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Prevention of introduction of species brought into Geraldton Harbour, Western Australia, by the dredge *Leonardo da Vinci*

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Abstract – In October 2002 the dredge *Leonardo da Vinci* arrived in Geraldton, Western Australia, for a major port enhancement program. It sailed from Jamaica, West Indies, through warm seas during the entire voyage. An arrival inspection in Geraldton demonstrated the stern and sea chests were fouled with a variety of non-indigenous marine species that could potentially be introduced to Geraldton, including pest species. The vessel was cleaned in water in Geraldton, with several steps taken to minimize the possibility of species being introduced. Surveys of key species of molluscs and crustaceans were undertaken in October 2003 and 2007. To date, none of these potential pest species have been found, except for *Amphibalanus reticulatus* which had already been recorded north and south of Geraldton.

Keywords – Introduced marine species, mollusc, crustacean, NIMS

INTRODUCTION

The introduction of marine species into new environments is one of the leading marine environmental issues on a worldwide scale (Padilla *et al*. 1996). Most introduced, non-indigenous species cause no apparent harm in their new environments. For example, Huisman *et al.* (2008) recorded 60 introduced marine species in Western Australia, but only three are on the national list of target species (NIMPCG 2006). A minority of the introduced species become pests that cause disease in native species and even humans, interfere with fisheries and aquaculture, foul industrial equipment, disrupt local ecosystems and/or even change the habitat in which they are living (Hallegraeff *et al.* 1988; Grosholz and Ruiz 1995; Siguan 2003; Schwindt *et al*. 2004; Bando 2006; Wallentinus and Nyberg 2007). There are three major mechanisms for introducing marine species: ballast water discharge; biofouling of vessel hulls, immersible equipment, or niche areas (e.g. anchor lockers, sea chests, internal seawater systems, etc), deliberate introductions, such as for aquaculture, and accidental escape from aquaculture facilities (Carlton 1985; Fofonoff *et al.* 2003; Minchin 2007).

Nationwide data on non-indigenous marine species known from Australian waters are available in Hewitt *et al.* (2002). Hewitt and Campbell (2007) review Australian mechanisms for prevention of marine bioinvasions. Port Phillip Bay, where the Port of Melbourne is located, has the highest known number of non-indigenous species in an Australian marine area: 99 species are regarded as introduced, and 61 are cryptogenic (Hewitt *et al.* 2004). In contrast, only 60 introduced species and 26 cryptogenic species are known from the entire state of Western Australia, with some 14,000 km of coastline (Huisman *et al.* 2008). The greatest concentration (46 species) is in the Fremantle area, the port with the largest number of vessel movements and a diverse marine environment. Seven introduced species, none of which are pest species, are known from Geraldton (Campbell 2003; Huisman *et al.* 2008).

In early October 2002 the cutter suction dredge *Leonardo da Vinci* arrived in Geraldton, Western

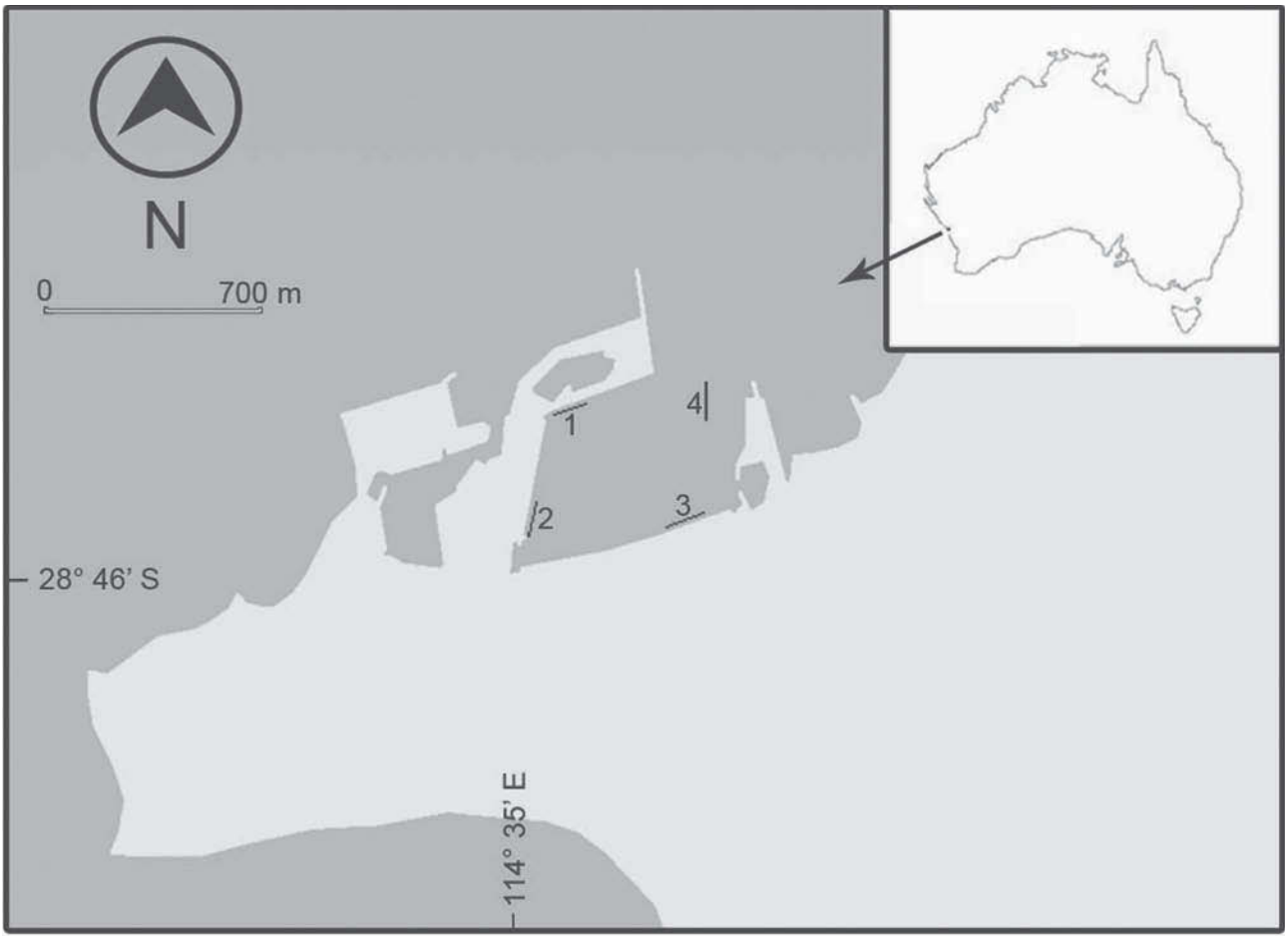

Figure 1 Map of Geraldton Harbour showing locations of the sample sites. 1. Northwest corner of harbour. 2. Berth 5, where the *Leonardo da Vinci* was berthed. 3. Berth 1, adjoining rock walls and slipway. 4. Rock groynes.

Australia to undertake a major dredging program in the harbour. The vessel sailed directly to Geraldton from Jamaica via the warm waters of the tropical Atlantic Ocean, Mediterranean Sea, Suez Canal, Red Sea, and the Indian Ocean with only brief refueling stops in Egypt and the Maldives. On arrival inspection in Geraldton it was discovered that the forward sections of the hull had been cleaned prior to the vessel departing Jamaica, but the stern and sea chests (containing about 60 m^3 of seawater) were heavily fouled with a variety of organisms, including several molluscs (Table 1): *Thais haemastoma* (Linnaeus, 1767); *T. rustica* (Lamarck, 1822); *Crepidula plana* Say, 1822; and *Brachidontes exustus* (Linnaeus, 1758). A juvenile oyster that was too small to be identified was also found. The following barnacles were identified: *Lepas anserifera* Linnaeus, 1767; *Chthamalus* sp.; *Striatobalanus amaryllis* (Darwin, 1854) (some were ovigerous); *Amphibalanus reticulatus* (Utinomi, 1967) (some were ovigerous); *Balanus trigonus* Darwin, 1854; and *Megabalanus coccopoma* (Darwin, 1854). Of these, all the identified species except *M. coccopoma* were previously known from Western Australia (Jones 1990; 1992; 2004). *Megabalanus coccopoma* occurs in the tropical East Pacific Ocean, the Atlantic Ocean, Gulf of Mexico and southeastern United States). The species has also been collected from vessels in New Zealand (A. Hosie, pers. comm.) and there is one recent record from a vessel at Brisbane, Queensland (D. Jones, unpublished data). Four decapod crustacean species were found in the samples provided. As they do not occur in Western Australia, WAM had no comparative material of the species. Provisional identifications are: *Pachygrapsus* sp.; *Percnon* sp.; xanthid sp., and grapsid sp. (juvenile). Because of the lack of appropriate taxonomic expertise in Western Australia and the urgent requirement for a decision on how to proceed, tubeworms, an encrusting sponge, ascidians, hydroids, and a filamentous green alga were not identified to species level. Material collected from *Leonardo* is held in WAM.

A hastily convened committee representing a range of government departments determined there was a serious risk of introducing marine pests into the port of Geraldton. Once in Geraldton, it was considered that it would be difficult

Table 1 Species recovered from the dredge *Leonardo da Vinci* and subsequent surveys of Geraldton port.

Species	Previously recorded in WA	*Leonardo da Vinci*	2003 survey	2007 survey
Molluscs				
Brachidontes exustus		X		
Cronia avellana	X		X	X
Crepidula plana		X		
Ostrea angasi	X			X
Stavelia horrida	X			X
Thais haemastoma		X		
Thais orbita	X			X
Thais rustica		X		
Crustaceans				
Barnacles				
Amphibalanus amphitrite	X		X	X
Amphibalanus reticulatus	X	X		X
Austromegabalanus nigrescens	X			X
Balanus trigonus	X	X	X	
Chthamalus sp.		X		
Lepas anserifera	X	X		
Megabalanus coccopoma		X		
Megabalanus tintinnabulum	X		X	
Striatobalanus amaryllis	X	X		
Tetraclita squamosa	X			X
Crabs				
Atergatis integerrimus	X			X
Leptodius exaratus	X			X
Pachygrapsus sp.		X		
Percnon sp.		X		
Portunus pelagicus	X			X
Thalamita sima				X

to stop the spread of these species into other Western Australian and Australian ports where suitable environments exist. Particular concern was expressed about the two species of *Thais.* If distributed in WA, these oyster drills could potentially disrupt the pearl oyster fishery, at the time the largest aquaculture industry in Australia with an annual value of over $A 100 million.

The dredge was too large for any of the drydocks in Western Australia; the nearest drydock of sufficient size was in Singapore, some 1500 nautical miles away. Even if the drydock were available, it would take a minimum of three weeks to clean the vessel in Singapore. Because of the urgency of starting a major dredging program during the limited period of favourable weather, taking the dredge to Singapore for cleaning in drydock was not a viable option. The decision was made to immediately clean the vessel in water in Geraldton. A number of procedures were undertaken immediately to minimize the threat of introductions. Above water fouled portions of the hull were scraped; animals and plants removed were collected and disposed of at a terrestrial dumpsite. Slats of the sea chests open to the ocean were sealed and biodegradable detergent was added to the sea chests to provide a total concentration of 5% (3 tonnes were used). The treated water was circulated to ensure uniform exposure to all areas. Detergent remained in the compartments until an inspection by the Department of Fisheries 48 hours later determined that mortality of related test species (the gastropods *Thais orbita* (Gmelin, 1791) and *Turbo intercostalis* Menke, 1843) placed in the sea chests had occurred; by this stage water in the sea chests was fetid. Liquid waste trucks were then used to remove as much treated water as possible prior to the slow release of remaining water and detergent into the port area. The stern of the vessel was scraped in-water by divers to remove fouling organisms. Material scraped fell into collecting bags. Prior to scraping a tarpaulin was placed along the berth face to prevent material accidentally attaching to existing wharf structures in inaccessible locations. After the stern was scraped, smaller basin dredges were used to extract all material on the bottom in the vicinity of *Leonardo da Vinci* and to pump it into the centre of a

nearby land reclamation area.

Berth 5, where the *Leonardo da Vinci* had been berthed was surveyed on 22 October 2003, just over a year after the arrival of the dredge. The survey concentrated on the species of barnacles and molluscs listed above. All were shallow water species that extended no more than a few metres below the waterline. The 2003 survey concentrated on the pilings on the seaward side of berth 5. At each piling, divers descended to the bottom at 6 m then searched the piling from bottom to the surface for non-indigenous species; the muddy bottom was also checked. Representatives of live barnacles near the surface were scraped off each piling and identified in the laboratory. No mollusc species from the *Leonardo da Vinci* were found. The barnacle species collected were typical of the Western Australia west coast barnacle fauna and contained three species, all of which had been previously collected from the Port of Geraldton (Huisman *et al.* 2008): *Amphibalanus amphitrite* (Darwin, 1854), *Balanus trigonus* and *Megabalanus tintinnabulum* (Linnaeus, 1758). The only thaid gastropod found was the Western Australian species *Cronia avellana* (Reeve, 1846).

A resurvey of Geraldton Harbour was undertaken on 24 October 2007, five years after the *Leonardo da Vinci* first arrived. Vessels were present at berths 2, 3, 4 and 6, precluding them from examination. Four sites were examined by divers using similar techniques to the 2003 survey (Figure 1): berth 5, on the southwest of the harbor, where *Leonardo da Vinci* had berthed in 2002; berth 1 and adjoining rock walls, and an adjacent slipway on the south east; and rock groynes on the northeast and northern side of the port. The four sites gave a good coverage of the port. The rock groynes extended to a depth of about 4 m before a muddy bottom was encountered. As all of the species on *Leonardo da Vinci* were either attached to the vessel or in association with the hard substrate of the vessel, the muddy bottom of Geraldton harbour was not examined except to ensure that it was in fact all mud.

None of the molluscs found on *Leonardo da Vinci* were found in 2007. Oysters were abundant on the rock groynes, but all were identified as the southern Australian *Ostrea angasi* (Sowerby, 1871). The only mussel found was the tropical *Stavelia horrida* Récluz, 1852, which occurs naturally in the region. The native thaids *Cronia avellana* and *Thais orbita* were found, but neither of the Caribbean species (*Thais haemastoma* and *T. rustica*). Barnacles collected were: *Tetraclita squamosa* (Bruguière, 1789), *Amphibalanus amphitrite, A. reticulatus* and *Austromegabalanus nigrescens.* Two species, *T. squamosa* and *A. nigrescens,* are typical of the Western Australia west coast barnacle fauna. *Amphibalanus amphitrite,* a cosmopolitan, cryptogenic species, has been previously collected from the Port of Geraldton (Huisman *et al.* 2008). Live specimens of *A. reticulatus* were identified from the *Leonardo da Vinci*. *Amphibalanus reticulatus* has been collected previously from a number of localities in Western Australia, both north and south of Geraldton, but not from Geraldton itself (Jones 2004; Huisman *et al.* 2008). Specimens collected in the present resurvey, near berth 1, indicate that this species has become established in the Port of Geraldton. *Amphibalanus reticulatus* is known to have originated in Japan and its widespread distribution has most probably been via ship fouling (Utinomi 1967). No introduced species of crabs were found. Several specimens of native crabs, *Portunus pelagicus* (Linnaeus, 1766), *Atergatis integerrimus* (Lamarck, 1801), *Leptodius exaratus* (H. Milne Edwards, 1834) and *Thalamita sima* H. Milne Edwards, 1834, were collected.

To date the procedures employed to prevent the introduction of Caribbean species into Geraldton appear to have worked. There is always a possibility that there may be one or more species that have established breeding populations that have not yet increased to a level where they have been found. Also, there is a possibility that groups not identified when *Leonardo da Vinci* arrived, may have been introduced. Therefore, it is recommended that a resurvey be undertaken in another five years.

The Geraldton experience has been beneficial in raising the profile of introduced marine pests in Western Australia. Ship operators are very much aware of the problems caused by the arrival of *Leonardo da Vinci* and the potential financial losses which will occur if a fouled vessel enters a Western Australian port and is denied entry to the port. The WA Environmental Protection Authority closely assesses all major development projects in the state, including marine and coastal projects. On EPA advice, the WA Minister for the Environment now routinely includes legally binding Ministerial Conditions that vessels entering WA waters for these projects are cleaned of attached species prior to arrival or are inspected for marine pests within 48 hours of arrival. *Leonardo da Vinci* returned to Port Hedland, Western Australia, late in 2006 under such Ministerial Conditions. Before coming to WA on this occasion it was slipped and cleaned in drydock in Singapore and inspected by an environmental consultant for the proponent and by an officer of the Department of Fisheries. The dredge was in general well cleaned. After some areas were further cleaned the vessel was cleared for entry to Western Australia, which occurred without incident. More recently (July 2008), *Leonardo da Vinci* was inspected by both environmental consultants for the proponent and officers of the Department of Fisheries in Abu Dhabi before

sailing to Western Australia.

The evidence is that the original incident of *Leonardo da Vinci* bringing pest species into Western Australia was handled effectively, and the species do not appear to have been introduced. Following this experience, detailed procedures are in place to minimize the chances of a similar incident.

This incident is not unique, and should serve to heighten awareness both that sea chests are important potential sources of introduced species and the risks posed by mobile infrastructure. Coutts *et al.* (2003) considered that sea chests are often overlooked as a potential source of introduced species. Coutts *et al.* (2007) followed up by surveying 42 vessels in New Zealand. A total of 150 species were recorded from the sea chests, approximately 15% of which were non-indigenous. In contrast to the restricted areas occupied by sea chests on most vessels, the 60 m^3 area occupied by those on *Leonardo da Vinci* were very accessible. Mobile infrastructure has been implicated in other studies, including a floating drydock that introduced two species of sponges and one mollusc into Hawaii (Eldredge and Smith 2001). Similarly, Foster and Willan (1979) reported barnacles being introduced into New Zealand by a floating oil platform. Mobile infrastructure such as dredges, oil rigs, drydocks, etc are particularly high risk for a number of reasons, including the fact that they may undertake a broad range of activities and may move considerable distances from one port to another. Often the vessels remain in port for extended periods, allowing the development of fouling communities on the hulls. The work often occurs in shallow waters where marine pests are concentrated, with equipment left in the water for 24 hours or more in close contact with the sea floor (Kinloch *et al.* 2003).

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