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Results of a 2007 survey of the Swan River region for four introduced marine species

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Executive summary

A survey of the Swan River region for four non-indigenous marine species was conducted in 2007: the European shore crab *Carcinus maenas*, the Asian bag mussel *Musculista senhousia*, the European fan worm *Sabella spallanzanii,* and the scallop *Scaeochlamys livida*. The first three of these species are global in their distribution and on the 'top-ten world's worst invaders listing; the last species is introduced from the eastern states of Australia.

In this survey divers on SCUBA examined 43 sites for each of the listed species. Despite previous records of *Carcinus maenas* and *Musculista senhousia* in this region the diver visual surveys found no evidence of either species. The European fan worm, despite anecdotal reports that it had died out in the Swan region, has actually increased its geographic spread, though the densities of this species in the more open waters of Cockburn Sound are much reduced from those reported in the early 1990's. The scallop *Scaeochlamys livida* has well-established populations in Cockburn Sound and the Swan River. There is some speculation that this species may have displaced the 'native scallop' *Mimachlamys asperrimus*.

There are currently 46 known non-indigenous species in the Cockburn Sound and Fremantle Harbour area. These species have the capacity to be translocated within the Swan River region quite easily; furthermore they have the capacity to be translocated to iconic areas such as Rottnest Island. As such, a study into the potential of these species to be translocated is needed.

1.0 Introduction

Non-indigenous species (NIS) are a global problem, and are ranked second only to habitat change and habitat loss in reducing global biodiversity (Crooks and Soulé 1999; Millennium Ecosystem Assessment 2005). However not all non-indigenous marine species (NIMS) become marine pests. Possibly the most widely known examples of non-indigenous marine species becoming pests are the black striped mussel (*Mytilopsis sallei*) in Darwin Harbour, Australia, the comb jellyfish (*Mnemiopsis leidyi*) invasion of the Azov and Black Seas (Minchin 1996), and the rapid spread of *Caulerpa taxifolia* in the Mediterranean (Ribera and Boudouresque 1995; Ruiz *et al.* 1997).

In a 'natural' state, for a non-indigenous species to become established in a new community (with little 'empty niche' space), let alone outcompete a native species, it would have to have conditions comparable to its home range or be so competitively dominant over the native species that environmental differences are inconsequential (Tyrrell and Byers, 2007). However there is another state that accounts for most incursions. A non-indigenous species may enter a disturbed environment that has been altered by anthropogenic disturbance. These disturbed habitats can create a 'mismatch between native species and the environmental conditions to which they have become adapted (Byers 2002).

Like other places in the world, non-indigenous species have been introduced into Western Australia, with 60 species having been introduced and currently surviving in the State (Huisman *et al.* 2008). Most of the introductions that have been reported have generally remained innocuous, or have been largely restricted to disturbed environments such as harbours. This parallels the situation in other Australian areas.

The National Introduced Marine Pests Coordination Group (NIMPCG) is currently developing a National System for the Prevention and Management of Marine Pest Incursions. The National System is designed to comprehensively address all marine pest risks. This system includes governance and infrastructure arrangements, measures for prevention (focused on ballast water and biofouling risks), emergency response, ongoing management and control, and supporting arrangements for monitoring, communications, research and development, and evaluation and review. Eighteen major ports nationwide are in the national monitoring system, including three Western Australian ports: Dampier, Port Hedland and Fremantle (NIMPCG 2006).

In October 2006, the Western Australian Department of Fisheries initiated a Natural Heritage Trust funded project on introduced marine pests in Western Australia. The main focus of this research was a trial of the National Marine Pest Monitoring Methodology in Albany. Another complementary component of this research was a survey of the Cockburn/Fremantle and Swan River region (hereafter referred to as Swan region – Figure 2) for the following four species of non-indigenous species (Figure 1):

- The Asian bag mussel *Musculista senhousia*,
- The European shore crab *Carcinus maenas,*
- The European fan worm *Sabella spallanzanii,* and
- The East Australian scallop *Scaeochlamys livida.*

Cockburn Sound and Fremantle Harbour, with 46 known non-indigenous species, have the greatest number of non-indigenous species in Western Australia (Huisman *et al.,* 2008). The four species surveyed here were chosen for two main reasons. The first three species are listed pest species with the Consultative Committee for Introduced Marine Pest Emergencies

(CCIMPE) and have documented distributions within the target region (Zeidler 1978; Slack-Smith and Brearley 1987; Clapin and Evans 1995). For these species the purpose was to document the extent of existing populations and to collect samples of *Musculista senhousia* for DNA analysis (a separate research project).

The remaining species, *Scaeochlamys livida,* is a non-indigenous species from the east coast of Australia. This species is a relatively new incursion (Morrison and Wells 2008) and is believed to have displaced the native scallop species. As such this study aimed to document the spatial extent of this species.

2.0 Materials and methods

2.1 Study sites

In September and October 2007 a series of visual surveys were conducted by two divers on SCUBA at 43 locations throughout the Swan Region (Figure 2, Table 1). These sites are based upon sites where the target species have been reported previously or would most likely occur.

Within the broader Swan Region there are two major vector nodes for introduction of non-indigenous species: Fremantle Harbour (including the anchorage areas of Gage Roads) and the southern and eastern parts of Cockburn Sound (Figure 3). The major potential source of introductions is through international shipping. The Fremantle inner harbour area is the main shipping port for this part of Western Australia. In 2006 there were 1722 ship visits to Fremantle Port. Of these, 937 were international and 785 were domestic. A total of 8,532,086 tonnes of ballast water was discharged, with 4,655,172 tonnes being from international sources and 3,876,914 being domestic (McDonald 2008).

Immediately adjacent to the harbour is the small, artificial Rous Head. There are a variety of marine industries in Rous Head, including a terminal for ferries and other service industries. Immediately to the south of Fremantle inner harbour are several small boat harbours, with the southernmost being the South Fremantle Yacht Club. Offshore, Gage Roads is the anchorage area for the Port of Fremantle. Upstream of Fremantle harbour area is the Swan Canning River system. There are scattered yacht and boat clubs throughout this area. However most tend to be concentrated in the lower Swan region.

Cockburn Sound is a large marine embayment in the southern part of the survey area. Within this broader region is Kwinana, which is the major heavy industry area of Western Australia, and includes all of the industrial area south of the actual port. The Royal Australian Navy also operates out of this region.

2.2 Diver visual surveys

Visual surveys by divers on SCUBA are one of the most widely used methods due to the low costs and high efficacy of the method, and are one of the accepted methodologies of the NIMPCG (2006) survey methodology. Divers entered the water together and descended to the seafloor where they would space themselves approximately 1-2 m apart, depending upon visibility, and available space. Divers would proceed along the seafloor searching for the four target non-indigenous species identified. The length of each survey varied according to the area being examined.

2.3 Abundances and collections

For *Scaeochlamys livida* estimates of mean abundance (number 0.5 m^2) were derived from three randomly placed square quadrats measuring 0.5 x 0.5 m. Four levels of relative abundance were utilised in the survey: absent, sparse, medium, and dense. These estimates are based on those of Clapin and Evans (1995), where sparse equates to < 1 individual per m^{-2}, medium 1-50 individuals per m^{-2}; and dense 50+ individuals per m^{-2}.

Length frequency data on *Scaeochlamys livida* was derived from a random sample of the population collected from numerous sites by each diver.

Samples of *Sabella spallanzanii* and *Scaeochlamys livida* were collected and identified in the laboratory to verify field-based identifications. All collected material was preserved in 70% ethanol.

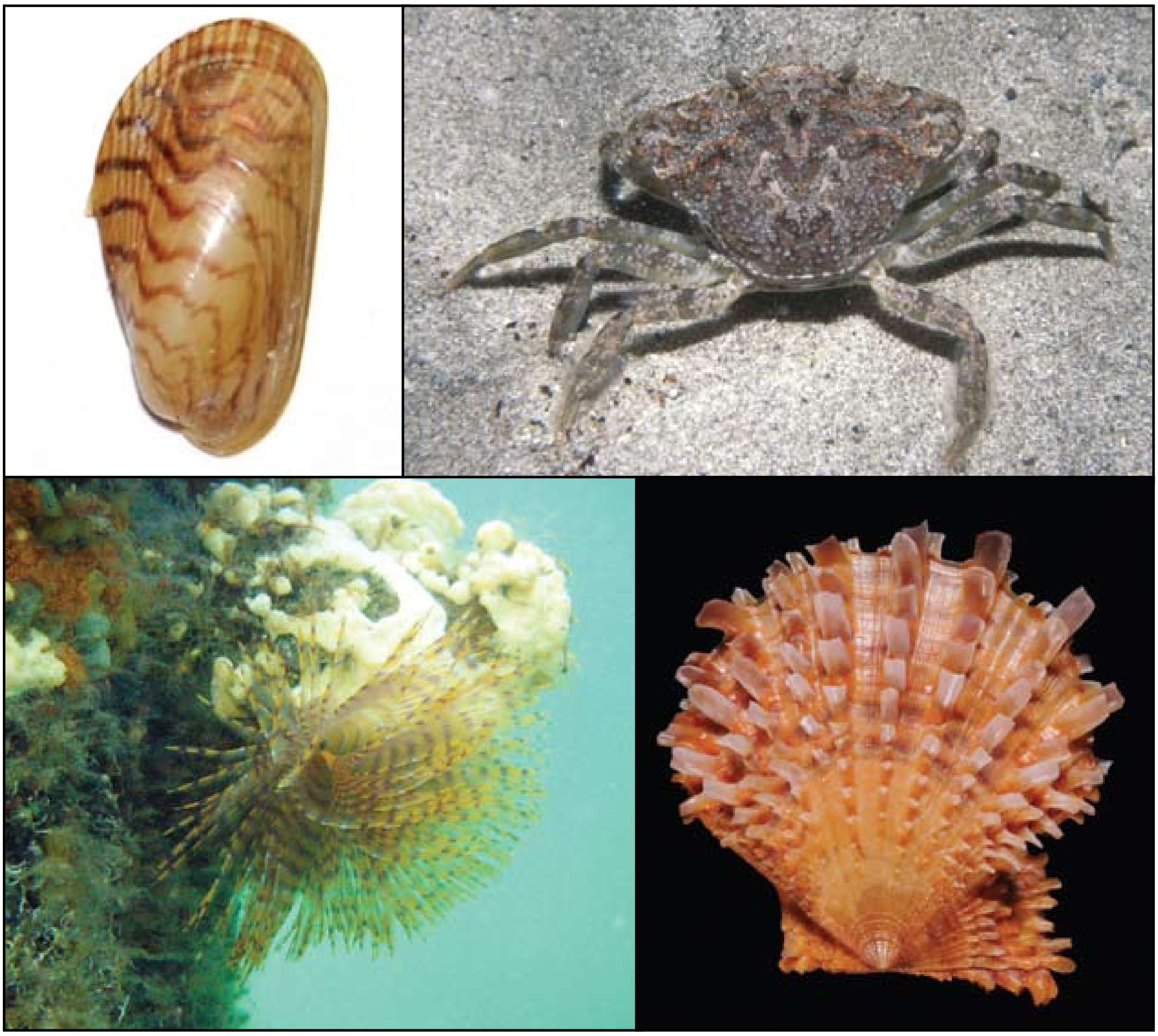

Figure 1. The four introduced marine species examined in this study: From top left to bottom right) Asian bag mussel *Musculista senhousia*, European shore crab *Carcinus maenas*, European fan worm *Sabella spallanzanii*, and East Australian scallop *Scaeochlamys livida.* (Photo credits: Helen Cribb; Karen Gowlett-Holmes; Justin McDonald and Clay Bryce).

Table 1. Sites targeted in 2007 survey. Includes site number (for reference to subsequent figures), survey location name and indicates the presence (X) or absence (blank) of each non-indigenous marine species targeted.

Site #	Sub-region	Location	*S. livida*	*S. spallanzanii*	*C. maenas*	*M. senhousia*
1	WarnbroSound	Saxon Ranger	X			
2	Cockburn Sound (CS)	Calista channel, port marker F	X	X		
3	CS	Challenger Passage lead marker 2	X			
4	CS	Garden Island Armaments Jetty	X	X		
5	CS	Garden Island, Navy Boats Harbour	X	X		
6	CS	Kwinana Bulk Jetty Jetty front	X	X		
7	CS	Kwinana Bulk Jetty shallow part	X	X		
8	CS	Kwinana Bulk Terminal 2	X	X		
9	CS	North Mole wreck	X			
10	CS	Northern Lead S & P channel	X			
11	CS	Old submarine netting	X			
12	CS	Rockingham L jetty		X		
13	CS	Rockingham middle jetty	X	X		
14	CS	Rockingham wreck front dive store		X		
15	CS	Rous harbour Barge	X			
16	CS	Southern flats 1				
17	CS	Southern flats 2				
18	CS	Southern flats 3				
19	CS	Southern flats 4				
20	CS	Southern flats 5		X		
21	CS	Stirling channel marker 1	X			
22	CS	Success channel marker 2	X	X		
23	CS	Success channel marker B	X	X		
24	CS	Success Channel marker F	X			
25	CS	Wreck of the D9	X			
26	Inner Harbour Fremantle (IH)	Fremantle Berth 2	X			
27	IH	Fremantle Berth 4	X	X		
28	IH	Fremantle Berth 5		X		
29	IH	Fremantle traffic Bridge (north side)	X	X		
30	Lower Swan River (LSR)	Blackwall Reach	X			
31	LSR	Chidley Point	X			
32	LSR	Keanes Jetty	X			
33	LSR	Matilda Bay		X		
34	LSR	Rocky Bay Channel	X			
35	LSR	Royal Freshwater Bay Yacht Club	X			
36	Canning River (CR)	Canning Bridge (SW Side)				
37	CR	Deepwater Point	X			
38	CR	Shelley Bridge				
39	Perth Waters (PW)	Sir James Mitchell Park (South Perth)				
40	Upper Swan River (USR)	Clarkson Reserve (Maylands)				
41	USR	Fish Market Reserve (Guildford)				
42	USR	Garrett Rd Bridge (AP Hinds Reserve)				
43	USR	Trinity College Foreshore				
		Total number of sites with NIS	27	16	0	0
		Percentage of sites with NIS	62.8	37.2	0	0

3.0 Results

Despite previously published evidence to the contrary, there was no evidence of either *Carcinus maenas* or *Musculista senhousia* in the 43 sites examined in the Swan region.

Non-indigenous marine species were recorded in 74.4% (32) of the sites examined. The European fan worm *Sabella spallanzanii* was recorded at 37% (16) of the sites surveyed (Figure 4). Unfortunately no density estimates were made for this species, therefore data are presence/absence only.

The east Australian scallop *Scaeochlamys livida* was recorded at approximately 63% (23) of the sites surveyed (Figure 5). Scallops were recorded in all locations with the exception of the upper Swan region. Densities of *S. livida* were greatest in Cockburn Sound and the Inner Harbour area (Table 2). Mean size was 56.2 mm ± 13.7 mm SD (minimum size 12 mm; maximum size 92 mm)(Figure 6). While scallops from Warnbro Sound had a smaller mean size (48.2 mm ± 18.2 mm SD; minimum size 24 mm; maximum size 65 mm) than those at other locations sampled, the mean size of *S. livida* did not differ significantly across locations within the survey area ($p > 0.05$).

Sabella spallanzanii and *Scaeochlamys livida* co-occurred at 11 (25.6%) of the 43 sites surveyed. However when we remove sites where no introduced species were found and examine infested sites only (32 sites), then these species co-occurred in 34.4% of infested sites. These co-occurring sites are located in the inner harbour of Fremantle port and scattered along the coastal region of Cockburn Sound (Figure 7).

Table 2. Estimates of Saeochlamys livida density within each sub-region examined.

Sub-region (number of sites examined)	Number of sites in each density category			
	Absent	Sparse (< 1 m^{-2})	Medium (1-50 m^{-2})	Dense (> 50 m^{-2})
Warnbro Sound (1)			1	
Cockburn Sound (24)	7	7	7	3
Fremantle inner harbour (4)	1		1	2
Lower Swan River (6)	3		2	1
Canning River (3)	2	1		
Perth Waters (1)			1	
Upper Swan River (4)	4			
Totals	17	8	12	6

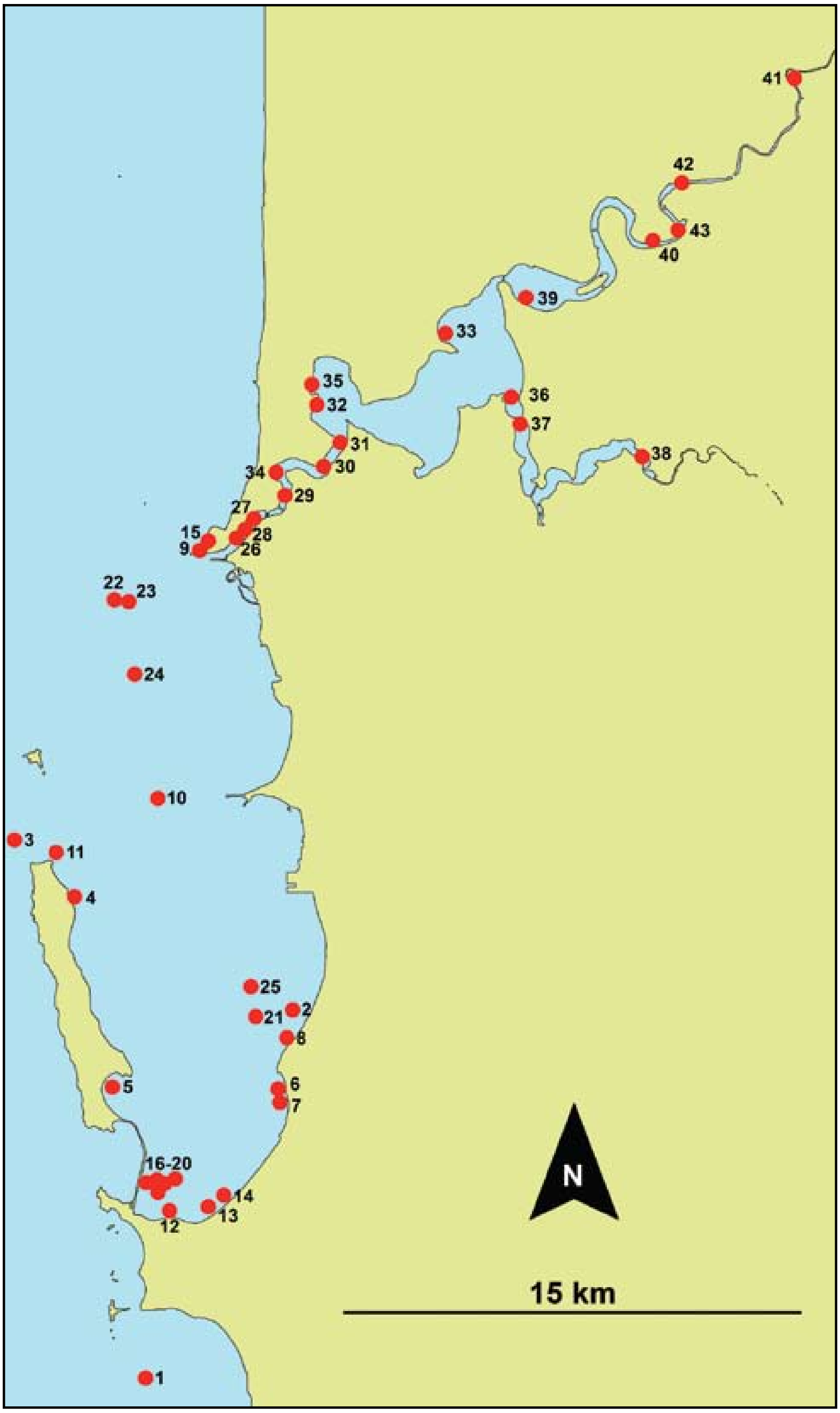

Figure 2. Sites surveyed within the Swan region (see Table 1 for site name details).

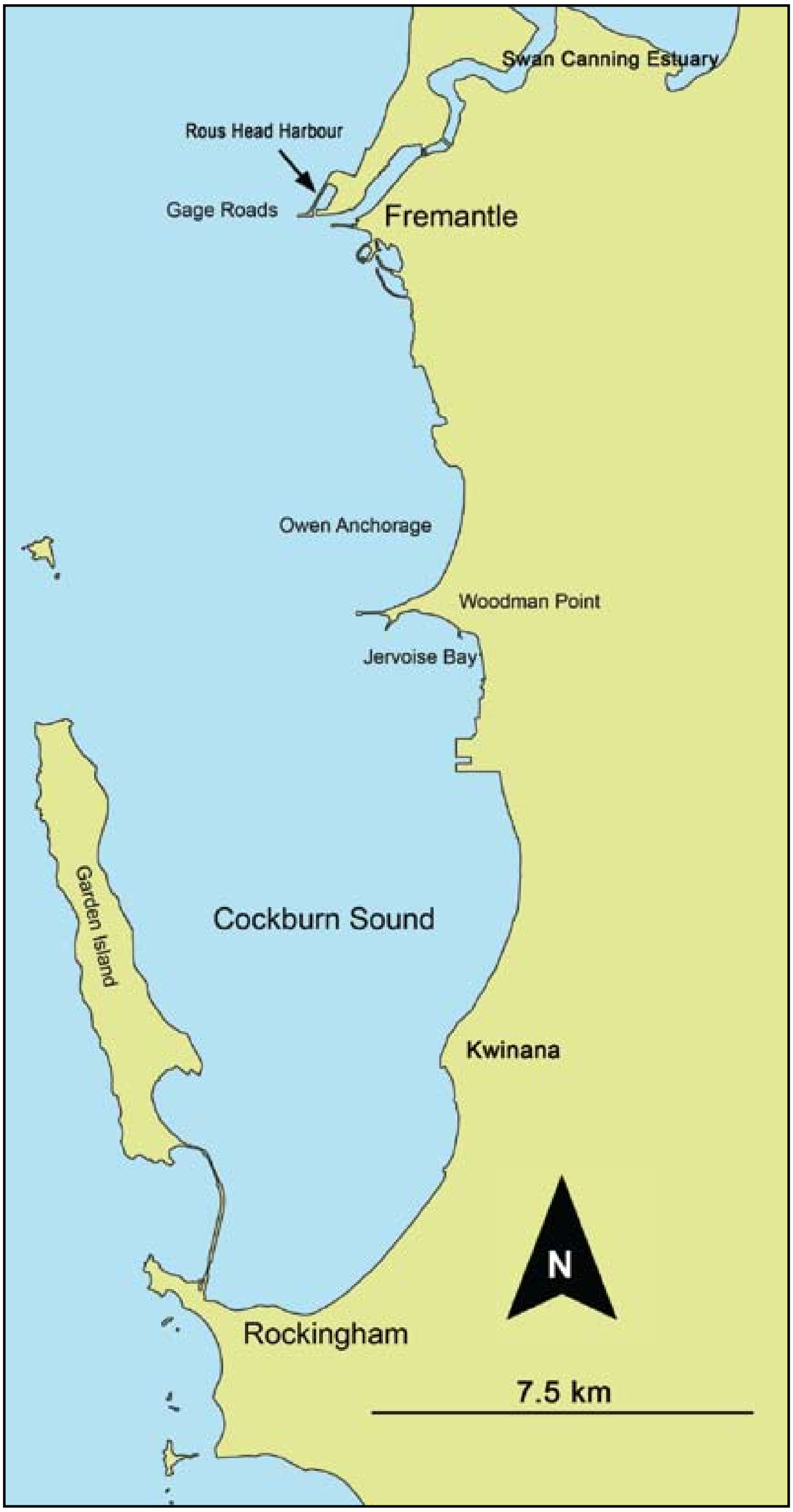

Figure 3. Map of entrance to Swan Region showing two major nodes of vessel activity Fremantle harbour and Cockburn Sound.

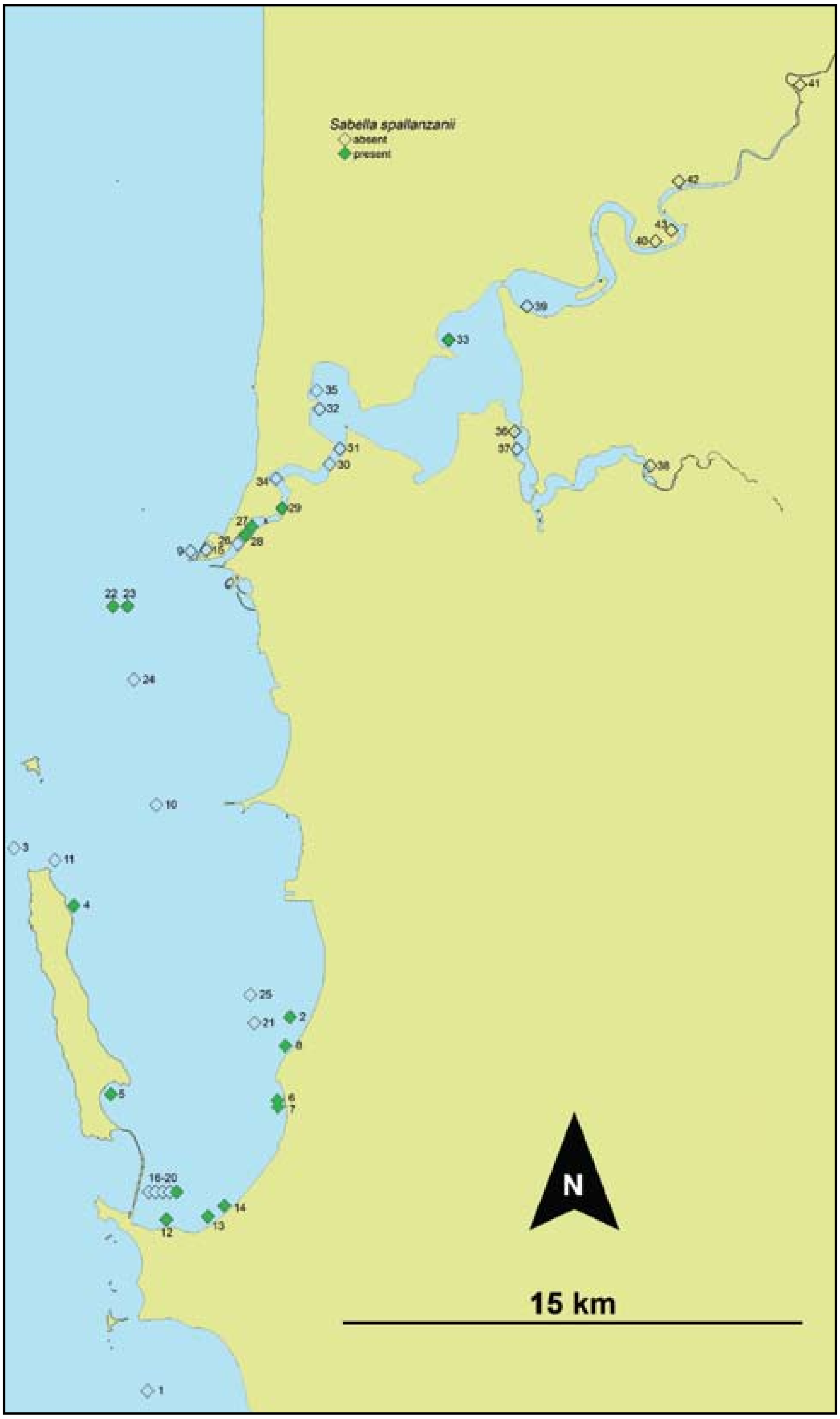

Figure 4. Distribution of *Sabella spallanzanii* within the Swan region.

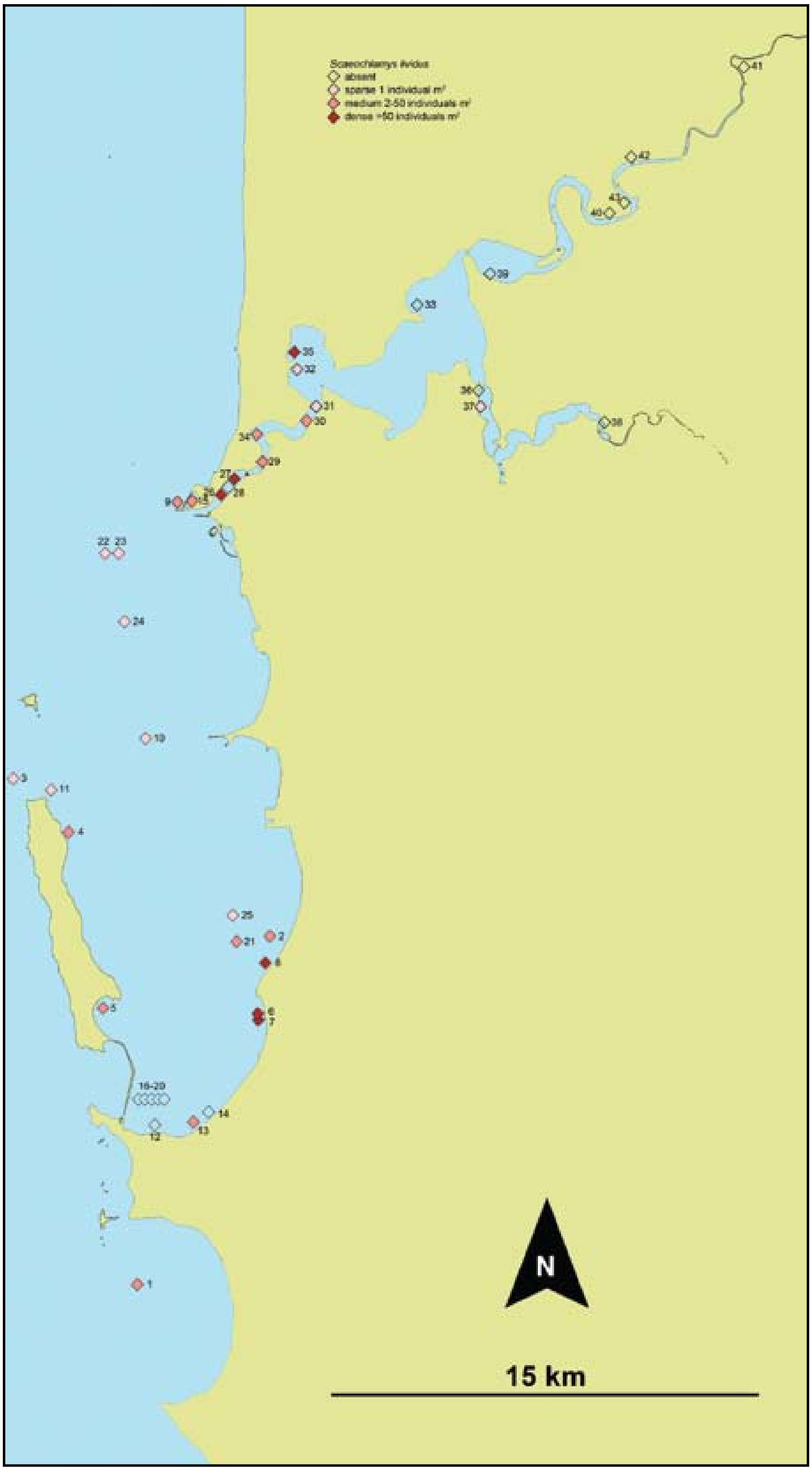

Figure 5. Distribution of *Scaeochlayms livida* within the Swan region.

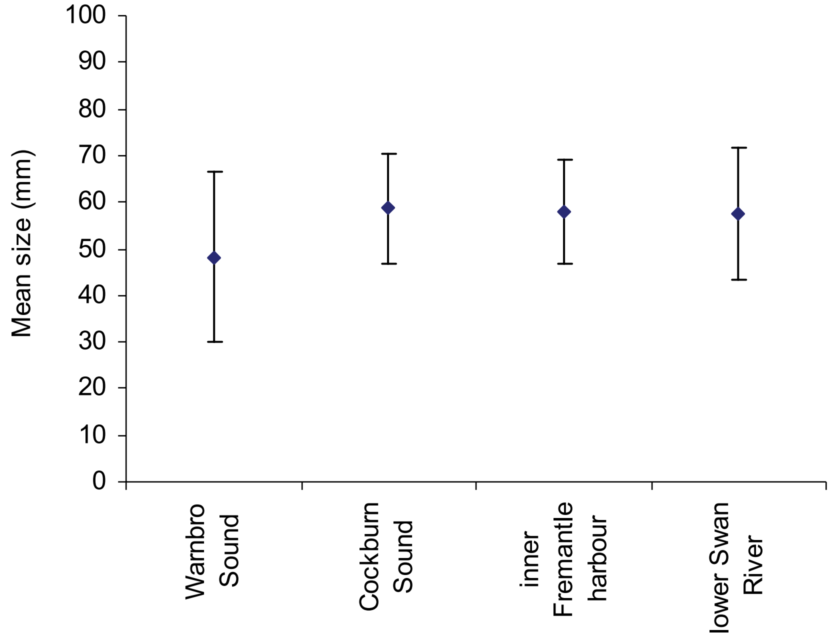

Figure 6. Mean size (mm ± SD) of *Scaeochlayms livida* across locations within the greater Swan region surveyed (sites where no scallops were recorded are not shown).

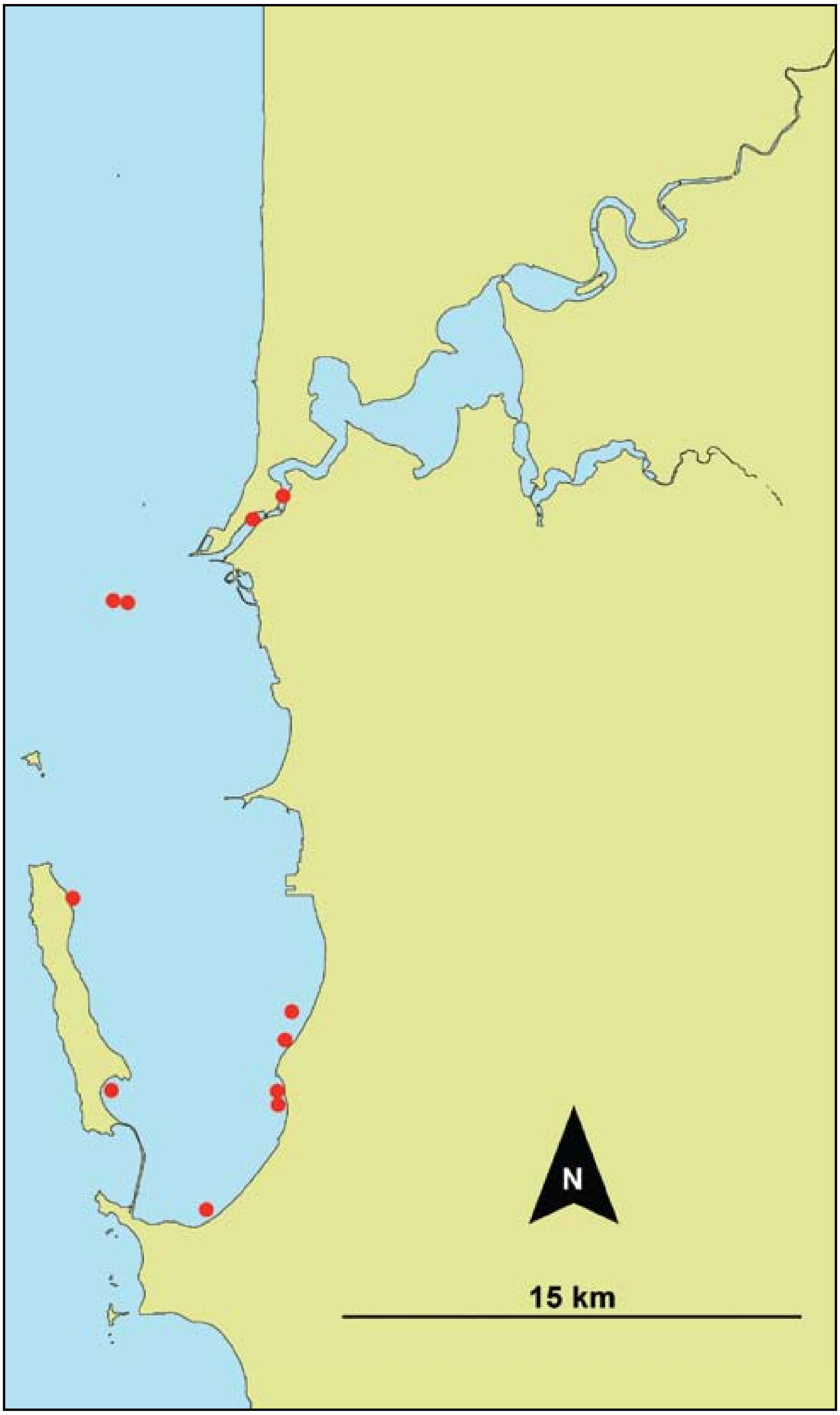

Figure 7. Sites showing co-occurrence of non-indigenous species.

4.0 Discussion

Three of the four species targeted in this study are on the Consultative Committee for Introduced Marine Pest Emergencies (CCIMPE) introduced marine pest target species list. Furthermore all three are regarded to be among the worst invasive marine species in the world (Hayes *et al*. 2005). As such it is important to know if they are established in the Swan region and if so what is their geographic distribution.

4.1 *Musculista senhousia* – Asian date mussel

The Asian date (or bag) mussel, *Musculista senhousia*, is native to the western Pacific coasts from Siberia and south to Singapore with the type locality in China (Slack-Smith and Brearley 1987). Once settled on soft substrata, the mussel will form a protective cocoon, and at high densities (>1500 m^2) the individual byssal cocoons coalesce to form a continuous mat or carpet on the sediment surface. The presence of these mats dramatically alters the natural benthic habitat, changing both the local physical environment and the resident macro invertebrate assemblage.

In Western Australia this mussel was first recognised in the Swan River in 1983, was subsequently found to be abundant in the middle and upper regions of that river, and also as far upstream as Canning Bridge in the Canning River (Slack-Smith and Brearley 1987). Densities of this species are recorded as high as 2500m^2 (Slack-Smith and Brearley 1987), well above the base density for mat forming. A smaller number of *M. senhousia* were also recorded in the upper reaches of the Swan River in 2005 by Wildsmith (2007).

In the 2007 survey, there was no evidence of *Musculista senhousia* living in any of the sites examined. Slack-Smith and Brearley (1987) note that *M. senhousia* populations in the Swan River exhibited high mortality. They postulate that this could be due to decreasing salinity, as with *Mytilus edulis planulatus*, or be post-reproductive, as in *Musculista glaberrima* (Wilson and Hodgkin 1967). This high mortality is further supported by Summers (1994) who documents significant declines associated with winter in populations monitored at Chidley Point (also the population used initially to identify this species). Summers (1994) states that populations declined by as much as 97% over autumn/winter.

We propose that an uncharacteristic summer rainfall event in 2000 (139 mm, compared to a mean of only 17.6 mm) (Bureau of Meteorology, 2008), coupled with the natural variability of the Swan populations may have been contributing factors to the apparent death of most *Musculista senhousia* populations in this system (McDonald and Wells in prep). A small number of *M. senhousia* were collected in 2005 in the upper reaches of the Swan (Wildsmith 2007), however there was no evidence of any *M. senhousia* at these sites in this study. The high-post reproductive mortality associated with this species seems the most likely cause of this upper Swan populations decline.

4.2 *Carcinus maenas* – European shore crab

The European shore crab *Carcinus maenas* is native to Europe but is a problem pest in several countries (Australia, Japan, South Africa and North America) (Cohen *et al.* 1995; Grosholz and Ruiz 1995). It is a tough, voracious, generalist predator of other crustaceans, bivalves and other benthic invertebrates, and thought to have a significant impact on invaded systems (e.g. Cohen *et al.* 1995; Thresher 1997 and papers therein; Grosholz *et al.* 2000). It was first recorded in

Australian waters in 1900 at Port Phillip Bay, Victoria and has a current range on the east coast of Australia that extends from eastern Tasmania in the south to Port Jackson in central New South Wales (Ahyong 2005).

The 2007 study did not find any evidence of this species at any of the 43 sites examined. The presence in this region of *Carcinus maenas* was based on a single mature male collected from Blackwall Reach in the Swan River in 1965 (Zeidler, 1978), this record was subsequently cited by Furlani (1996), Hass and Jones (1999), Pollard and Hutchings (1990) and Ahyong (2005). It is not known what became of any remaining animals.

4.3 *Sabella spallanzanii* – European fan worm

The European fan worm, *Sabella spallanzanii*, is a major introduction that occurred about the same time in eastern Australia. This species probably came on the hull of a ship (Carey and Watson 1992). It was found in Albany, Western Australia, as early as the mid 1960s and in Cockburn Sound in 1994 (Clapin and Evans 1995). It has since been found in other southwestern Australian harbours (Huisman *et al.* 2008) from Fremantle to Esperance.

Sabella spallanzanii is generally found in shallow subtidal areas between 1-30m depth, preferring harbours and embayments sheltered from direct wave action. It colonises both hard and soft substrata, often anchored to hard surfaces within the soft sediments. In Australia, the worm is usually found in harbours where it readily colonises man-made hard surfaces such as wharf piles and facings, channel markers, marina piles and pontoons, and submerged wrecks. It can also be found in extensive beds at densities greater than 300 individuals m^{-2} (Parry *et al*. 1996).

Sabella spallanzanii is not known to be predated by native fish due to high arsenic and/or vanadium content (Notti *et al.* 2007) and if attacked has a high tolerance to wounding (Clapin and Evans 1995; Furlani 1996), to the extent of being capable of regenerating from fragments (Hewitt *et al.* 2002). In Port Phillip Bay, Victoria, *S. spallanzanii* has been observed to overgrow seagrass beds (Hewitt *et al.* 2002) and is regarded as significant pest species and a threat to the local scallop fishery. Holloway and Keough (2002a) found that the presence of a canopy of *S. spallanzanii* feeding fronds resulted in substantial short-term differences in the establishment of an underlying sessile community but no apparent changes in established systems. Epifaunal growth and survival were affected although responses lacked consistency (Holloway and Keough 2002b).

In the 1990's this species had very high densities in the Swan region (Clapin and Evans 1995). Surveys conducted in early 2000's speculated that the populations of *S. spallanzanii* in Cockburn Sound had died out and it became accepted locally that this species was no longer present in the region (Anonymous). Results from this study prove conclusively that not only is *S. spallanzanii* present in many of the original sites, but also has spread to sites further up the Swan River. The impacts of *S. spallanzanii* in Western Australian marine systems are unknown and require further investigation, particularly given the geographic spread of this species over recent time.

4.4 *Scaeochlamys livida* – Eastern Australian scallop

The introduction and the apparent successful colonisation of the eastern Australian scallop *Saeochlamys livida* in Cockburn Sound is an example of how introductions occur, not only between countries, but also between different regions of the same country, *i.e.* from the east to west coasts of Australia (Morrison and Wells 2008). *Saeochlamys livida* was likely to have been first introduced into temperate waters in Western Australia between the late 1970's and early 1980's and the first confirmed specimen was collected in south-western Cockburn Sound in 1989 (Morrison and Wells 2008). In 2000, the CSIRO Centre for Research into Introduced Marine Pests (CRIMP 2000) surveyed Fremantle Harbour, including Cockburn Sound, for introduced pest species. Specimens of *Saeochlamys livida* were recorded from four different stations in Fremantle Harbour and the lower Swan River.

The native scallop *Mimachlamys asperrimus* previously occupied much of the range now occupied by populations of *Scaeochlamys livida.* It has been speculated as to whether the populations of *M. asperrimus* declined independently at about the same time as *S. livida* bloomed, or whether *S. livida* out competed *M. asperrimus*. The two species are taxonomically related, feed and reproduce in the same way, and live in similar habitats. The mechanism by which *S. livida* would out compete *M. asperrimus* is not known. The impacts of *S. livida* in Western Australian marine systems are uncertain and requires further investigation, this is particularly so given the apparent spread of this species, and the possible displacement of local species.

5.0 Conclusions

The results from the investigations through the Cockburn/Swan region were from both ends of the spectrum. There was no evidence of *Musculista senhousia* or *Carcinus maenas* at any of the sites examined. At the other extreme there was an increase in the geographic spread of *Sabella spallanzanii* and *Scaeochlamys livida*.

The distributions of *Sabella spallanzanii* and *Scaeochlamys livida* were not surprisingly all closely linked to the main commercial port of Fremantle and the Kwinana industrial area, both highly modified habitats. Furthermore the densities of the scallop *Scaeochlamys livida* were greatest in these regions. There is a significant body of knowledge that demonstrates that non-indigenous species (NIS) are more likely to occur in disturbed habitats. Anthropogenic disturbances can change community dynamics and facilitate the establishment of non-indigenous species through a variety of mechanisms. The most common is through increased resource availability, either by the introduction of new resources or by decreasing resource-use by resident species (Davis *et al*. 2000). Anthropogenic disturbance can play a very important role in the creation of available open space within an affected assemblage (Johnston and Keough 2002). Anthropogenic disturbance may also facilitate invasion by decreasing diversity in native recipient communities. Species richness may be negatively related to the invasibility of a system (Naeem *et al*. 2000; Kennedy *et al*. 2002). Furthermore specific types of anthropogenic disturbance, often associated with harbours have been demonstrated to increase the invasion potential of exposed systems by complimenting inherent characteristics of NIS. For example, it has been shown that certain species and/or populations of NIS have a greater tolerance to heavy metal pollution relative to closely related native species (Piola and Johnston 2006a, 2006b; 2008). Such NIS may experience a competitive advantage over native species at recipient locations subject to transient or persistent metal pollution. Metal pollution in particular has been shown to greatly decrease the diversity of sessile and benthic fauna (Medina *et al*. 2005).

Both *Sabella spallanzanii* and *Scaeochlamys livida* were concentrated in areas that may be regarded as anthropogenically 'disturbed' habitats. There were no *S. livida* and only one

S. spallanzanii associated with the more 'natural' southern flats area. The impacts of both species need to be investigated, as it seems illogical to assume these species are having no effect. Furthermore both of these species have the capacity to be translocated within the Swan River region quite easily and they have the capacity to be translocated to iconic areas such as Rottnest Island or further afield. As such a study into the potential of these species to be translocated and the new translocation 'hot-spots' is recommended.

It seems likely that in addition to human-caused modifications in the local environment, climate change, in particular, will interact with species arrivals in new areas to modify ecosystem functions and biological diversity. Changes in the environment (both of origin and recipient environments) will alter species availability for transport and the degree of susceptibility to invasions, such that they are expected to continue to occur at unprecedented rates in nearly all ecosystems on earth (e.g., Vitousek *et al*. 1997; Janzen 1998).

6.0 Acknowledgements

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