NRM FINAL REPORT

A DETAILED BENTHIC FAUNAL AND INTRODUCED MARINE SPECIES SURVEY OF PORT DAVEY, BATHURST CHANNEL AND BATHURST HARBOUR IN SW TASMANIA

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Executive Summary

Port Davey – Bathurst Harbour is arguably the most pristine estuarine system in southern Australia and certainly one of the most unusual. The system is characterised by strongly stratified and tannin stained surface waters, and extremely low levels of nutrients and low aquatic productivity. Whilst the remoteness of this region has largely protected it from human impacts, a number of introduced marine species are now known to occur within the system, notably the NZ screw shell *Maoricolpus roseus* and the toxic dinoflagellate alga *Gymnodinium catenatum*. Past research in the region has focussed primarily on the hydrology of the estuary, in addition to the ecology of plankton, fish and reef communities, however, there is little known about the ecology of benthic soft-sediment communities – the major habitat in this system. This study aims to at least partially fill this gap by undertaking a comprehensive survey of the benthic fauna of Port Davey – Bathurst Harbour and adjoining Payne Bay, James Kelly Basin and Hannant Inlet. This will provide important information on the composition and structure of benthic faunal communities and the distribution of any introduced species amongst the benthos.

In February/ April 2007 invertebrate faunal communities were sampled at 70 locations throughout the system – with the greatest intensity of sites located within Port Davey, Bathurst Channel and Bathurst Harbour. One hundred and ninety-seven native species were recorded during this survey including 79 crustaceans, 59 marine polychaete worms, 46 molluscs and 5 echinoderms. Not one single introduced species was found amongst the benthos. This finding was perhaps a little surprising given that 7 other introduced species have been recorded from the region. Moreover, this study failed to find any *M. roseus* shells despite earlier sightings (< 10 shells in total recorded). Only a single *Gymnodinium catenatum* dormant cyst was found in Bathurst Harbour extending the distribution of this species beyond three earlier sites sampled at the western end of Bathurst Channel. This finding suggests further studies are required to clarify the distribution of this species.

Benthic invertebrate assemblages appeared to be distributed in relation to sediment type. Whilst Port Davey sediments were primarily dominated by crustaceans, the muddier and organically enriched sites in Bathurst Channel and Bathurst Harbour were dominated by deposit-feeding polychaete worms. The highest species diversity of invertebrates was recorded for sites sampled in Bathurst Channel.

Analysis of past marine species introductions to this region indicates that the greatest risk of further introductions derives from hull fouling organisms (such as encrusting byrozoans and ascidians) and/or accidental or inadvertent introductions from visiting vessels. It is not clear how the dinoflagellate *G. catenatum* arrived (usually transported in ballast water), but may represent an historical introduction to the region. Recommendations for targeted future monitoring and ways in which the risk of further species introductions can be possibly mitigated are provided.

Introduction

Port Davey, Bathurst Channel and Bathurst Harbour in south-west Tasmania comprise one of most pristine estuarine ecosystems in Australia. With the exception of fishing, historical timber extraction and small-scale mining operations, this system remains essentially undisturbed by human activities. The marine component is now protected within the Port Davey Marine Reserve, whilst the surrounding coastline and catchments are protected within the Southwest National Park and World Heritage Area. The Bathurst Harbour/Bathurst Channel component of the Marine Reserve are unique amongst Australian estuaries in having (1) virtually no anthropogenic impacts within the estuary or catchment areas, (2) strongly stratified and tannin stained surface waters, and (3) extremely low levels of nutrients and low aquatic productivity (Edgar and Creswell 1991, Last and Edgar 1994, Barrett *et al.* 2004, Edgar *et al.* 2007).

The ecological significance of this area is widely recognised and is a major reason why it is now protected within the Tasmanian Marine Reserve system (RPDC 2004). There has been some research into the biological and physical systems within the Port Davey Marine Reserve over the past two decades and this is summarised in detail in a recent review (Edgar *et al.* 2007). This research includes studies on hydrology, plankton, fish and reef assemblages (fish, macro-invertebrates and algae), habitat distribution and mapping. These studies vary in their spatial extent, degree of replication and extent of species identification; however, they do give a basic insight into the systems they represent. One component that is conspicuously absent is an understanding of the infauna and epifauna of the benthic sediments. These sediments form the majority of the seabed within the port and associated estuarine systems, and the need to document the biological composition of these sediments has been identified as an urgent research priority in a recent review (Edgar *et al.* 2007).

Introduced species form a conspicuous and abundant component of the marine benthos in south-eastern Tasmania, with one recent study indicating that introduced species comprised 45% of the biomass of species associated with fish farming leases (Edgar *et al.* 2005). Currently, 133 introduced species have been recorded from Australian marine waters (Hayes et al. 2004). A further 175 species are classified as cryptogenic – that is likely to be non-native in origin, but having no verifiable invasion history (Hayes et al. 2004). Of the 133 introduced species 53 are listed as target species under the National System for the Prevention and Control of Marine Pest Incursions in Australia because these species have demonstrated impacts on human health, economic interests or environmental values. In Tasmania at least 40 introduced species have been recorded to date (CRIMP unpub. data), including 9 target species. This includes the Pacific Oyster (*Crassostrea gigas*), Northern pacific seastar (*Asterias amurensis*), European shore crab (*Carcinus maenas*), Japanese kelp (*Undaria pinnatifida*), the molluscs *Musculista senhousia, Corbula giba* and *Theora lubrica*; and polychaete worm *Euchone limnicola*. None of these species has been recorded from Port Davey, but their establishment could cause major declines in populations of native species.

A number of Tasmanian ports (including Port Davey) have been surveyed for introduced species in the last decade as part of the States obligations to the Australian Quarantine and Inspection Service (AQIS) (Aquenal 2001, 2002, 2003). Introduced species were present at all ports surveyed; however, the incidence of non-native species suggests that the number of introductions is clearly related to the volume of vessel traffic experienced by each port.

The primary source (dispersal vectors) of new introductions has been via ship/vessel hull fouling and ballast water (Hewitt et al. 2004, Hayes et al. 2004), although, historically, mariculture has also been an important vector. For example, in the case of Tasmania a number of non-native species (e.g. NZ screwshell and the crabs *Petrolisthes elongatus*, *Metacarcinus novaezelandiae* and *Halcarcinus innominatus*) were introduced to Tasmania during the transfer of live flat oysters from New Zealand to Tasmania in the 1920-30s. Strict protocols now limit the dumping of ballast of water in Australian ports and live transfer of mariculture species (ref??)

Port Davey is one of the most remote and isolated ports in southern Australia and consequently receives substantially less traffic than most Tasmanian ports. Nevertheless, a range of introduced species have been recorded from the Port Davey region including the reef-dwelling species *Astrostole scaber*, *M. novaezelandiae* and *H. innominatus* (see review in Edgar et al. 2007). The New Zealand screw shell (*Maoricolpus roseus*) is a more recent introduction to the region. In 2003 three live shells were found by a diver in Bathurst Channel. Subsequent searches found only a small number of living individuals (Edgar et al. 2007). Another notable recent introduction reported is the toxic dinoflagellate *Gymnodinium catenatum* which was discovered in a recent survey (Aquenal 2003). This phytoplankton species poses a significant risk to human health via bioaccumulation of toxins in marine food chains. *Gymnodinium* cysts (the dormant benthic stage resident in sediments) have only been recorded from the western end of Bathurst Channel, although nothing is known of its distribution elsewhere in this system.

The Aquenal (2003) survey also reported one other introduced species, the fouling bryozoan species *Bugula stolonifera*, and several other crypotogenic fouling species, but surveys were only limited to three locations most commonly used by visiting vessels. This study aims to fill some of the missing gaps in our understanding of the ecology of this system by undertaking a survey of soft-sediment dominated benthic habitats found in Port Davey Bathurst Channel, Bathurst Harbour, James Kelly Basin and Hannant Inlet. The benthic fauna, including any introduced or cryptogenic species, will be described in detail for the first time using a spatially comprehensive survey of the region's soft-sediment habitats. In addition to indicating the extent of possible species introductions, this dataset will form an invaluable reference set against which future changes can be assessed. To further this task all specimens collected have been lodged with the Tasmanian Museum and Art Gallery for future reference. A database containing all the biological data collected in this study also accompanies this report to allow, where appropriate, future analysis (Port Davey benthic survey.mdb MS Access database). The report also includes an assessment of current and future risk of marine species introductions, and recommendations to minimise and contain these risks.

Methods

Site description

Bathurst Harbour and Port Davey, adjoin the Southwest National Park and Tasmanian World Heritage area in southwest Tasmania. They are connected by a 12km long channel, Bathurst Channel, from which a number of smaller embayments originate (Joe Page Bay, Horseshoe Inlet). Payne Bay and a smaller, shallower embayment, James Kelly Basin border Port Davey to the north, Hannant Inlet borders Port Davey to the east (Fig. 1).

Bathurst Harbour is a shallow bay of relatively uniform depth (3-7 m) dominated by fine silty sediments dominated by high % of particles <63µm (Table 1). Depths within Bathurst channel are by comparison more variable: depths within the central channel range 20-30 m, but may reach 40 m in places (Barrett et al. 2004), whilst at the margins of the channel depths fall within the range 10-20 m. The benthos in Bathurst Channel is dominated by silty sediments at the eastern end grading to sandier sediments at the western end (e.g. Bramble Cove, Waterfall Valley). Bays adjoining the channel are shallow (<7 m) and dominated by fine silty sediments similar to those found in Bathurst Harbour. By comparison Port Davey is dominated by coarse sandy sediments with a much smaller % of finer sediment particles. Depths range from 20-40 m and the regions is exposed to large oceanic swells. The organic carbon content of the finer silts and muds in Bathurst Channel and Bathurst Harbour was much higher that recorded for Port Davey sediments (Table 1).

Table 1 Summary of sediment properties for sites situated within Port Davey, Bathurst Channel and Bathurst Harbour

Sediment properties	Port Davey	Bathurst Channel	Bathurst Harbour
% <63µm (min. – max.)	6.4 – 34.3	6.5 – 99.4	24.3 – 99.9
mean % <63µm	19.8	67.0	82.1
mean % organic C	0.9	8.0	10.7

There a number of major freshwater sources which flow in to this system including the Old and North Rivers which flow into Bathurst Harbour, the Spring River which flows into Joe Page Bay and the Davey River which flows into Payne Bay (Fig. 1). Bathurst Harbour and the Channel are characterised by vertically stratified waters. Freshwater runoff entering the system is stained by tannins leached from buttongrass and heathland. These tannins deeply stain the low-salinity waters which overlay a clearer near-marine (and denser) layer below – producing a visible halocline which persists throughout the year. This dark surface layer effectively blocks sunlight to the benthos reducing productivity and inhibiting the growth of aquatic plants (e.g. seaweeds) (Barrett et al. 2004).

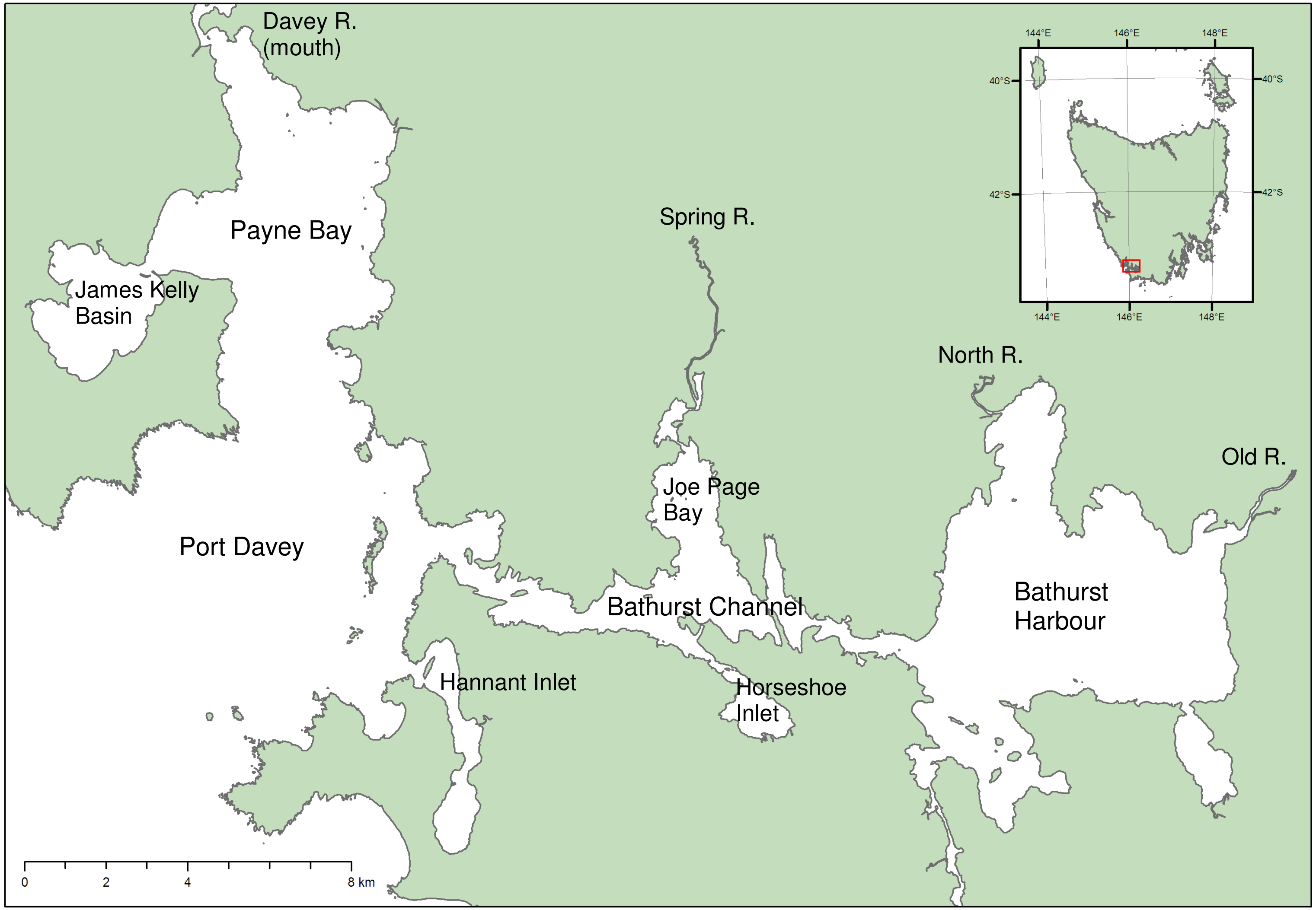

Fig. 1 Map showing location of important features referred to in the text.

During this study (Feb. 2007) bottom water salinities varied from 30-34‰. Surface water salinity above the halocline was 18‰ adjacent to the Old River mouth (Bathurst Harbour), 22-24‰ for much of the remaining harbour and channel increasing sharply to 33‰ at the western end of the channel. Open marine salinities in southwest Tasmania are typically ~34‰ (Edgar and Cresswell 1991). Dissolved oxygen levels in bottom waters may also be reduced during certain times of the year due to poor mixing between surface and bottom waters (Edgar and Cresswell 1991). Freshwater runoff is very low in nitrates (<0.1 µm), whereas bottom waters have regional marine levels of 1.0-3.9 µm (Edgar and Cresswell 1991). Marine tidal incursions are thus believed to be the major source of nitrogen into this system (Edgar et al. 2007). This is unusual for Australian estuaries where the dominant source of nitrogen derives from the terrestrial catchment.

Field methods

Seventy locations were sampled throughout the Port Davey – Bathurst Harbour system (Fig. 2). Sites were representative of a range of locations, depths and sediment types. Depth was measured from the surface using a depth sounder. Benthic invertebrate communities were sampled from the surface using an Eckman grab (in silty and muddy sediments) or a Van Veen grab in sandy sediments (information shown in appendix 1). At each site three replicate grab samples were collected and amalgamated in the field after sieving through a 1.0 mm mesh sieve then fixed in buffered 10% formalin seawater solution. An additional grab sample was collected for sediment physical and chemical analysis (C. Reid, Queens University, Canada). Surface and bottom water salinity were recorded at each location using a conductivity-salinity probe. The geographical position of each site was marked using GPS.

At a subset of sites (6) sediment was collected to determine the presence of *Gymnodinium catenatum* and *Alexandrium* dinoflagellate cysts (see table 3) in Bathurst Harbour and the eastern end of Bathurst Channel. *G. catenatum* cysts were previously recorded from the western end of the channel (Aquenal 2003). Sediments were stored at 4 °C and processed by the Harmful Algal Blooms Research Group, University of Tasmania.

Sites 1-47 were sampled from 19-28 February whilst based out of Melaleuca. Sites 50-72 were sampled from 22-26 April using a chartered vessel working in and around Port Davey (appendix 1). The depth of samples collected ranged from 1.5–29 m (the limit at which the grabs effectively operated). All sites sampled were unvegetated with exception of PD53 in James Kelly Basin where the benthos was dominated by dense beds of the green alga *Caulerpa trifaria*.

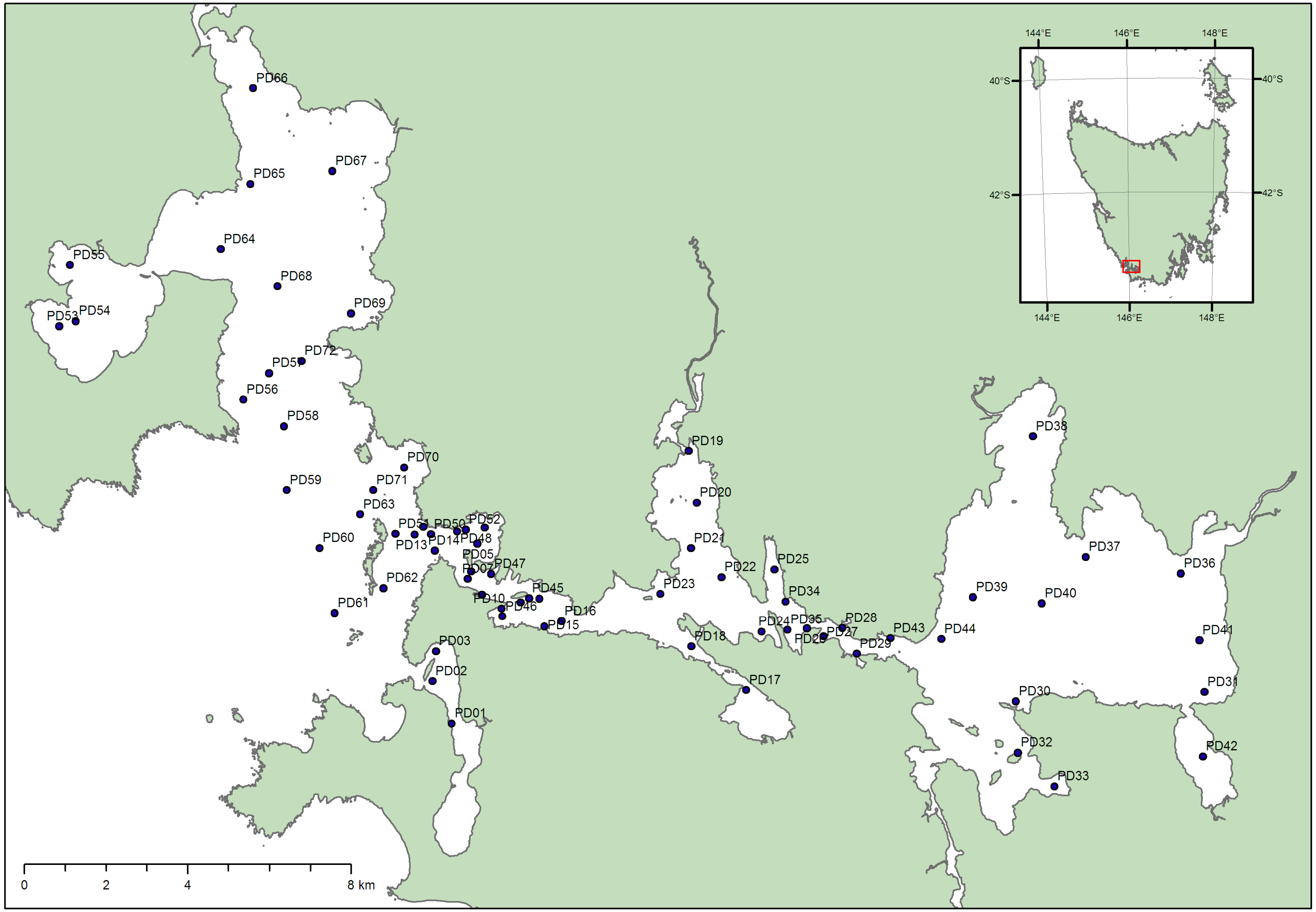

Fig. 2 Location of sites sampled during this study corresponding with sites shown in appendix 1.

Lab methods

Invertebrate specimens were identified to species, where possible, and then counted for each site using a dissecting microscope. Specialist taxonomic advice and identifications were provided by G. Walker-Smith, L. Turner and K. Moore (Tasmanian Museum and Art Gallery); R. Wilson, T. O'Hara, J. Taylor, D. Staples and G. Poore (Museum Victoria) and A. Hirst, L. Meyer, G. Edgar and C. McCleod (TAFI). Ostracod crustaceans could not be identified beyond the class-level, however, there are no introduced ostracod species currently listed (Hayes 2005 database). Species lists were cross-referenced against a list of 133 introduced and 175 cryptogenic marine species currently listed by CSIRO's Centre for Introduced Marine and Pest Species as established within Australia (Hayes 2005 database). In the case where species identifications were not initially possible, specimens were sent to specialist taxonomists where the genus or family of the specimen coincided with known introduced or cryptogenic species. For example, the sabellid worm *Euchone* sp. was determined to be the native species *Euchone variablis* rather than the introduced species *Euchone limnicola*. In many cases the absence of full species names for specimens is a reflection of the poor state of taxonomic knowledge of many groups in southern Australia – particularly crustaceans and polychaetes. This increases our uncertainty about the origin of specimens.

Sediment particle size-distribution was determined by wet sieving samples through a nested series of sieves. Sediments retained by different sieves were weighed after drying at 50° C. The proportion of fine particulates <0.63 mm that passed through the final sieve was calculated by subtracting the total weight of sediments retained on the nested sieves from the initial dried weight of the sediment sample. Sieve fractions were expressed as a % of the total sediment sample. Organic carbon content of the sediments was calculated using mass spectrometry elemental analysis. Sediments were first treated with 1M hydrochloric acid to remove inorganic carbon in the form of carbonates prior to analysis.

Sediment cores were examined for dinoflagellate cysts using standard methods developed by the Harmful Algal Blooms Research Group, University of Tasmania. Heavier particles (including cysts) were separated from finer organic silt particles using a sodium polytungstate density separation technique. These heavier fractions were then sorted under a microscope and any dinoflagellate cysts present identified.

Results

Benthic macroinvertebrate fauna

198 species/taxa were recorded during this study. A full list is provided in appendix 2. The most diverse group were the crustaceans (80 taxa), followed by marine polychaete worms (59), molluscs (46) and echinoderms (5). None of the species recorded are listed as either introduced (non-native) or cryptogenic in origin. The specimens include a new genus of pycnogonid (sea spider) collected from Bathurst Channel (D. Staples pers. com.) and a new species of nebalid crustacean collected from Port Davey (G. Walker-Smith pers. com.). These have yet to fully identified.

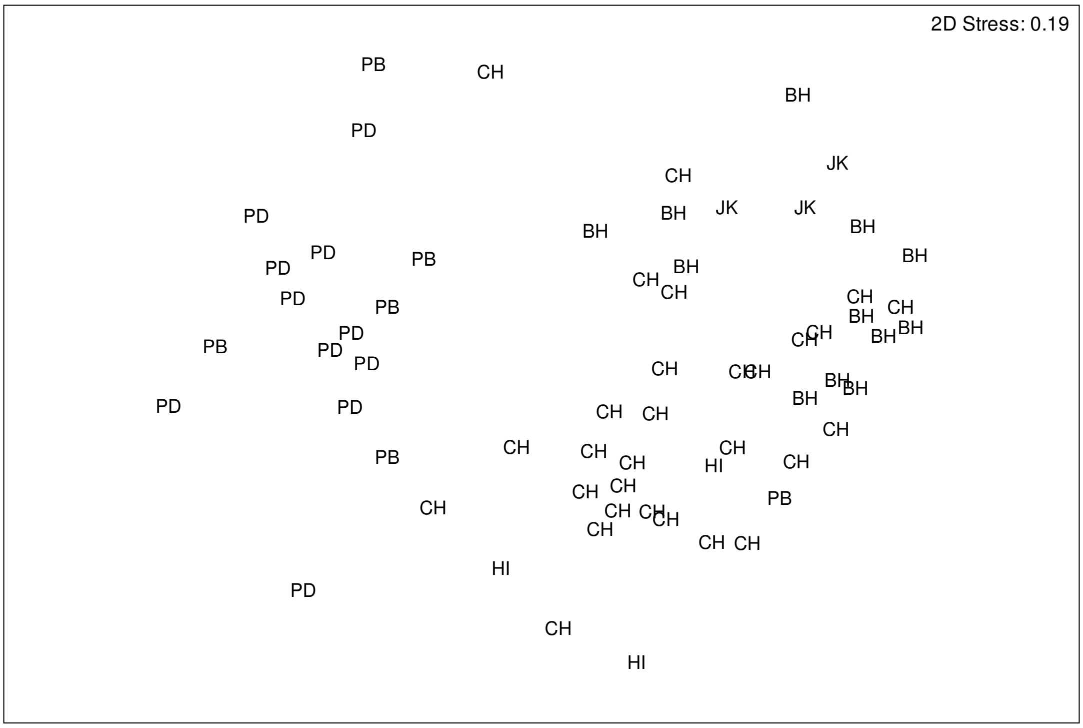

Fig. 3 nMDS ordination showing the relative compositional similarity of benthic invertebrate communities surveyed at sites in Port Davey (PD), Payne Bay (PB), Hannant Inlet (HI), James Kelly Basin (JK), Bathurst Channel (CH) and Bathurst Harbour (BH) regions. Sites in Port Davey and Payne Bay can be clearly distinguished from those found in Bathurst Harbour and Bathurst Channel on the basis of similarity of invertebrate assemblages (or lack thereof).

MDS ordination of the sites indicated that benthic invertebrate communities in Port Davey and Payne Bay differed from those found in Bathurst Channel and Bathurst Harbour (Fig. 3). By comparison, invertebrate assemblages sampled in Hannant Inlet and James Kelly Basin showed greater similarity with sites sampled in Bathurst Channel and Bathurst Harbour. The invertebrate species which characterised these six broad sampling regions are shown in table 2. In general the Port Davey fauna includes a greater compliment of crustacean fauna in comparison to the largely polychaete dominated Bathurst Channel and Harbour sites (Table 2). Characteristic Port Davey crustaceans included the cumaceans *Cyclaspis tribulis*, *Cyclaspis sheardi* and *Leptocuma* sp.; the isopod *Austrochaetilia capeli* and the amphipods *Urohaustorius* spp., *Birubius* spp. and Oedicerotidae sp. A. A range of polychaete species dominated the sediments in Bathurst Channel and Bathurst Harbour including the spionids *Prionospio coorila* and *Paraprionospio coora*; the capitellid *Mediomastus australiensis*; 2 unidentified ampharetid polychate species; the maldanids *Asychis* sp MoV907 and *Clymenopsis* sp.; the ophellid *Ophelina* sp. MoV285; the trichobranchid *Terrebellides kowinka* and *Nephtys australiensis*. Many of these are surface deposit feeders particularly the spionid, terrebellid, ampharetid, maldanid and trichobranchid species (Beesley et al. 2000). The heart urchin *Echinocardium cordatum* and the molluscs *Nemocardium thetidis*, *Tellina* sp. and *Tatea* spp. were also important components of the Bathurst Harbour fauna.

The longer species lists for Bathurst Channel, Bathurst Harbour and Port Davey do not necessarily infer differences in overall diversity, but reflect the larger numbers of sites sampled within these regions (refer to table 2). In general, sites located within Bathurst Channel and Hannant Inlet supported the greatest number of species (mean species richness of 22 and 23 species per site, respectively) compared to sites collected from Port Davey which contained the fewest species (mean = 8.2 species per site).

Table 2 Species/taxa characteristic of regions within the survey derived using similarity percentage tests (90% SIMPER similarity; PRIMER 6, Clarke and Warwick 2001).

Region	**Characteristic species/taxa**
Hannant Inlet (3 sites)	*Dimorphostylus cottoni* Lumbrinereid sp. A Ostracod sp. C *Microspio granulata* Oedicerotidae sp. D *Leodomas johnstonei* *Litogynodiastylis ambigua* *Euchone variablis*
Bathurst Channel (29)	*Prionospio coorilla* Terebellidae spp. *Nephtys australiensis* *Mediomastus australiensis* Ampharetidae sp. A Ampharetidae sp. B *Dimorphostylus cottoni* *Birubius* spp. *Ophelina* sp. MoV 285 *Paraprionospio coora* *Falcidens* sp. *Amphiura constricta* *Solemya australis* *Tellina* sp. *Echinocardium cordatum* *Caulleriella* sp. *Terrebellides kowinka* *Phyllodoce* sp. Ostracod sp. L *Scalibregma* sp. *Wallucina assimilis*? *Asychis* sp MoV907 Oedicerotidae sp. D *Alia* sp. *Clymenopsis* sp.
Bathurst Harbour (12)	*Nephtys australiensis*

	Amphiura constricta *Paraprionospio coora* Ampharetidae sp. A *Nemocardium thetidis* *Echinocardium cordatum* *Asychis* sp MoV907 *Tellina* sp. Ostracod sp. C *Wallucina assimilis*? *Phyllodoce* sp. *Tatea* spp.
Port Davey (13)	*Prionospio coorilla* *Cyclaspis tribulis* *Leptocuma* sp. *Glycera* sp. A Oedicerotidae sp. A *Urohaustorius* spp. *Magelona* sp. B *Cyclaspis sheardi* *Birubius* spp. *Austrochaetilia capeli* *Nuculana crassa*
Payne Bay (6)	*Prionospio coorilla* Ostracod sp. C *Leptocuma* sp. *Diplocirrus* sp. B Oedicerotidae sp. A *Placamen placidum* *Cerapus* sp. *Glycera* sp. A *Birubius* spp. Lysianassid sp. B
James Kelly Basin (3)	*Nephtys australiensis* *Tellina* sp. *Terrebellides kowinka*

Distribution of Gymnodinium catenatum cysts

Gymnodinium catenatum first appeared in Tasmanian waters in the early 1970s. Its natural range is believed to be the northern Pacific, but may have arrived in Tasmania via New Zealand (McMinn et al. 1997). Recent molecular evidence indicates that toxic dinoflagellate species may have been directly introduced to Australia, most probably via ballast water, from Japan and/or south-east Australia (Bolch and de Salas 2007). In Australia *G. catenatum* is found in south-eastern Australia and Tasmania, although is distribution in Tasmania is generally limited to the east coast (Bolch and de Salas 2007) with the exception of cysts detected in the sediments of Bathurst Channel.

In 2003 Aquenal established that *G. catenatum* cysts were present in the sediments at the western end of Bathurst Channel at frequently used anchorages (sites 1–3, table 3, fig. 3). A further 6 sites were sampled in this study extending the range of sites examined to central and eastern Bathurst Channel and Bathurst Harbour (see fig. 3). Only a single *G.*

catenatum cyst was recorded in this study, at a site in western part of Bathurst Harbour (table 3). This finding further supports the conclusion of the earlier study (Aquenal 2003) that *G. catenatum* is present in the system; however, it is ambiguous about its overall distribution.

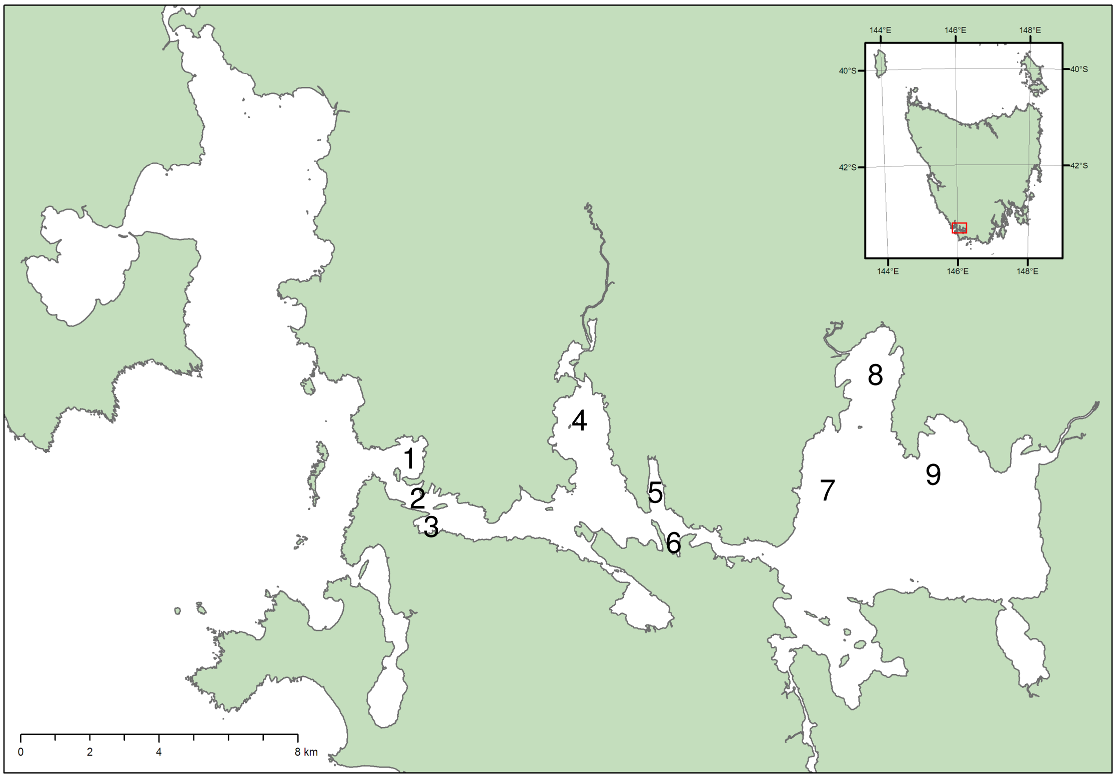

Fig. 3 Location of samples 1–9 listed in table 3

Table 3 Presence of *Gymnodinium catenatum* cysts at 9 locations located throughout Bathurst Channel and Bathurst Harbour (see Fig. 3)

Map ref	Site	Project	Pres.
1	Bramble Cove	Aquenal (2003)	x
2	Waterfall Bay	Aquenal (2003)	x
3	Schooner Cover	Aquenal (2003)	x
4	Joe Page Bay	this study	
5	Ila Bay	this study	
6	Frogs Hollow	this study	
7	W. Bathurst Harbour	this study	x*
8	North Bay	this study	
9	N. Bathurst Harbour	this study	

* only a single *G. catenatum* cyst found

Discussion

Introduced species in Port Davey/Bathurst Harbour

Although no introduced or cryptogenic fauna were discovered amongst the soft-sediment benthos in this study, a number of introduced species have been recorded from the other habitats in Bathurst Channel and Bathurst Harbour (see Aquenal 2003, Sutton et al. 2006). A thorough review of the status of introduced species in the region is also provided by Edgar et al. 2007. This list includes *Maoricolpus roseus* (soft-sediment benthos), the crabs *Metacarcinus novaezelandiae* and *Halcarcinus innominatus* (reef or algal dwellers); the ascidian *Botrylloides leachii*, and the bryozoans *Bugula stolonifera* and *Bowerbankia gracilis* (encrusting fauna). A range of cryptogenic fouling species (mainly bryozoans) have also been recorded (Aquenal 2003, Edgar et al. 2007). To place this into some kind of context, we have included a table showing the number of introduced species recorded from other locations around Tasmania (Table 4).

Table 4 The number of total, soft-sediment and encrusting introduced species recorded from Tasmanian Ports. Source: Aquenal 2001, 2002, 2003, Hewitt et al. 2004.

Port	Total	Soft-sediment	Encrusting
Derwent R. (Hobart Port)	27	7	12
Kettering	17	4	10
Dover	14	7	5
St Helens	12	4	5
Tamar R. (Port of Launceston)	12	3	5
Port Davey/Bathurst Harbour	7	2	3
Bridport	4	2	1
Grassy, King Is.	3	0	3
Strahan	2	1	1
Port Phillip Bay, Victoria	99		

Note that many of the studies featured in table 4 are more limited in their spatial extent than the current Port Davey survey. For example the Port of Launceston survey (Aquenal 2001) only surveyed the Port of Launceston, rather than the entire Tamar River estuary – a system comparable in scale to the entire Bathurst Harbour/Channel system – and then only at 5 locations. Similarly information for the Port of Strahan is presented, but not the remainder of Macquarie Harbour. Nevertheless Port Davey/Bathurst Harbour has fewer introduced marine species than ports located in south-eastern Tasmania and only one of these species, the dinoflagellate *Gymnodinium catenatum*, is listed as a target species of concern.

The incidence of introduced species across locations is primarily linked to the volume of vessel traffic a port receives – the primary vector for the introduction of many exotic species (Hayes et al. 2004). In the case of Port Phillip Bay, the busiest port in Australia, introduced species account for 8% (99) of all benthic species recorded (Hewitt et al. 2004) and have been linked to significant shifts in the structure and functioning of benthic ecosystems (Wilson et al. 1998, Currie and Parry 1999, Holloway and Keough 2002). It is therefore not surprising that smaller and more remote ports will have fewer introductions as the opportunities for potential species introductions are less. Nevertheless, introduced species have been found at all ports surveyed to date.

Of the seven introduced species recorded only two species *Maoricolpus rosea* and *Gymnodinium catenatum* are of concern. The New Zealand screw shell *Maoricolpus roseus* forms dense aggregations on the east coast of Tasmania altering the structure of benthic habitats and potentially displacing introduced species. In 2003 three live shells were found by a diver in Bathurst Channel. It is not known how *M. roseus* was introduced; however, it is likely to have been via a larval settlement event during favourable oceanographic conditions. Subsequent targeted searches on three separate occasions by Aquenal and TAFI (University of Tasmania) revealed six additional living individuals and a similar number of dead shells (Edgar et al. 2007). Recent searches during this study by TAFI (February and April 2007), however, failed to locate either live or dead shells, and previous searches by TAFI (in 2005 and 2006) only located dead shells. This suggests that the *M. roseus* population in Bathurst Channel is either very small or has simply failed to establish after its initial introduction. Edgar et al. (2007) suggest that environmental conditions in Bathurst Channel may be marginal for the survival of *M. roseus*, presumably due to its low productivity. Further research is required to clarify the status of *M. roseus* in Bathurst Channel.

The toxic dinoflagellate *G. catenatum* poses a significant risk to human health within the region due to the bioaccumulation of toxins in marine food chains. The results of this survey and those undertaken by Aquenal (2003) indicate that *G. catenatum* is present in the system, particularly the western end of Bathurst Channel, but remain ambiguous about its distribution elsewhere in the system.

All specimens collected in this project were lodged with the Tasmanian Museum and Art Gallery for future reference. In time these specimens will help increase our knowledge of the taxonomy and ecology of Tasmanian marine communities. However, at present a large percentage of Tasmania marine invertebrates remain undescribed (as evidenced by limited number of crustacean and polychaete species which could be identified to species in appendix 2). This means that they have not been formally described and classified by a taxonomist. As a consequence, significant proportions of Tasmania's marine biodiversity remain unknown. This poses a problem when attempting to detect invasions in marine systems because poor knowledge of Tasmania's marine biodiversity obscures efforts to distinguish native from non-native species. Whilst conceding that the challenge to catalogue the biodiversity of Tasmania's marine ecosystems is great; a chronic lack of funding for taxonomic research and taxonomists at all levels of government has hindered this situation. At present only one marine invertebrate taxonomist is employed in Tasmania (although CSIRO employs a number that work at a national level). It is fair to say that without the assistance of taxonomists, at in particular, the Museum of Victoria this project would not have been achievable in its current form.

Risk Assessment

With exception of *Bugula stolonifera* (recorded from Victorian Ports) all of the introduced species recorded to occur in Port Davey and its environs are also found in south-eastern Tasmania. This region is thus the likely source of many of the introduced species currently found in Port Davey and is also historically the region from which the majority of visiting vessels originated. For example, the crabs *Metacarcinus novaezelandiae* and *Halcarcinus* *innominatus* were originally introduced to south-eastern Tasmania during the transfer of live flat oysters from New Zealand to Tasmania in the 1920-30s and have subsequently been introduced to Port Davey. The mechanisms by which non-native species are transported to a new location are called vectors. Assessment of the risk of future introductions requires 1) that vectors be identified, and 2) that the relative importance of different vectors be assessed. By understanding the circumstances behind past introductions we may be able to anticipate future sources of new introductions. This is not always an easy task because it is often difficult to identify the exact mechanism/event by which individual species were introduced. There is, however, an increasingly expansive literature on the science of marine species introductions and invasions (see reviews in Hayes et al. 2004, Hewitt et al. 2004) and this report draws heavily from this literature.

Table 5 shows that a number of vectors are responsible for the current array of introduced species in Port Davey. It is unclear how *M. roseus*, *M. novaezealandiae* and *H. innominatus* were introduced to Port Davey, although it is thought that all these species first arrived in Tasmania as passive passengers amongst live flat oyster imports. Subsequent transportation to Port Davey may have occurred as a result of accidental transportation of adult animals associated with anchors or fishing equipment or through larval settlement from the plankton. Recent research has shown that *M. roseus* has a long-living planktonic larval stage (Gunasekera et al. 2005, Probst and Crawford *in review*) capable of being transported in the water-column to the southwest coast.

Table 5 Vectors for introduced species recorded from Port Davey indicating past and potential future risk factors

Introduced species	**Habitat**	**Transport vectors**
Gymnodinium catenatum	Adult – plankton, cysts - sediment	Ballast Water (Hayes et al. 2004)
Maoricolpus roseus	Soft-sediment, free-living	Mariculture/Ballast Water/Natural range expansion
Metacarcinus novaezelandiae	Reef, free-living	Mariculture/Natural range expansion
Halcarcinus innominatus	Free-living on sandy and shelly bottoms	Mariculture/Natural range expansion
Botrylloides leachii	Encrusting on hard surfaces	Hull fouling (Hayes et al. 2004)
Bowerbankia gracilis	Encrusting on hard surfaces	Hull fouling (Hayes et al. 2004)
Bugula stolonifera	Encrusting on hard surfaces	Hull fouling (Hayes et al. 2004)

A substantial component of the introduced and cryptogenic fauna of Port Davey are fouling organisms that would have arrived attached to the hulls of visiting vessels. This continues to be the largest source of introduced species in Australia (Hayes et al. 2004) and is likely to be a continuing source of further introductions to Port Davey. There are a number of introduced fouling organisms endemic to south-eastern Tasmania not currently recorded from Port Davey and its environs – all are potential future colonists. It is expected that hull fouling will remain the most significant vector for the introduction of non-native species into Port Davey as the dumping of ballast water into Port Davey is not permitted (Parks and Wildlife Service 2004). Accidental introductions are likely to be the next most important source of future introductions.

Another factor to consider when assessing the risk of future species introductions is the natural resilience of the system to invasions. As a general rule healthy ecosystems are more resilient to invasions than systems stressed by a range of human activities (Carlton 1996).

Artificial structures such as piers, pontoons and seawalls may facilitate the invasion of many fouling species by providing preferential surfaces for colonisation by invading species (Glasby et al. 2007). Pollution and habitat destruction may degrade natural ecosystems and biological assemblages creating niches into which introduced species can successfully establish and diffuse. In the case of Port Davey it is unclear to what extent the highly stratified, estuarine waters of this system deter colonisation by some invasive species. Similarly, we also wonder whether the low number of introductions to the benthos (to date) suggests this environment is relatively resilient to invasions by non-native species. Whilst the benthos supports diverse invertebrate faunal assemblages, the low productivity of the system may not be conducive to the establishment and growth of some invasive species adapted to more productive benthic environments elsewhere in the world.

Many invasive species naturally inhabit protected waters and estuaries (e.g. Ports) and are unsuited to life along the open coast. Translocation is generally from port to port, whereas diffusion beyond such environments is generally limited. In this respect the southern coast of Tasmania may act as an effective barrier limiting the natural dispersal of many invasive species from south-eastern Tasmania to the more remote and isolated south-west coast. We contend that the geographic remoteness, pristine state and natural resilience of Port Davey have all contributed to the relatively low number of species introductions to date. However, the greatest risk is likely to be associated within increasing visitation to the area, particularly from recreational vessels. These, and other vessels, will continue to be a source of, in particular, introduced fouling organisms. Such fouling organisms constitute a serious threat to the unique native invertebrate (fouling) communities that dominate the reefs in Bathurst channel in the absence of macroalgae. The high conservation value of these communities has been well documented by Last and Edgar (1994) and Barrett et al. (2004). Recommendations to minimise this risks and associated impacts follow.

Recommendations

Management of Port Davey and its associated estuarine environment falls within the province of the Tasmanian Parks and Wildlife Service (TPWS). Management actions within the region follow two statutory management plans, the *Tasmanian Wilderness World Heritage Area Management Plan 1999* and the *Melaleuca-Port Davey Area Plan 2003* (Parks and Wildlife 2004). A key outcome of these plans is that “The marine and estuarine ecosystems of Port Davey – Bathurst Harbour are maintained and protected”. We recommend that NRM South supports and funds, where applicable, TPWS efforts to achieve these outcomes in terms of management of introduced marine species in the region. This would include:

1. A more comprehensive assessment of the distribution and seasonal abundance, particularly in the plankton, of the toxic dinoflagellate *Gymnodinium catenatum*. This might also include toxicological tests of edible bivalves (e.g. *Mytilus* sp.) to directly assess the risks to human health.

2. Continue targeted searches for *Maoricolpus roseus* to establish the status of the population in Bathurst Channel. If possible a study of zooplankton should be undertaken to assess whether *M. roseus* are present as larvae in the plankton, but

not settling and establishing on the benthos. Where possible genetic probes may be the most cost-effective way of doing this (see Gaunasekera et al. 2005).

3. Continue monitoring for introduced species using systematic methods (e.g. CRIMP protocols) every 3-5 years. This should include an emphasis on fouling organisms (settlement plates) and the early detection of target species particularly *Asterias amurensis*, *Crassostrea gigas*, *Corbula gibba* and *Undaria pinnatifida*.

4. Prevention is paramount when managing introduced species as it often impossible to remove introduced species once they become established. This should include mitigating, where possible, risks associated with vectors. As we have discussed, the primary vectors for the introduction of non-native species into this system are via hull fouling and accidental transportation associated with visiting marine vessels. Prevention can be partly achieved by raising visitor's awareness to these risks through education programs. This would include recommendations that all visitors check anchors and fishing gear for introduced species and regularly clean and anti-foul exposed surfaces.

5. Support a program to encourage visitors to anchor only at designated anchorage points away from critical habitats (e.g. reefs).

6. Continue baseline monitoring of critical habitats such as reef and soft-sediments at least every 5 years to monitor changes to this unique ecosystem over time. Given comprehensive baseline datasets now exist (this study and Barrett et al. 2004) it may be sufficient to only revisit a subset of these sites depending on the aims of future projects.

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Appendices

Appendix 1 List of sites sampled in this study. Shown is the latitude and longitude for each site in decimal degrees, type of grab used (or dredge) and the depth of the benthos sampled.

Site	Lat	Long	Grab type	Depth (m)
PD01	43.3660588	145.9898348	Eckman	1.5
PD02	43.3567032	145.9841461	Eckman	1.5
PD03	43.3500795	145.9852855	Eckman	2.2
PD04	43.3229277	146.0004601	Eckman	9
PD05	43.3264607	145.9981013	Eckman	10
PD06	43.332594	145.9961945	Eckman	18
PD07	43.3342017	145.9951441	Eckman	18
PD08	43.33771	145.999368	Eckman	7
PD09	43.3394959	146.0110231	Eckman	25
PD10	43.3408624	146.0052426	Eckman	10
PD11	43.3387046	146.0168017	Eckman	9
PD12	43.3226642	145.9818508	Dredge	9
PD13	43.3242874	145.9792671	Dredge	10
PD14	43.3278591	145.9852536	Dredge	13
PD15	43.3448391	146.018168	Dredge	9
PD16	43.343749	146.0232869	Eckman	25
PD17	43.3594154	146.078868	Eckman	2
PD18	43.3496888	146.0624736	Eckman	7
PD19	43.3065635	146.0622849	Eckman	1.5
PD20	43.3179498	146.0645709	Eckman	7
PD21	43.328022	146.0626927	Eckman	10
PD22	43.3344565	146.0718219	Eckman	7
PD23	43.3380202	146.0533172	Eckman	10
PD24	43.3465778	146.0837508	Eckman	6
PD25	43.3328706	146.0877877	Eckman	10
PD26	43.3459415	146.097447	Dredge	12
PD27	43.347755	146.1024904	Eckman	3.5
PD28	43.3459372	146.1081614	Eckman	13
PD29	43.3517204	146.1124282	Eckman	10
PD30	43.3625282	146.160375	Eckman	7
PD31	43.3608992	146.2174931	Eckman	6
PD32	43.373937	146.1608919	Eckman	3.5
PD33	43.381414	146.1718753	Eckman	3
PD34	43.3399662	146.0911796	Eckman	15
PD35	43.3462059	146.091616	Eckman	8
PD36	43.3347039	146.210625	Eckman	4.5
PD37	43.3308547	146.181981	Eckman	6.5
PD38	43.3040796	146.1663746	Eckman	4
PD39	43.3394039	146.1477692	Eckman	6.5
PD40	43.3409284	146.1685697	Eckman	6.5
PD41	43.349444	146.2160788	Eckman	7.9
PD42	43.3751706	146.2168176	Eckman	2

PD43	43.3483361	146.1226541	Eckman	15
PD44	43.3486698	146.1380381	Eckman	9
PD45	43.3386132	146.0136208	Eckman	12
PD46	43.3425629	146.00547	Eckman	6.5
PD47	43.3331323	146.0022384	Eckman	5
PD50	43.3242947	145.9841464	Van Veen	12
PD51	43.3241015	145.9734187	Van Veen	10
PD52	43.3233792	145.9947045	Van Veen	14
PD53	43.2772792	145.8727207	Eckman	3
PD54	43.2761867	145.8777538	Eckman	3
PD55	43.2637957	145.8761841	Eckman	1
PD56	43.2939099	145.928103	Van Veen	12
PD57	43.2881672	145.9358429	Van Veen	13
PD58	43.299968	145.9401676	Van Veen	18
PD59	43.3141021	145.9407794	Van Veen	29
PD60	43.3270145	145.9504698	Van Veen	29
PD61	43.3413152	145.9548241	Van Veen	28
PD62	43.335975	145.9696362	Van Veen	20
PD63	43.3196371	145.9628643	Van Veen	21
PD64	43.2607295	145.9217296	Eckman	3
PD65	43.2463549	145.9309563	Van Veen	5
PD66	43.2252706	145.932156	Eckman	3
PD67	43.2437063	145.9558106	Van Veen	5
PD68	43.269039	145.938718	Van Veen	9
PD69	43.2753091	145.9608756	Van Veen	9
PD70	43.309436	145.9763983	Van Veen	10
PD71	43.3143524	145.9669413	Van Veen	16
PD72	43.2856238	145.9456807	Van Veen	10

Appendix 2 Species/taxa collected from sites within Port Davey (PD), Payne Bay (PB), James Kelly Basin (JK), Hannant Inlet (HI), Bathurst Channel (CH) and Bathurst Harbour (BH) regions. Shown is the total number of specimens collected in each region.

PHYLUM/Order	Family	Taxonomic name	PD	PB	JK	HI	CH	BH
POLYCHAETA	Ampharetidae	Ampharetidae sp. A		11	1	3	270	101
		Ampharetidae sp. B					231	46
	Arenicolidae	*Arenicola bombayensis*						1
	Capitellidae	*Capitella* sp.				8	13	1
		Heteromastus sp.		1				
		Mediomastus australiensis			4		169	26
	Cirratulidae	*Caulleriella* sp.				6	28	
		Chaetozone sp.					20	
	Cossuridae	Cossuridae unid.		1			5	
	Dorvilleidae	Dorvilleidae unid.			2	1		
	Flabelligeridae	*Diplocirrus* sp. A				8	2	3
		Diplocirrus sp. B		16	1			
		Flabelligera sp.					19	
		Flabelligerid sp.			2			
	Glyceridae	*Glycera* sp. A	5	5		3	9	3
		Glycera sp. B					3	5
	Goniadidae	*Goniada* sp.					11	3
	Hessionidae	Hessionidae unid.			1		1	2
	Lumbrinereidae	Lumbrinereid sp. A		1	2	40	11	
		Lumbrinereid sp. B				5	2	
		Lumbrinereid sp. C					1	
	Magelonidae	*Magelona* sp. A					1	
		Magelona sp. B	4					
	Maldanidae	*Asychis* sp MoV907					176	53
		Clymenella sp.					17	
		Clymenopsis sp.		2			42	

	Nephtyidae	*Nephtys australiensis*		4	21	2	97	90
	Nereiididae	*Platynereis antipoda*			1		1	
		Simplisetia amphidonta				2	3	
	Opheliidae	*Armandia* sp. MoV 282				6		
		Ophelia sp. MoV 284	4					
		Ophelina sp. MoV 285				2	92	
	Orbinidae	*Leodomas johnstonei*	2	1		9	20	
		Scoloplos simplex		1		3	15	4
	Paraonidae	*Alia* sp.					22	3
		Paraonella sp.						1
	Phyllodocidae	*Phyllodoce* sp. A			1		33	17
	Polynoidae	Polynoid unid.					4	
	Sabellidae	*Euchone variablis*				21		
		Sabellastarte sp.					2	2
	Scalibregmidae	*Scalibregma* sp.					18	
	Serpulidae	*Salmacina* sp.					9	
	Sigalionidae	*Labioleanira* sp.	5					
	Spionidae	*Dipolydora protuberata*					2	
		Microspio granulata		1		1	21	
		Paraprionospio coora		1			54	31
		Prionospio coorilla	29	10		1	206	7
		Spionid unid.	2					3
	Syllidae	Syllidae unid.					5	
	Terebellidae	*Eupolymnia* sp.		1			3	
		Lysilla spp.					6	1
		Pista pectinata					1	
		Terebellidae spp.		5	4	3	125	19
	Trichobranchidae	*Terrebellides kowinka*			12		21	2
		Trichobranchus spp.		1			7	
NEMERTEA								
	Nemertea	Nemertean unid.	2		2	2	31	

ASCIDACEA								
		Cnemidocarpa radicosa			2			
		Asterocarpa humilis			1			
CNIDARIA								
		Edwardsia spp.				2	7	
		Sarcoptilus grandis					1	
CRUSTACEA								
Amphipoda	Ampeliscidae	*Ampelisca euroa*				3	14	8
	Ampithoidae	*Cymadusa* sp.					5	
	Aoridae	*Bemlos* sp.	1	5			14	8
	Caprellidea	Caprellid unid.					12	
	Corophiodea	Corophiodea sp. A	3			1		
		Corophiodea sp. B	3					
	Cyproideidae	*Austrophenoides* sp.					1	
		Cyproidea ornata					1	
	Dexaminidae	Dexamnidae unid.	1				1	
	Eusiridae	Eusirid sp. A					2	
		Tethygeneia sp.				1	8	
	Isaeidae	*Gammaropsis* sp.					4	
		Photis sp. A					2	
		Photis sp. B					2	
	Ischyroceridae	*Cerapus* sp.	1	5			7	
	Liljeborgiidae	*Liljeborgia dubia*					3	1
	Lysianassidae	Lysianassid sp. A					2	
		Lysianassid sp. B	5	1	1	1		
	Melitidae	Melitidae unid.	1			3	1	
	Oedicerotidae	*Oediceroides* sp.					2	
		Oedicerotidae sp. A	7	2		3		
		Oedicerotidae sp. B		1				
		Oedicerotidae sp. C	2					
		Oedicerotidae sp. D				7	17	1

	Paracalliopiidae	*Paracalliope* sp.	2				3	
	Phoxocephalidae	*Birubius* spp.	6	4		5	32	2
		Limnoporeia sp.		3				
		Metaphoxus sp.					24	
		Phoxocephalid sp.					8	
		Tipimegus sp.					9	
	Platyischnopidae	*Tomituka doowi*	8	2		4	2	
	Podoceridae	*Podocerus* sp.		1			8	
	Urohaustoriidae	*Urohaustorius* spp.	8	2				
Cumacea	Bodotridae	*Cyclaspis globosa*	6	2				
		Cyclaspis sheardi	9					
		Cyclaspis tribulis	17					
		Leptocuma sp.	11	2				
	Diastylidae	*Dimorphostylus cottoni*	1			14	50	3
		Dimorphostylus sp.						2
		Dimorphostylus tribulis	9	1			4	
	Gynodiastylidae	*Dicoides* sp.		1			1	
		Litogynodiastylis ambigua	1	1		9	6	
Decadopa	Grapsidae	*Paragrapsus laevis*			3			
	Ocypodidae	*Macrophthalmus latifrons*			1			
	Palaemonidae	*Macrobrachium novaehollandiae*			20			
	Callianassidae	*Biffarius areonosus*						2
	Leucosiidae	*Ebalia intermedia*		1				
Isopoda	Anthuridae	*Amakusanthura* sp.					8	
		Haliophasma cribensis						4
		Haliophasma sp.					2	2
	Austrarcturellidae	*Austrarcturella oculata*					1	
	Chaetiliidae	*Austrochaetilia capeli*	5	1				
	Cirolanidae	*Natatolana* sp.		1		2	12	4
	Leptanthuridae	*Leptanthura boweni*					6	
		Leptanthura diemenesis				1	3	

	Paranthuridae	*Paranthura* sp.					1	
	Serolidae	*Serolina* sp.	3	1			3	
	Sphaeromatidae	*Ischyromene rubida*					3	
Leptostraca	Nebalidae	*Nebalia* sp.	1					
		Paranebalia sp. A					4	
		Paranebalia sp. B					2	
Mysida		Mysidae unid.				2	2	1
Ostracoda		Ostracod sp. A		4		5		
		Ostracod sp. B		5	1			
		Ostracod sp. C		11		9	26	20
		Ostracod sp. D	1		1	1	10	1
		Ostracod sp. E	4	1			7	3
		Ostracod sp. F		2		1	1	
		Ostracod sp. G					4	
		Ostracod sp. H					4	2
		Ostracod sp. I					5	
		Ostracod sp. J					2	
		Ostracod sp. K					10	3
		Ostracod sp. L					40	5
		Ostracod sp. M					1	
		Ostracod sp. N					5	
		Ostracod sp. O						2
Pycnogonida	Ammotheidae	*Ammothella* sp.					1	
	Callipallenidae	*Propallene vagus*	4					
		Pycnogonid sp. (new genus?).					1	
Tanaidacea	Agathotanaidae	Agathotanaidae unid.					2	
	Anathruridae	Anathruridae unid.					2	
ECHINODERMATA								
Echinodea	Loveniidae	*Echinocardium cordatum*		1		1	37	21
Ophiuroidea	Amphiuridae	*Amphiura* sp MoV 5494	1					
		Amphiura constricta				1	59	50

		Amphiura elandiformis					9	
Holothuroidea		Holothuroidea sp. A				1		
MOLLUSCA								
Aplacophora		*Falcidens* sp.					64	
Bivalvia	Cardiidae	*Nemocardium thetidis*					18	15
	Condylocardiidae	*Cuna concentrica*				1	2	
	Cuspidariidae	*Cuspidaria* sp.					2	
	Galeommatidae	*Lepton trigonale*				1		
		Marikellia solida					9	8
	Glycymerididae	*Glycymeris mayi*		4	1			
		Glycymeris sp.		3			1	
	Lanternulidae	*Lanternula* sp.					7	5
	Limopsidae	*Limopsis* sp.					3	
	Lucinidae	*Wallucina assimilis*			2		94	12
		Epicodakia tatei	2			4	4	
		Lucinidae unid.						4
	Mactridae	*Mactra* sp.				3		
		Spisula trigonella					46	10
	Myochamidae	*Myadora complexa*	1					
	Mytillidae	*Modiolus aeriolatus*					3	1
	Nuculanidae	*Nunculana crassa*	3	4				
	Solemyidae	*Solemya australis*				3	101	5
	Tellinidae	*Tellina* sp.			15		29	34
	Thraciidae	*Eximiothracia lincolnensis*					3	
	Ungulinidae	*Felaniella globularis*				9	1	
		Ungulinidae unid.					12	
	Veneridae	*Callista diemenensis*		1		3	1	
		Irus griseus					1	
		Placamen placidum		35		11	19	
Gastropoda	Amphibolidae	*Salinator fragilis*					34	1

	Cingulopsidae	Cingulopsidae unid.						2
	Dialidae	*Diala suturalis*			4			
	Eulimidae	*Eulima columnaria*	1					
	Marginellidae	*Austroginella formicula*		1				
	Nassidae	*Nassarius* sp. A		2			6	
		Nassarius sp. B					6	
	Naticidae	*Polinces incei*		2				
	Philinidae	*Philine angasi*				1	10	3
	Pyramidellidae	*Syrnola bifasciata*					5	
		Turbonilla beddomei					2	
	Retusidae	*Retusa pelyx*				1		
	Rissoidae	*Eatoniella* sp.					2	
		Merelina hulliana						1
		Rissoina gertrudis					4	
		Tatea spp.				1	7	54
	Turridae	*Guraleus incrustus*					2	
	Atyidae	*Haminoea* sp.			1	2	6	
Scaphapoda		Scaphapoda unid.					24	1
		Cephalaspidea unid.					1	