>	x		x		x		x	x		
<i>Polykrikos</i>	<i>schwartzii</i>	x									
<i>Preperidinium</i>	<i>meunieri</i>							x			
<i>Prorocentrum</i>	<i>gracile</i>				x						
<i>Prorocentrum</i>	<i>minimum</i>			x							
<i>Prorocentrum</i>	<i>micans</i>			x							
<i>Prorocentrum</i>	<i>triestinum</i>					x					x
<i>Protoperdinium</i>	spp.	x	x	x	x	x	x	x	x	x	x
<i>Protoperdinium</i>	<i>avellana</i>							x			
<i>Protoperdinium</i>	<i>bipes</i>		x		x	x					x
<i>Protoperdinium</i>	<i>brevipes</i>			x		x		x	x		
<i>Protoperdinium</i>	<i>conicum</i>					x					
<i>Protoperdinium</i>	<i>leonis</i>			x	x			x	x		
<i>Protoperdinium</i>	cf. <i>nudum</i>	x		x	x			x	x	x	x
<i>Protoperdinium</i>	<i>pallidum/pellucidum</i>	x	x	x	x	x	x	x	x	x	x
<i>Protoperdinium</i>	<i>steinii</i>									x	
<i>Protoperdinium</i>	<i>subinermis</i>						x		x	x	
<i>Pyrophacus</i>	<i>steinii</i>		x								
<i>Scrippsiella</i>	spp.			x			x				
<i>Scrippsiella</i>	<i>trochoidea</i>	x	x	x		x	x	x		x	x
Unidentified	sp.	x	x					x			x

Table 4. Density of dinoflagellate cysts (cysts/mL wet sediment) and percentage of total cyst count due to each species in samples collected in Western Port on 11 July 2000.

Sample	Cowes 1	Cowes 2	Cribb 1	Cribb 2	Cribb 4	Hanns 2	Hastings 1	Hastings 2	Long	Steel 1
Cysts/ml wet sediment	no cysts	5.0	36.0	44.0	28.0	24.0	26.0	48.1	no cysts	no cysts
Genus	Species									
<i>Protoperidinium</i>		60.0	22.2	27.3	57.1		15.4	16.2		
<i>Protoperidinium</i>			11.1							
<i>Protoperidinium</i>			11.1	9.1						
Gymnodinioid		40.0	22.2	45.5		66.7	53.8	54.1		
<i>Scrippsiella</i>			33.3	18.2	42.9	33.3	30.8	2.7		

Table 5. Number of records of phytoplankton of the genus *Alexandrium* and *Gymnodinium* in Port Phillip Bay and Westernport (Flinders) based on surveys between Sep 1987 and Dec 1996 and held in a MAFRI database.

	Blairgowrie	Dromana	Balcombe Bay	Wooley Reef	Beaumaris	Sand'ham	St Kilda	Port Melb	Will'town	Altona	Werribee	Arthur the Great	Clifton Springs	Point Richards	Grassy Point	Corio Quay	Flinders
<i>Alexandrium catenella</i>	3	3	2	2	11	8	27	41	25	14	1	3	1	.	2	2	2
<i>Alexandrium tamarense</i>	3	7	4	2	3	3	6	5	2	3	5	4	8	6	7	9	3
<i>Gymnodinium mikimotoi</i>	1	3	8	8	16	8	7	10	20	2	5	6	9	.	6	4	1
<i>Gymnodinium pulchellum</i>	11	14	14	19	24	15	11	20	26	13	9	16	17	3	15	15	.
<i>Alexandrium</i> cysts	.	.	.	1	.	.	.	1	.	.	1	.	.	.	.	.	.
<i>Alexandrium margalefii</i>	1	1	3	2	1	2	.	1	.	1	2	1	.	.	.	.	1
<i>Alexandrium ostenfeldii</i>	.	2	.	1	.	.	.	2	.	.	.	1	.	.	.	.	2
<i>Gymnodinium</i> cysts	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Gymnodinium sanguineum</i>	.	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	3
<i>Alexandrium</i> unidentified spp.	1	5	2	4	6	5	7	11	8	6	6	6	4	5	6	1	.
<i>Gymnodinium</i> unidentified spp.	101	39	39	121	141	122	40	29	125	30	112	42	141	9	40	30	23
<i>Alexandrium pseudogonyaulax</i>	2	2	2	1	1	2	1	2	1	2	2	2	5	1	2	5	.
<i>Alexandrium compressum</i>	.	.	.	.	.	1	1	1	1	1	.	.	.	.	.	.	.
<i>Alexandrium minutum</i>	.	1	.	1	.	.	1	.	.	1	.	2	1	1	1	2	.
<i>Gymnodinium breve</i>	.	.	.	.	.	1	.	.	.	.	.	.	2	.	.	.	.
Total number of samples	188	190	170	181	216	187	179	178	197	165	153	184	203	42	192	147	68
Percentage occurrence of species																	
<i>Alexandrium catenella</i>	1.6	1.6	1.2	1.1	5.1	4.3	15.1	23.0	12.7	8.5	0.7	1.6	0.5	.	1.0	1.4	2.9
<i>Alexandrium tamarense</i>	1.6	3.7	2.4	1.1	1.4	1.6	3.4	2.8	1.0	1.8	3.3	2.2	3.9	14.3	3.6	6.1	4.4
<i>Gymnodinium mikimotoi</i>	0.5	1.6	4.7	4.4	7.4	4.3	3.9	5.6	10.2	1.2	3.3	3.3	4.4	.	3.1	2.7	1.5
<i>Gymnodinium pulchellum</i>	5.9	7.4	8.2	10.5	11.1	8.0	6.1	11.2	13.2	7.9	5.9	8.7	8.4	7.1	7.8	10.2	.
<i>Alexandrium</i> cysts	.	.	.	0.6	.	.	.	0.6	.	.	0.7	.	.	.	.	.	.
<i>Alexandrium margalefii</i>	0.5	0.5	1.8	1.1	0.5	1.1	.	0.6	.	0.6	1.3	0.5	.	.	.	.	1.5
<i>Alexandrium ostenfeldii</i>	.	1.1	.	0.6	.	.	.	1.1	.	.	.	0.5	.	.	.	.	2.9
<i>Gymnodinium</i> cysts	0.5	.	0.6	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Gymnodinium sanguineum</i>	.	.	.	.	0.5	.	.	1.1	.	.	.	.	.	.	.	.	4.4
<i>Alexandrium</i> unidentified spp.	0.5	2.6	1.2	2.2	2.8	2.7	3.9	6.2	4.1	3.6	3.9	3.3	2.0	11.9	3.1	0.7	.
<i>Gymnodinium</i> unidentified spp.	53.7	20.5	22.9	66.9	65.3	65.2	22.3	16.3	63.5	18.2	73.2	22.8	69.5	21.4	20.8	20.4	33.8
<i>Alexandrium pseudogonyaulax</i>	1.1	1.1	1.2	0.6	0.5	1.1	0.6	1.1	0.5	1.2	1.3	1.1	2.5	2.4	1.0	3.4	.
<i>Alexandrium compressum</i>	.	.	.	.	.	0.5	0.6	0.6	0.5	0.6	.	.	.	.	.	.	.
<i>Alexandrium minutum</i>	.	0.5	.	0.6	.	.	0.6	.	.	0.6	.	1.1	0.5	2.4	0.5	1.4	.
<i>Gymnodinium breve</i>	.	.	.	.	.	0.5	.	.	.	.	.	.	1.0	.	.	.	.

Table 6. Exotic species recorded in Western Port, and those with self-sustaining populations, based on criteria described in the text.

Species	Common name	Source
Exotic species with self sustaining populations in Western Port		
<i>Carcinus maenus</i>	European shore crab	Currie and Crookes (1997); Cohen <i>et al.</i> (2000a)
<i>Musculista senhousia</i>	Asian mussel	Currie and Crookes (1997)
<i>Theora lubrica</i>	Asian bivalve	Currie and Crookes (1997)
<i>Bugula neritina</i>	Bryozoan	Currie and Crookes (1997)
<i>Watersipora subtorquata</i>	Bryozoan	Currie and Crookes (1997)
<i>Codium fragile tomentosoides</i>	Algae	Ferns and Curnow (1998)
<i>Asciella aspersa</i>	Ascidian	Cohen <i>et al.</i> (2000a)
<i>Ciona intestinalis</i>	Ascidian	Cohen <i>et al.</i> (2000a)
<i>Styela clava</i>	Ascidian	Cohen <i>et al.</i> (2000a)
<i>Styela plicata</i>	Ascidian	Cohen <i>et al.</i> (2000a)
<i>Ulva lactuca</i>	Algae	Cohen <i>et al.</i> (2000a)
<i>Alexandrium tamarense</i>	Dinoflagellate	MAFRI phytoplankton database (summarised Table 5 this report)
Exotic species that probably have self sustaining populations in Western Port		
<i>Alexandrium minutum</i>	Dinoflagellate	Table 3 this report
<i>Alexandrium catenella</i>	Dinoflagellate	MAFRI phytoplankton database (summarised Table 5 this report); Table 3 this report
Other exotic species that have been found in Western Port, but without self-sustaining populations-		
<i>Sabella spallanzanii</i>	European fanworm	Only recorded on mussel farms (Cohen <i>et al.</i> 2000a), none found near farms and improved treatment of mussel ropes should prevent further translocation of this species to W'port
<i>Crassostrea gigas</i>	Pacific oyster	Small numbers found in and near Rhyll Inlet
<i>Undaria pinnatifida</i>	Japanese kelp	12 immature plants found growing on discarded abalone shells at Flinders in Dec 2000/Jan 2001. This population has probably been eradicated.
<i>Corbula gibba</i>	European clam	A single valve found by Currie and Crookes (1997), but not found in extensive surveys in this report

Appendix 1 Eradication program for *Undaria pinnatifida* at Flinders pier

Gunthorpe, L., Cohen, B.F., Werner, G.F. and Parry, G.D.
Marine and Freshwater Resources Institute

Introduction

Undaria pinnatifida is a large brown algae, native to Japan, that has 'marine pest' status in southern Australian waters.

On 21 December 2000, Dr Gerry Kraft, a marine botanist from The University of Melbourne, advised the Department of Natural Resources and Environment that he had found 7-8 plants of *Undaria* growing on abalone shells at Flinders Pier on 13 December, 2000. Dr Kraft and an associate removed all the plants they found. All the plants were growing on abalone shells that had been shucked and discarded. The shells were concentrated over a 3 x 3 m area in 3 m depth near a low landing on the pier. It appeared that the *Undaria* had been introduced to the area on the discarded shells.

This report describes the actions undertaken by MAFRI to minimise the risk of *Undaria* establishing in Westernport. The response was managed by Department of Natural Resources and Environment, guided by the *Interim Victorian protocol for Managing Marine Exotic Organisms Incursions*.

Issues considered in determining the appropriate response

The responses have been based on the pest status of *Undaria*. This is the first reported introduction of *Undaria* to Westernport, despite surveys for it as recently as November 2000.

The reproductive characteristics of *Undaria* mean that a 'rapid response' will only be effective if the entire population is removed, and this must occur prior to any discharge of spores. Removal of the entire *Undaria* population seemed possible as the *Undaria* appeared to have been introduced as tiny gametophytes on abalone shells, and the removal of the abalone shells should remove all the *Undaria*. However if *Undaria* were introduced by some other means then the *Undaria* population may be more widespread, although this would not be evident until late May 2001, when the sporophytes become visible. Should further *Undaria* plants be discovered in May 2001 the appropriate response will then depend on the feasibility of eradicating the (probably larger) population then evident.

Objectives of Immediate Actions

To remove shells from the pile of discarded abalone shells observed by Dr Kraft.

To survey the Flinders pier area to determine whether there were more *Undaria* or discarded shells in the area.

To determine whether abalone shells appeared to have been discarded recently and whether discarding appeared to be an infrequent or an ongoing activity (daily/weekly)

Follow-up Actions

Fisheries Victoria to determine the activity leading to the discarding of the shells.

NRE to determine future approach to this issue following an inspection of the area in late May 2001 when *Undaria*, if present, will begin to mature and again become visible.

Methods

Initial Survey 28 Dec 00

On 28 December 2000 a visual (surface) inspection of the pylons on Flinders Pier and of the adjacent seabed surface was undertaken by walking the length of the pier. A 500 m section of the rocky reef to the north of the pier was also visually inspected.

Divers removed all *Undaria* and *Undaria*-like plants on the pile of shells identified by Dr Kraft and these were preserved in formalin for later identification. It proved impractical to remove all the shells in the pile identified by Dr Kraft, but all abalone shells on the surface layer of this pile were removed.

Two divers were deployed and collectively they swam the length of the pier recording the presence of any abalone shells and *Undaria* within approximately 1m of the outer pylons on each side of the pier. The area beneath the pier was also surveyed inshore of the most landward low landing (Fig 1). Poor visibility at the seaward end of the pier made observations beneath the pier impractical. The location of abalone shell dumps was recorded from their proximity to pylons, which had been individually labelled by the port authority.

Follow-up Surveys 12 Jan 01, 22 May 01

On the 12 January 2001 and 22 May 2001 Flinders Pier was re-surveyed. On both occasions divers swam the entire length of both sides of the pier, searching for abalone shell dumps and recording their locations, using pile numbers. Two transects were also swum through the mooring areas north and south of the pier. The area in which *Undaria* was found previously was searched thoroughly on each occasion. This area was search three times on 22 May 01, as the underwater visibility was low.

On 12 Jan 01 a video was used to record the appearance of the shell dumps. On 12 Jan 01 underwater visibility was approximately 3-5 m, enabling the distribution of shells to be much more accurately determined than during the initial surveys. On 22 May 01 visibility was only ~1.5 m in the main search area, but increased to ~5 m at the outer end of the pier.

During both follow-up surveys intertidal walks were conducted 250 m north and south of the pier to search for *Undaria* washed upon the beach.

Results

Initial Survey 28 Dec 00

The physical conditions experienced at the site on the day of the survey were not ideal for under water visual surveys. Visibility was poor, decreasing from 3 m to less than 1 m over the survey period. Visibility averaged 1.5 m for most of the survey period. The survey was also hampered by a medium swell.

The location of abalone shell dumps and *Undaria* plants detected in the survey of 28 Dec 00 are shown in Figure A-1.

Fourteen fish bins of abalone shells were removed from a large dump in the vicinity of pylon F154. These shells were taken from the surface layer of the shell dump first identified by Dr Kraft and were estimated to constitute 1- 5 % of the total volume of shell in this dump. The abalone shells in this area were largely contained in onion bags, which were fragile and tore upon collection, suggesting that these shells had been in the water for some time. The depth of abalone shells in the vicinity of pylon F154 was estimated to be 350 mm.

Four specimens of *Undaria* were found on one shell near pylon F154. This is the near where Dr Kraft had previously collected specimens. The sporophylls on these plants ranged up to 3cm in diameter. The abalone shell on which they were found was 103 mm in diameter.

A further algal specimen, probably *Ecklonia radiata*, was observed in the vicinity of pylon F123, but was not collected.

As visibility was poor, it is possible small specimens of *Undaria* may not have been detected even within the area surveyed.

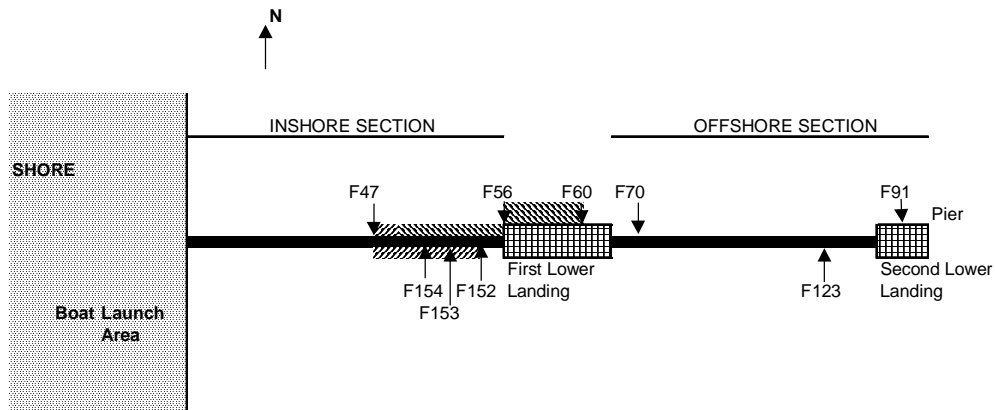
Follow-up Survey 12 Jan 01

No *Undaria* were observed either in the water or washed up on the beaches.



The distribution of abalone shells determined during each survey is shown in Figure A-1. The improved visibility on the 12 Jan 01 survey indicated that there was a large shell dump under the first low landing, which extends to pile F56-F60 on the north side of the pier. This appears to be a bigger shell dump than that observed around piles F152-154, near where the *Undaria* was observed. Aside from small, isolated clumps, the vast majority of the shell dump is situated in the second seaward quarter of the pier, out to the first low landing. Overall, approximately 50 % of the dump, by area, is of shells contained within onion bags, the remainder is loose scattered shell. However, by number, most shells are probably still contained within onion bags. No shells were collected during this survey.

Follow-up Survey 22 May 01

No *Undaria* were observed either in the water or washed up on the beaches, although divers collected small *Ecklonia*. Divers were very confident that there was no *Undaria* on the pier, and confident that there was no *Undaria* in the high risk area where the infected shell pile occurred.



LEGEND

-  area of abalone dump detected in survey 28/12/00
-  area of abalone dump detected in survey 12/01/01
- F # Pylon Identification number

Field Notes

- F47** abalone shell dump
- F56** large abalone shell dump
- F60** large abalone shell dump
- F70** a few abalone shells detected
- F91** a few abalone shells detected
- F123** a small macroalgae on abalone shell - probably *Ecklonia*
- F152** 100s of abalone shells in onion bags
- F153** abalone shell dump
- F154** *Undaria* specimens collected

Figure A-1 Schematic map showing location of abalone shell dumps and suspected *Undaria* plants removed during the surveys of the 28 Dec 00 and 12 Jan 01.

Summary

- The seabed, pylons and mooring areas on both sides of Flinders Pier and the intertidal beach north and south of the pier were inspected during three surveys.
- Four *Undaria* specimens were collected growing on one abalone shell in the same area they were found by Dr Kraft.
- The number of abalone shells found was very much larger than expected. The 14 fish bins removed during the first survey represented a very small fraction of the number of shells found in that particular shell dump i.e. < 1-5%.
- The location of the shell dumps, in close proximity to the pier, and the lack of dumps observed in the mooring areas strongly suggests that all dumping activities had been undertaken from the pier. Therefore, it appears that the entire extent of the dumps was fully documented. The vast majority of loose shell probably represents shell initially dumped in onion bags, which subsequently broke open. It would appear that at least these shells have been present for some time.
- The containment of the abalone shells in onion bags suggests these dumps have not accumulated from the isolated discards of recreational fishers, but that a systematic process was involved.
- Investigations by Fisheries Victoria suggests that the shells were placed below the pier as part of an operation to clean up shells prior to their sale. The operation appears to have ceased some years ago, but the source of the shells is uncertain.
- The minimum legal size of abalone shells harvested in Bass Strait, between Lorne and Lakes Entrance, is 110 mm, while the minimum size in Port Phillip Bay is 100 mm. The shell upon which the *Undaria* was found was 103 mm, which suggests that these shells may have come originally from an infected area within Port Phillip Bay.
- The absence of *Undaria* during the most recent surveys suggests that *Undaria* was successfully eradicated but confirmation requires further monitoring.

Appendix 2. Tables of Phytoplankton abundance in Port Phillip Bay and Western Port