5 APPRAISAL OF POSSIBLE VECTORS FOR MARINE AND TERRESTRIAL INTRODUCED SPECIES

5.1 Merchant ships

5.1.1 Type, frequency and origin of ships

A subset of vessel movement reports obtained from the Australian Maritime Safety Authority (AMSA) for the period 1 January 1999 to 30 September 2001 in the Timor Sea – Arafura Sea area (>15,000 records) was used to extract merchant vessel type, position and voyage data for the western Timor Sea region (between 8°20'S and 15°00'S and 122°00'E and 129°30'E). This region is shown inside Fig. 8, and it lies west of Darwin and south of the Indonesian archipelago, and extends to the south and west of Ashmore Reef (12°15'S 123°02'E) and Cartier Island (12°31'S 123°33'E). It was chosen to identify all reported voyages passing on any side of Ashmore Reef and Cartier Island.

The regional data set contained 7787 position records covering a total of 4417 voyages. These voyages were broken down into categories of vessel type, which are shown in Table 7. During the reporting period of 21 months (638 days), the average number of recorded voyages in the western Timor Sea region was 210 per month (= 6.9 per day). Because not all ships make regular (daily) position reports, the actual number of voyages is higher.

Table 7: Vessel voyages in the western Timor Sea region

VESSEL TYPE	No of Ships	No of Voyages	Percentage of Total
BULK CARRIERS	799	1860	42.1%
GENERAL CARGO SHIPS	143	512	11.6%
CRUDE OIL TANKERS	137	469	10.6%
CONTAINER SHIPS	68	361	8.2%
OFFSHORE TUG/SUPPLY SHIPS	57	356	8.1%
LIVESTOCK CARRIERS	28	282	6.4%
PRODUCTS TANKERS	45	128	2.9%
RO-RO VESSELS	22	73	1.7%
GAS TANKERS	20	70	1.6%
CHEMICAL TANKERS	39	64	1.4%
PASSENGER SHIPS	27	57	1.3%
BARGES & LANDING CRAFTS	10	45	1.0%
VEHICLE CARRIERS	20	38	0.9%
OIL EXPLORATION VESSELS	3	29	0.7%
RESEARCH VESSELS	14	40	0.9%
SEISMIC SURVEY (PETROLEUM) VESSELS	2	11	0.2%
OIL PRODUCTION VESSELS	3	11	0.2%
REFRIGERATED CARGO SHIPS (REEFERS)	5	5	0.1%
CABLE LAYERS	1	2	0.05%
YACHTS	2	2	0.05%
DREDGERS	1	1	0.02%
HEAVY LOAD CARRIERS	1	1	0.02%
UNREPORTED VESSEL TYPES	215	463	10.5%
22 + 1 unknown group	**1447**	**4417**	3 voyages/ship

The large majority of merchant vessels were bulk carriers (42.1%) and general cargo ships (11.6%) trading to northern Australian ports on routes to and from Indonesia, Singapore and more distant ports west of the of Indo-Malay archipelago. Crude oil tankers made up 10.6% of the total number of voyages, followed by container ships (8.2%). Private vessels such as cruising yachts are not held by AMSA, and the two reported 'yachts' are probably sail training ships. Voyages where the vessel type had not been reported amounted to 10.5%.

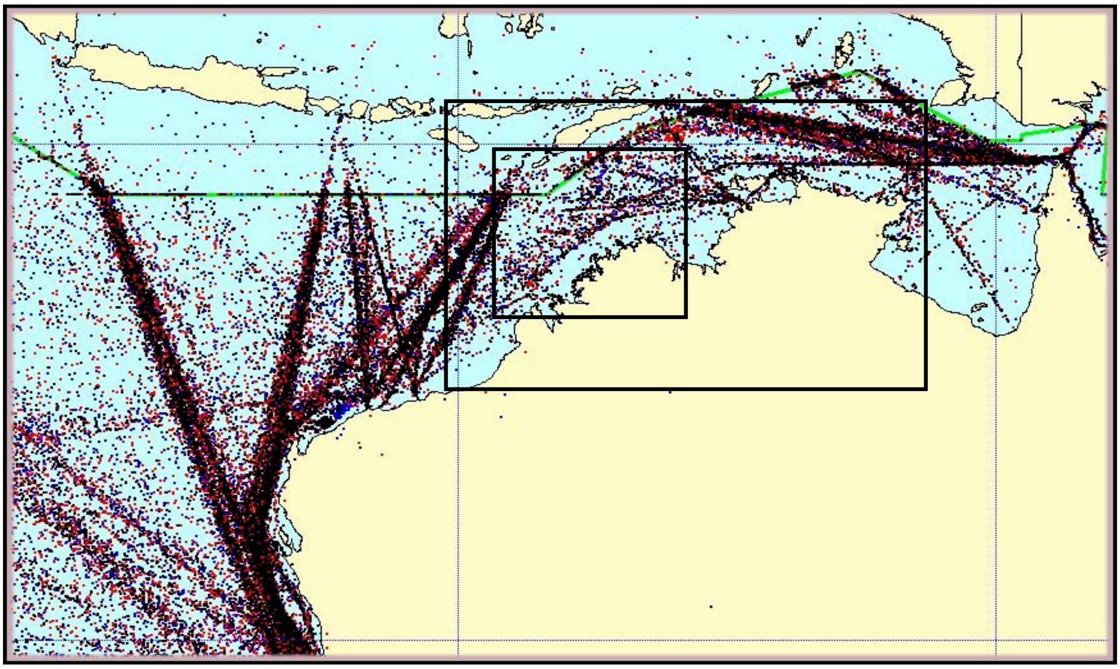

Figure 8: Vessel movement reports off northern Australia in 1999-2001, showing the approximate boundaries of the Timor Sea - Arafura Sea database (outer square) and western Timor Sea region (inner square)

The vessel position plots in the western Timor Sea region are shown in Fig. 9. The subset summarised in Table 7 and shown in Fig. 9 was broken down further to reveal those voyages which passed less than 100 km from Ashmore Reef and/or Cartier Island. The vessel types reporting these voyages are summarised in Table 8.

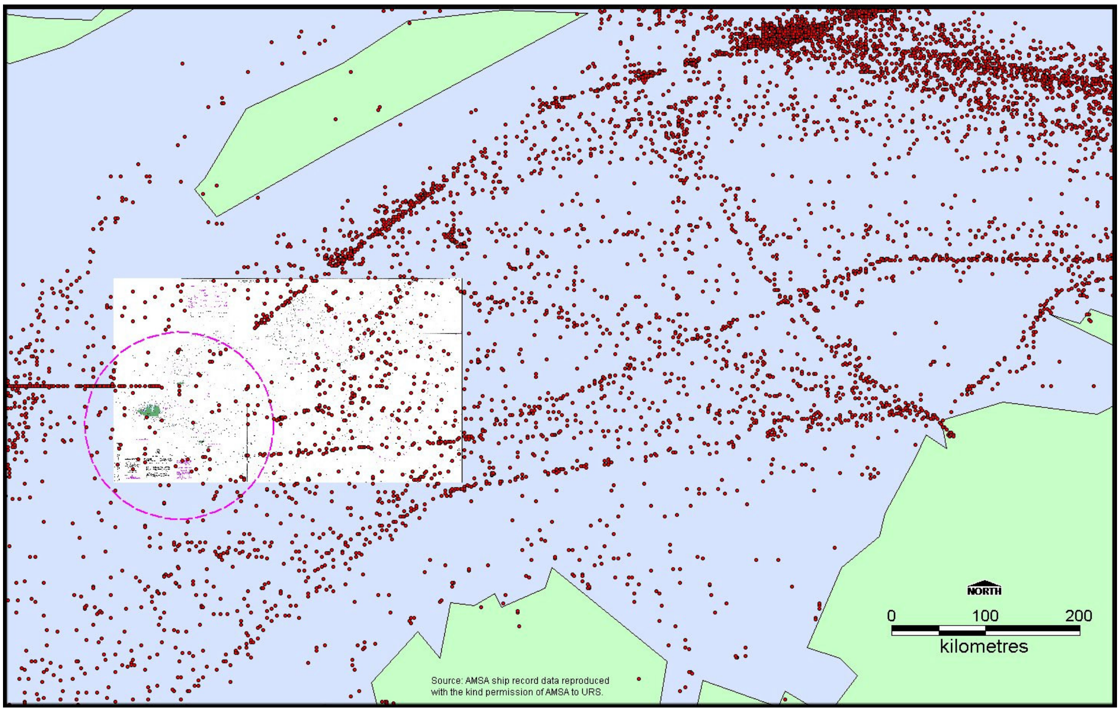

Figure 9: Plot of vessel movement reports in the western Timor Sea in 1999-2001

Table 8: Vessel voyages passing near Ashmore Reef and/or Cartier Island

VESSEL TYPE	No of Ships	No of Voyages	% of Region Voyages	% of Area Voyages
BULK CARRIERS	110	151	8.1%	33.6%
GENERAL CARGO SHIPS	13	33	6.4%	7.3%
CRUDE OIL TANKERS	23	31	6.6%	6.9%
CONTAINER SHIPS	2	7	1.9%	1.6%
OFFSHORE TUGS/SUPPLY SHIPS	24	66	18.5%	14.7%
LIVESTOCK CARRIERS	19	53	18.8%	11.8%
PRODUCTS TANKERS	5	6	4.7%	1.3%
RO-RO VESSELS	3	25	34.2%	5.6%
GAS TANKERS	3	3	4.3%	0.7%
CHEMICAL TANKERS	1	1	1.6%	0.2%
PASSENGER SHIPS	6	6	10.5%	1.3%
BARGE & LANDING CRAFTS	1	1	2.2%	0.2%
VEHICLE CARRIERS	0	0	0.0%	0.0%
OIL EXPLORATION VESSELS	2	9	31.0%	2.0%
RESEARCH VESSELS	6	11	27.5%	2.4%
SEISMIC SURVEY (PETROLEUM) VESSELS	1	1	9.1%	0.2%
OIL PRODUCTION VESSELS	2	4	36.4%	0.9%
REFRIGERATED CARGO SHIPS (REEFERS)	0	0	0.0%	0%
CABLE LAYERS	0	0	0.0%	0%
YACHTS	1	1	50.0%	0.2%
DREDGERS	0	0	0.0%	0%
HEAVY LOAD CARRIERS	0	0	0.0%	0%
UNREPORTED VESSEL TYPES	28	40	8.6%	8.9%
22 + 1 group of unknown vessels	**250**	**449**	1.8 voyages/ship	

The average frequency of these reported voyages was 21 per month (0.7 per day), although the actual number probably exceeds one a day. More voyage tracks are 'missed' as the spatial resolution increases, as well as the incidence of ships not making regular reports.

The proportions of merchant vessel types undertaking voyage tracks that passed near Ashmore Reef and Cartier Island was generally similar to the regional pattern, although voyages by 19 livestock carriers (11.8% of total) were the second most numerous after the bulk carriers (33.6%), followed by general cargo ships (7.3%), crude oil tankers (6.9%) and 25 voyages made by three RO-RO ships (5.6% of all voyage tracks in the area).

5.1.2 Risk of grounding

It is interesting to note that the bulk carriers and crude oil tankers, which can be expected to have the deepest drafts as well as undertaking the largest ballast water exchanges in open waters away from mainland Australia, undertake the fewest number of repeat voyages in the area. This in line with the highly 'spot-charter' nature of the international shipping business for these types of trading vessels.

Although deck officers on these vessels may have the least familiarity of the various crews plying the outer Sahul Shelf, Ashmore Reef is adequately charted, and the marked bathometry change of the almost linear shelf break is easy to follow and interpret. Thus unlike the inner passage off Queensland's north-east coast and the shallow, restricted channels through Torres Strait, the Ashmore Reef area is not conducive for accidental groundings and none are known for either this reef or Cartier Island in recent history.

5.1.3 Hull fouling and ballast water

Because it is easy for merchant ships to keep well clear of the Ashmore and Cartier reefs, the hull fouling vector is essentially non-existent. With respect to ballast water exchanges, these have been actively encouraged by the AQIS Seaports Program since the early 1990s, with mandatory reporting introduced in July 2001.

A previous analysis of empty 'handy-size' and 'handy-max' bulk carriers en route from Asian ports to an export terminal in north-west Australia indicated that the majority were exchanging their ballast water in relatively sheltered areas (including the Timor Sea), rather than in truly oceanic areas (East Indian Ocean) where swell conditions are generally larger (URS, unpublished confidential report to DEH, 2000).

It can therefore be expected that some ballast water originating from east Asian ports is discharged in the vicinity of Ashmore Reef (perhaps as close as 20-30 nautical miles) by bulk carriers and oil tankers approaching Australian ports and terminals. However, even at the times of the strongest favourable surface currents (eg. as may be caused during peak periods of the Indonesian through-flow plus strong easterly trade winds), the number of dilutions and degree of dispersal over this distance would be vast.

Both the IMO and AQIS Guidelines for ballast water exchange recommend that ships should not undertake exchanges in or near shallow coastal areas, and this type of education is slowly percolating through the international shipping industry. Thus although the ballast water vector is potentially present, it is unlikely to pose a regular or significant present or future threat, even under the most conducive water current conditions.

5.2 Offshore Petroleum Industry activities

5.2.1 Type, frequency and origin of units

The voyage statistics of the four types of vessel associated with the region's offshore petroleum exploration and production activities are listed in Tables 7 and 8. These comprise the offshore tenders/supply vessels, seismic survey vessels, oil exploration units (includes self-propelled drilling ships) and ships associated with oil production (FSOPs leaving or returning to their wellhead location). When added together, the proportion of the total number of voyages reported for within 100 km of the Reserves (Table 8) is small (about 10% of voyages in the region).

In line with the location of the petroleum tenements (Fig. 5), most voyage tracks were to the east and south of Ashmore/Cartier area, with those of the offshore tender/supply ships being by far the most numerous, and typically originating from Darwin, Broome or Port Hedland and very occasionally from Wyndham.

5.2.2 Risk of grounding

Grounding risks are very low since there are no exploration or production areas close to either Reserve (Fig. 5).

5.2.3 Hull fouling and ballast water

The contributions made by vessels working for the offshore petroleum exploration and production industry to the hull fouling and ballast water vectors is minimal and essentially zero respectively. These vectors are likely to be represented more by the crude oil tankers which traverse the region on their way from and to the load-out terminals respectively, although their role in aiding introductions to the Reserves is not considered significant (Section 5.1).

5.3 Australian commercial fisheries and fishing units

The AMSA database does not contain the position reports of Australian or Foreign registered fishing units. The Australian fisheries include the Commonwealth managed Northern Prawn Trawl Fishery and Northwest Slope Trawl Fishery, the WA and Joint Authority managed northern shark fisheries, and the northern demersal scalefish fishery (Fig. 10). Because of their remoteness from mainland fishing grounds, the levels of offshore wet line, shark and trawl fisheries effort close to Ashmore Reef and Cartier Island is very low or non-existent. The majority of shallow reefs on the Sahul Shelf are closed to commercial trap and line units, and currently there is no active shelf slope trawling near the Reserves.

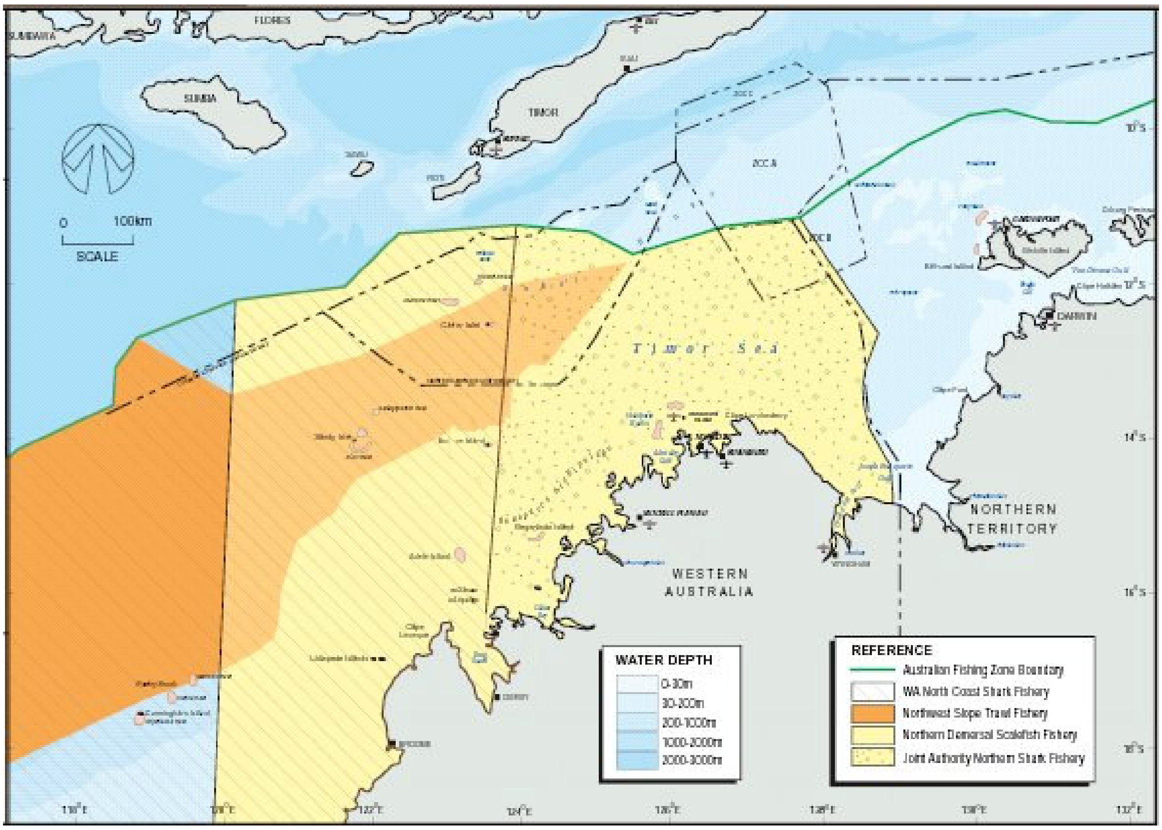

Figure 10: Commercial Fishery Areas managed by State, Territory and Joint Authorities

5.4 Cruising yachts, tourist/charter launches and recreational fishing vessels

Ashmore Reef is on the main cruising route for yachts departing from Darwin for Indonesia (Rote, Kupang, Bali, Jakarta), East Timor (Dili), Singapore, or the Western Indian Ocean (Christmas Island, Cocos Keeling Islands, Reunion), and its protected western lagoon provides a relatively safe and convenient stopover for many vessels heading west.

Accurate yacht and other recreational vessel arrival data are available for Ashmore Reef for the period May 2001 – August 2003 (Table 9). During this time there were a total of 64 yacht arrivals at Ashmore Reef: 15 (23.4%) Australian vessels, 39 (60.9%) overseas registered, and 10 (15.6%) vessels of unknown register.

Table 9: No. of yacht and other recreational visits to Ashmore Reef by month (May 2001 – July 2003)

	2001	2002	2003
Jan	-	0	0
Feb	-	0	0
Mar	-	0	0
Apr	-	0	0
May	4	2	0
Jun	0	0	3
Jul	14	10	1
Aug	0	12	-
Sep	6	8	-
Oct	1	1	-
Nov	1	3	-
Dec	0	0	-

Yachts arrived between May and November, with a peak in July - August (Table 9). This corresponds with the dry season, when the easterly trade winds are most favourable for westerly sailing, and there is no risk of tropical cyclones.

The last port of call for the majority of yachts (50 or 78.1% of the total) was Darwin, with four (6.3%) arriving from Broome and one each (1.6%) from Kupang, West Timor, and Port Klang, Malaysia. Most yachts stayed for 1-4 days. Yachts are permitted only to anchor in West Lagoon and their crews are permitted access to land on the open areas of West Island (Fig. 4).

The main port of departure, Darwin, has no designated AIMPAC marine pest species (Russell and Hewitt 2000).

Ocean cruising yachts are generally well maintained and the majority visiting Ashmore Reef can be expected to have clean hulls, since many are freshly anti-fouled before leaving Darwin for the Indian Ocean. While these yachts are not considered to pose a significant risk for introducing species to Ashmore Reef, it is possible that the skipper of a yacht who had not stopped or cleaned the hull in Darwin may decide to undertake some in-water hull cleaning whilst anchored in the sheltered lagoon. This risk has been described by Hutchings *et al.* (2002) based on knowledge and information of cruising yachts on the East Coast of Australia. Any such hull cleaning inside the Reserve would be an offence under the EPBC Regulations as the discharge of any solid waste or polluting substance inside the Reserve is prohibited (Regulation 12.14).

Cartier Island Marine Reserve is closed to public access. A prohibition notice closing the Reserve to the public under the EPBC Act was issued in May 2003. The area has been closed as a former Defence Practice Area for some decades. While Indonesian fishing vessels have continued to visit Cartier Reef, from July 2003 this closure is being progressively enforced. The only visits to Cartier reef are by Australian Government vessels such as Customs and RAN vessels, or possibly an occasional research vessel under permit from DEH.

Because of the remoteness of Ashmore and Cartier Reefs from mainland Australia, visits by tourist charter launches and recreational fishing vessels are very infrequent. These vessels generally come from Broome or Darwin, and only commercial tourism operators require a permit from DEH to visit Ashmore Reef or Cartier Island. However these vessels are usually well maintained and because their homeports are presently free of invasive species, they pose little risk of introducing any NIS.

Yachts arriving at Ashmore Reef from overseas ports, however, may present a higher risk, similar to that of Indonesian fishing boats or SIEVs (see 5.6 And 5.7 below), and should be discouraged from anchoring at Ashmore Reef, or subject to inspection to ensure that they do not carry unwanted marine and terrestrial species.

Some modern yachts may carry ballast trim water which could harbour NIS or pathogens, and these vessels should not be permitted to discharge or exchange ballast water inside the Reserve boundaries.

It was noted in the Boarding Records, that some yachts and other recreational vessels carry cats or dogs on board. Under no circumstances should domestic pets be allowed to be landed on West Islet.

5.5 Government patrol vessels and moorings

Aside from records of DEH chartered vessels and Australian Customs Vessels (ACVs), accurate records of visits by RAN patrol boats and other vessels were not available. Since the mid-1980's DEH has maintained a (more or less) continuous presence at Ashmore Reef, at least during the dry season (April – November), by charter vessel from Darwin. More recently (from May 2000) a presence has been maintained at Ashmore Reef by having an ACV continuously on station in the West Island Lagoon at Ashmore Reef, with a changeover frequency between 12 – 28 days.

In addition, there are regular visits by RAN patrol boats and occasional visits by other RAN vessels, such as the Landing Craft (Heavy) HMAS *Balikpapan*, which laid a series of moorings in the lagoon near West Island in November 2001. All of these vessels generally have come from either Darwin or (less frequently) Broome and have clean, well-maintained hulls. The risk of introducing fouling organisms from the Australian mainland via the RAN or other patrol vessels is therefore insignificant, although this would need to be reviewed if the RAN bases ever became subjected to a significant infestation of an unwanted fouling species similar to that seen in Darwin's lock-gate marinas in 1998-99.

None of the ACVs or RAN vessels carries ballast water in the conventional sense, although the patrol boats and Landing Craft have trim tanks which can hold several tonnes of seawater for compensation purposes. In fact no large vessels with conventional ballast tanks are known to have visited Ashmore or Cartier Reefs or are likely to in the future (see Section 5.1).

To provide good cyclone resistant moorings and to prevent anchor damage to coral in the Ashmore Reef lagoon, 11 moorings were laid in the lagoon near West Island in November 2001. Thirteen additional moorings were laid in July 2003 for use by Indonesian fishing vessels, yachts and larger vessels. These were installed subsequent to the marine survey. Only two of the large (3 tonne) moorings are currently in use. The mooring blocks provide potential settling sites for non-indigenous fouling species, although no NIS were found on the various blocks inspected by the marine survey (Section 3.6.1).

Compared to marine species, the potential for visiting ACV and RAN vessels to unintentionally introduce terrestrial species is probably higher. While specific data were not available, it is clear that Australian Customs personnel, DEH staff and scientists frequently visit West Island, and less frequently East and Middle Islands for patrol, inspection and research purposes respectively. During 2002, a RAN Helicopter landed on West Island and RAN and Army personnel visited West Island.

All of these types of visit pose the risk of introducing weeds and terrestrial animals from mainland Australia, such as from seeds attached to clothing or gear, or insects in containers and equipment. The wheels and skids of helicopters do not provide a vector as these craft are regularly and thoroughly washed down to avoid salt corrosion (an important maintenance procedure). The chances that patrol or research visits could cause an animal introduction are also low owing to the relatively harsh conditions and limited habitats on the islands, but the risk of transferring an unwanted plant and some type of insect cannot be discounted, particularly via seeds or soil lodged in clothing, field equipment, boots, containers and packages.

We therefore recommend that any clothing or equipment to be taken ashore should be thoroughly inspected and, where necessary, washed and decontaminated prior to departure from Australian ports. To this end, standard procedures for AC or other landing parties should include a careful check of personal clothing, boots, and field equipment for plant material, soil, and insects. We recommend that DEH adopt strict quarantine standards and procedures similar to those developed for Barrow and Thevenard Islands off the Western Australia coast (Chevron Texaco 2003a, 2003b).

5.6 Indonesian (artisanal) fishing boats

As described in Section 2.3.1, Indonesian fishermen have been visiting Ashmore and Cartier Reefs for probably several centuries, and these visits continue today, albeit on a more restricted and controlled basis. The main Indonesian ethnic groups involved in fishing are the Madurese, Bajau Laut, and Butonese, who sail from small fishing villages throughout Eastern Indonesia (Fox *et al.* 2002).

Data on Indonesian fishing vessel (perahu) arrivals at Ashmore Reef are available from October 1985 – October 1999, although records are generally incomplete or lacking for the period mid-December to mid-March most years because of the seasonal nature of monitoring of vessel arrivals by the Australian Government. However, since far fewer perahus visit Ashmore Reef during the NW Monsoon between December and February (Australian coastal surveillance data), the data summarised here represent a good indication of general perahu movements over the whole year.

Of the 1662 perahu visits recorded between 1985-1999, the majority (85.6%) of arrivals had departed from Rote, with a much smaller number (8.8%) from other ports throughout East Indonesia (including South and South-East Sulawesi, Taka Bone Rate, Flores, Pantar, Alor and West Timor; Fig. 11). Some perahus had apparently departed from Madura (4.4%) and Surabaya in East Java (1.2%). The distribution of perahu departure points between 1985-1999 is similar to that analysed in detail by Russell and Vail (1988) over a much shorter period (1986-1988), and indicates a consistent pattern of movements. A more detailed analysis of ports of origin of fishers is provided by Fox *et al.* (2002).

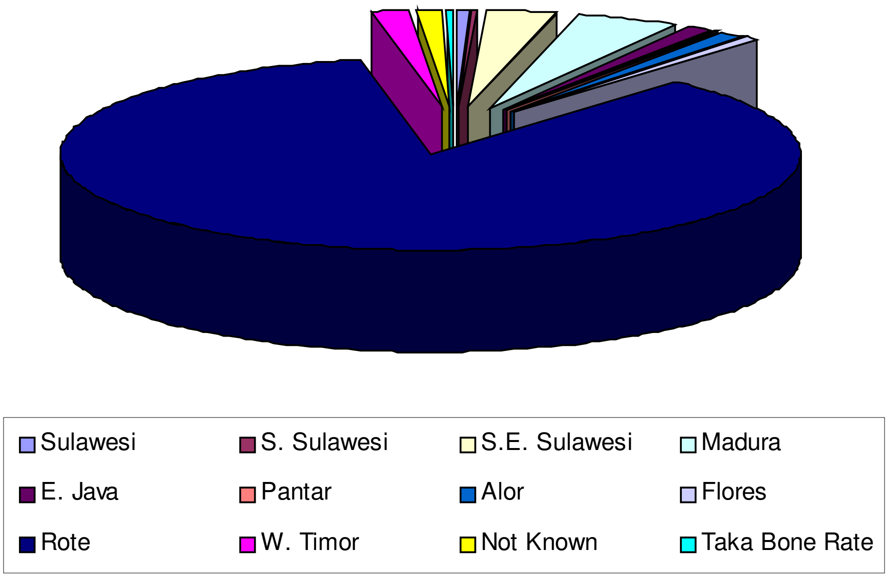

Figure 11: Indonesian fishing perahu arrivals at Ashmore Reef, October 1985 – October 1999, by Port of Origin area

Perahus are wooden-hulled vessels, classed as Type I, II or III, based on DEH records. Type I perahus are of the leti leti type (Fig. 12a) and come mostly from East Java (Madura, Tundu). Type II perahus are of the lambo type (Fig. 12b), and a few have small, inboard diesel motors. Type III perahus are motorised lambo, known as perahu layar motor (PLM) (Horridge 1986, N. Birningham, pers. comm.). Type I and II perahus are widely found throughout Eastern Indonesia.

(a) (b)

Figure 12: **(a)** Perahu leti leti (Type I), and **(b)** Perahu lambo (Type II).

Russell and Vail (1988) found a pattern of repeated visits by many of the same individual perahus in successive years. About 15% of the vessels were recorded in three recurrent years, and another 11% of vessels visited in two recurrent years, with most of these regular visitors coming from Rote. As with the present data, Rotinese boats predominated the number of perahus visiting Ashmore Reef in 1986-88. Visits by these vessels constitute a regular and sustained fishing effort at Ashmore Reef. Few other vessels were regular visitors (Russell and Vail 1988).

Although records are incomplete for all months of the year, the data indicate there are two modal peaks in arrivals – in May and August (Fig. 13). Strong winds during the onset of the SW Monsoon mean there are few visits during December-February, and few perahus are present before March or after December (Russell and Vail 1988). Mean duration of stay ranged from about 2-16 days per month (Russell and Vail 1988).

Indonesian fishing perahu visits constitute by far the largest number of vessel visits to Ashmore and Cartier Reefs, with most departing from small secondary (non-commercial) home or transit ports that can be characterised as 'clean water' areas likely to be of low risk from non-indigenous marine species. The exception is the small number of vessels (1.2%) originating from the East Javanese commercial port of Surabaya, where unwanted species are reported to be present, including *Mytilopsis sallei*.

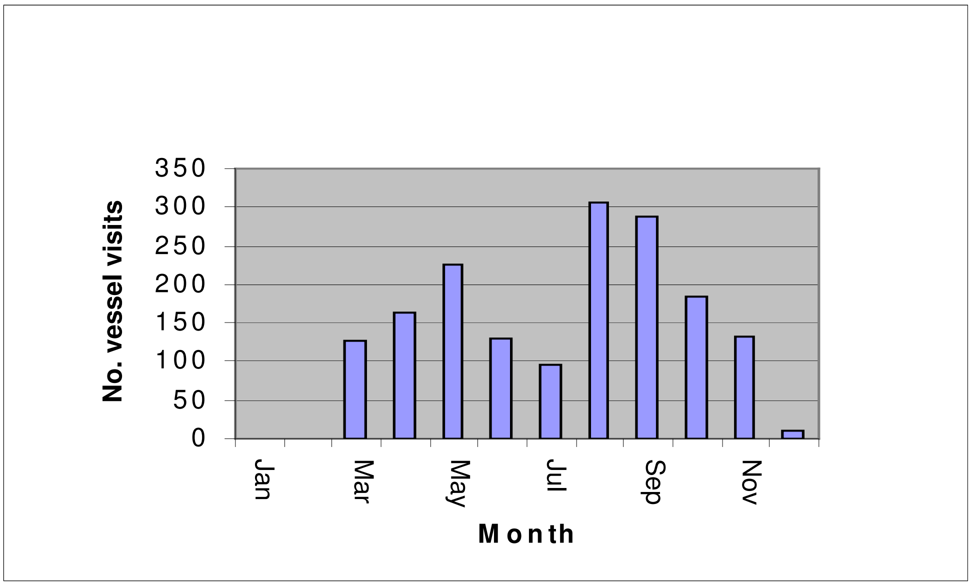

Figure 13: Number of Indonesian fishing vessel arrivals at Ashmore Reef, October 1985 – October 1999, by month of arrival

The general condition of most Indonesian fishing perahus is good and their hulls are generally well maintained and free of fouling organisms (P. Clark, pers. comm.), and the vessels inspected at Ashmore during the marine survey were consistent with this (K. Neil, pers. obs.). A key reason is the tradition of dragging these vessels to foreshore locations when voyages are completed, so as to reduce rotting rates and extend hull life (anti-fouling paints are expensive and thus sparingly used, if at all). The risk of transferring marine NIS to Ashmore Reef from the Indonesian ports is, therefore, considered low. Present information indicates that a poorly-maintained fishing vessel arriving at Ashmore Reef following a protracted mooring period in the port of Surabaya would pose the highest risk of transferring unwanted fouling species such as *Mytilopsis sallei* or *Austromegabalanus krakatauensis*. Such a scenario would be rare, and a badly fouled perahu should be relatively easy to detect from a brief waterline inspection, since water clarity in the West Lagoon is typically excellent.

Of more concern is the potential for introduction of terrestrial species by Indonesian fishers. While data are not available on frequency of visits to the Ashmore Reef islands and Cartier Island by Indonesian fishers, there is archaeological and historical evidence of past visits and occupation, particularly on West Island, where there is a freshwater well and where visits are still permitted. It is likely that these visits in the past have been responsible for the introduction of both plant and animal NIS, and current levels of access warrant attention.

For example, DEH data indicate that Indonesian fishers continue to visit West Island fairly frequently for watering purposes, and they are also allowed access to other islands for visits to grave sites. These visits cannot easily be prevented since the supply of fresh water is provided for in the MOU and visits to graves were agreed during previous negotiations with Indonesia.

The main concern is inadvertent introduction of the seeds of weedy plants plus unwanted insects (particularly ant species). The chances of unwanted rodent introductions such as mice or rats are considered low owing the type and size of the perahus and customs of the Indonesian fishers, in using small dugout canoes to come ashore. Steps for reducing the risks of introduction of NIS might include the piping of water from the well on West Island to the landing beach (thereby avoiding walking over the island) and limiting access to the grave sites to marked paths, which can be more readily monitored for possible non-indigenous weed species.

5.7 Suspected illegal-entry vessels (SIEVs)

Ashmore Reef is only about 80 nautical miles from the Indonesian island of Rote, and is the closest Australian Territory to Indonesia. In recent years Ashmore Reef has become a target for illegal people smuggling, an activity that reached a peak during 2000-2001.

Data provided to DEH by the Department of Immigration and Multicultural and Indigenous Affairs for the period July 2000 – August 2001 indicates there were a total of 41 Suspected Illegal Entry Vessel (SIEV) arrivals, with 22 during July-December 2000 and 19 during January-August 2001.

Following action by the Australian Government to strengthen border protection, no further SIEVs have been recorded arriving since November 2001. The pattern of SIEV arrivals (Fig. 14) shows vessels arrived in most months, with the highest number of vessels (8) arriving in December 2000.

The 'Port of Origin' (PoO) of a large proportion of SIEVs (44%) was not recorded, but where it was, PoO areas include Surabaya (East Java), South and South-east Sulawesi, Lombok, Sumbawa, Flores, Alor, Sumba, West Timor and Rote (Fig. 15).

As with the Indonesian fishing vessel data, most of the reported PoO appear to be from 'low risk' areas of Indonesia. Only two vessels (5%) were from ports of high risk for NIS (Surabaya, East Java). Almost all of the apprehended vessels, however, were in poor or unseaworthy condition and many were heavily fouled. It is also not clear how many of the PoOs were merely a last port of call rather than the true origin (homeport) of the SIEV.

AC personnel have reported the presence of insects (cockroaches) and rats on board many vessels, and it is likely that ants and geckos could also be present. Consequently, all SIEVs must be considered 'high risk' for terrestrial as well as marine NIS. We recommend that rat poison, cockroach baits and other insecticide should be therefore be laid on all intercepted SIEVs as a routine procedure to minimise the chances of animal pests reaching the islands.

The potential for SIEVs evading apprehension and landing people on East and Middle Islands is also of concern. While our brief surveys of these islands did not indicate the presence of mice or rats, the potential for reintroduction of these as well as other NIS remains high.

The mooring of heavily fouled vessels in the lagoon at Ashmore Reef poses an unacceptably high risk of introduction of NIS. The risk of inoculation of larvae of non-indigenous marine species into the lagoon at Ashmore Reef is will increase significantly with time, particularly if the fouling organisms are in breeding condition and capable of producing eggs and larvae.

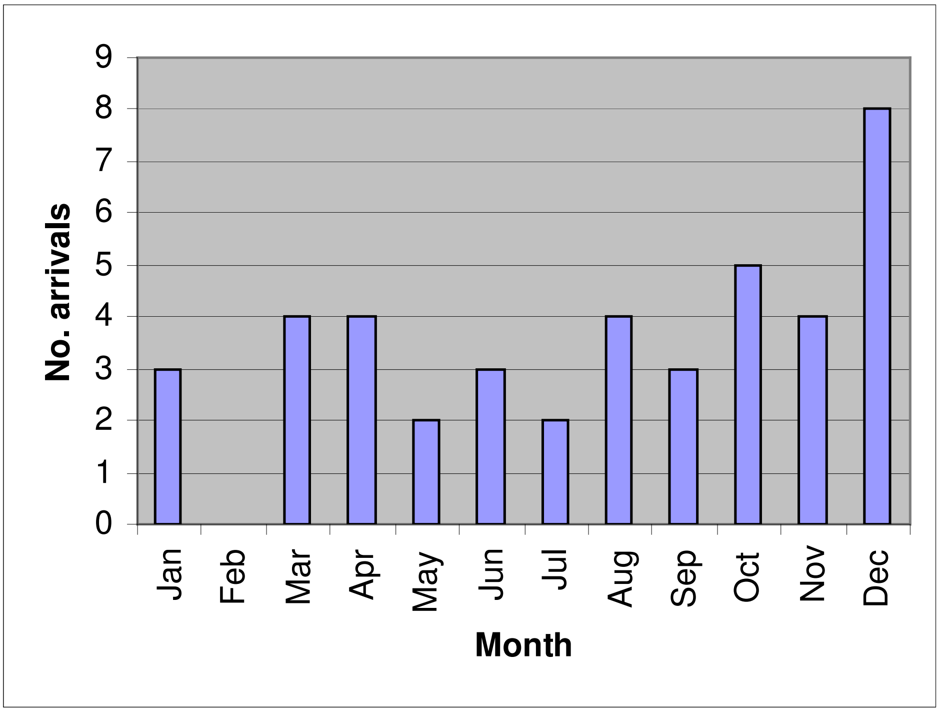

Figure 14: Number of Suspected Illegal Entry Vessel (SIEV) arrivals at Ashmore Reef, July 2000 – August 2001, by month of arrival

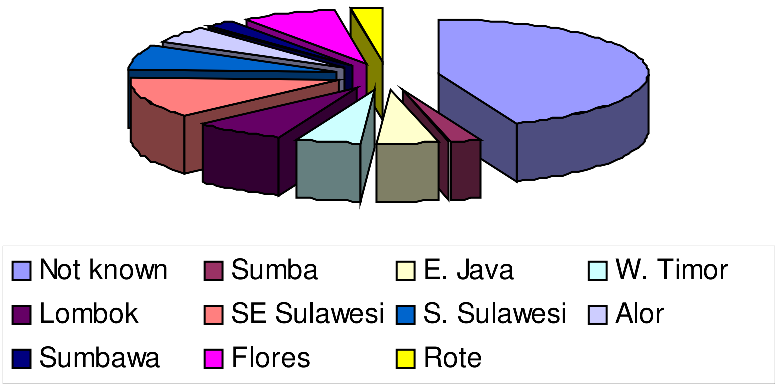

Figure 15: Suspected Illegal Entry Vessel (SIEV) arrivals at Ashmore Reef, July 2000 – August 2001, by Port of Origin region

In general, SIEVs should not be held in the lagoon for more than a few days unless the hull has been carefully inspected and shown to be free of unwanted marine and terrestrial species. If the vessel is unseaworthy and passengers must be transferred ashore for safety, a suitable landing craft or ferry should be mobilised to Ashmore Reef to re-embark them as soon as possible.

We therefore recommend a policy that all SIEVs should be intercepted at sea wherever possible and safe to do so, and that DEH investigate the practicality of establishing one or more permanent moorings outside of West Lagoon to receive such vessels.

6 RISK ASSESSMENT OF SPECIES INTRODUCTIONS

Risk is a measure of the likelihood of an event and magnitude of its consequences, and can be estimated by qualitative, semi-quantitative or quantitative means, depending on the type and amount of available information and the completeness of models of the investigated process. The risk assessments and proposed strategies that address marine and terrestrial introductions are addressed in Sections 6.1 and Sections 6.2 respectively.

6.1 Marine species risk assessment

This section provides a qualitative risk assessment for marine species introductions based on the results and information in Sections 3, 5, and Appendix 1. Definitions and discussion of the terms and methods in marine invasion risk assessment are also given in Appendix 1.

An important initial part of any risk assessment is a hazard analysis to identify the potential consequences associated with the activities of concern (Appendix 1). Section 6.1.3 provides a hazard analysis of the transfer vectors and species of concern to Reserves, summarising information in Sections 3, 5 and Appendix 1. Assessment conclusions are given in Section 6.1.5, and proposed prevention and management strategies in Section 7.

6.1.1 Risk assessment method

Conventional quantitative risk assessment methods cannot be used to evaluate marine species introductions owing to major gaps in our knowledge of marine species distributions, taxonomy, and the incompleteness of biological invasion models (Appendix 1). These gaps result in rapidly increasing uncertainties with each step of the invasion process (eg. Hewitt and Hayes 2002). However the risk posed by vessel or debris-mediated marine species transfers can be estimated, provided the consequence of such transfers (= end point of the risk analysis process) is simplified (Appendix 1).

For example, in the case of marine Reserves and other protected areas managed for conservation purposes, an ideal end-point would involve some measure of predicted reduction to native biodiversity, damage to a key ecosystem process or other impact pertaining to their identified value for each NIS taxa. Such end-points would allow the use of risk-acceptance criteria to help decision-making regarding the cost-benefits of different management options taken for each transfer mechanism (vector) and route. This approach is prevented, however, by current limitations in (a) knowledge of marine NIS characteristics and present distributions, and (b) understanding of the patterns and factors of the invasion process (particularly for tropical areas and vectors such as fouling of hulls and discarded fishing gear; Appendix 1).

While it is not possible to quantify with any useful certainty the likelihood of end-points involving population establishment and specific impacts, a simpler end-point can avoid this problem and permit a qualitative estimation of risk relevant to the Reserves. It also facilitates evaluating both the pathways (ie. the vectors and routes which can transfer marine NIS to the Reserves) and the types and characteristics of the most likely taxa, based on past experience and events. The three hazard analysis components are given in Section 6.1.3, and provide the basis of the qualitative risk assessment in Section 6.1.5.

6.1.2 Identifying the end-point

It is important for any hazard analysis to identify a useful yet practical end-point, since this influences the chance as well as the scope and magnitude of the consequences requiring prediction (Appendix 1). As noted earlier, end-points involving some measurable loss to one or more defined biodiversity or ecosystem values in a declared Reserve would be ideal but do not allow predictions with any useful certainty. Compromise end-points are required because marine species invasion theory is an emerging discipline where the name of the game remains '*ecological roulette'* (Carlton and Geller 1993, Hewitt and Hayes 2002, Appendix 1).

As with end-points used by AQIS' Decision Support System (DSS) for assessing voyage-specific ballast water discharges (Appendix 1) and by the UNDP-IMO GloBallast Program for identifying hazardous trading routes (PCU 2002, Raaymakers and Hilliard, in press), a suitable end-point for the two Reserves would be:

"Inoculation of any life-cycle stage of a non-native species which, based on current evidence and knowledge, would be capable of surviving and possibly establishing a population at the Ashmore Reef or Cartier Island Reserves." [1]

The main difference between the above end-point and that used by the DSS is the absence of reference to specific species targeted as known or suspected pests. The latter is more relevant to multi-use coastal waters near ports and harbours, where there is no management objective concerning a need to prevent all NIS incursions. Even if there was, the actions required to minimise these would incur inordinate shipping delays and costs.

In the case of remote Reserves managed for native biodiversity conservation, and where practical measures can be taken to reduce the risk of NIS incursions, the proposed end-point is appropriate, as there is no need to predict ultimate consequences following an introduction. As noted by Hewitt and Hayes (2002), expressions of risk relating only to the possibility of NIS establishment carry *"…an implicit assumption that the establishment of any exotic species in the locality is an undesired event. This is equivalent to an expression of environmental value that wishes to preserve 'natural' or existing species assemblages."*

The question of end-point selection therefore turns on the values and management goals of the Ashmore Reef National Nature Reserve and the nearby Cartier Island Marine Reserve. In the context of values, the Reserves' Management Plan notes that: *"The Reserves were established by the Commonwealth for the purposes of protecting their outstanding and representative marine ecosystems and to facilitate scientific research"* and *"The Reserves protect unique and vulnerable marine ecosystems with high biological diversity. The Reserves include reefs which are part of remote reefal systems which provide critical stepping stones for the transportation of biological material from the centres of biodiversity in the Indo-Pacific to the reefal and other inter-dependant ecosystems located along the Western Australian coast."* (Commonwealth of Australia 2002).

As to management goals, the two Reserves form part of the National Representative System of Marine Protected Areas (NRSMPAs) and the Management Plan notes *"…the primary goal of the NRSMPA is to… contribute to the long-term ecological viability of marine systems, to maintain ecological processes and to protect Australia's biological diversity at all levels."*

The Plan also calls for the development and implementation of *"…a marine and terrestrial introduced species prevention and management strategy (this strategy also applies to sections 6.4* [Unauthorised Boat Arrivals] *and 6.5* [Tourism and Recreation], *and is relevant for all users of the Reserves)."* With respect to management performance targets, the Plan also notes: *"Key elements of the performance assessment for these Reserves include:*

- *marine and terrestrial introduced species, specifically their means of introduction and impact on natural values."*

In accordance with the EPBC Act 1999, the Plan assigns both Reserves overall to the category 'strict nature Reserve' (IUCN category Ia), for which the following management principles apply:

- *The Reserve or zone should be managed primarily for scientific research or environmental monitoring;*
- *Habitats, ecosystems and native species should be preserved in as undisturbed a state as possible;*
- *Genetic resources should be maintained in a dynamic and evolutionary state;*
- *Established ecological processes should be maintained.*

[1] Inoculation means release of viable organisms in sufficient numbers and/or frequencies that provide more than a negligible chance of successful settlement and establishment at or near the site of interest (Appendix A). For hull-fouling NIS, risk of release of 10^{3-6} propagules increases with age and maturity of transferred adults, hence period spent by vessel remaining at exposed arrival site where no initial temperature/salinity shock was experienced (can induce rapid spawning in <4 hours).

For that part of Ashmore Reef zoned National Park (IUCN category II), the management principles applying to this area require protection and management to preserve its natural condition, including:

- *Representative examples of physiographic regions, biotic communities, genetic resources and native species should be perpetuated in as natural a state as possible to provide ecological stability and diversity.*

In summary, the Management Plan confirms the priority for conserving native biodiversity and its requirement for *"…a marine and terrestrial introduced species prevention and management strategy"* makes no distinction between 'harmful' or 'harmless' NIS.

We consider the precautionary approach towards prevention and management of all NIS, irrespective of their ecological status, is the most appropriate in achieving the proposed management goals for Ashmore Reef National Nature Reserve and Cartier Island Marine Reserve

6.1.3 Hazard analysis of NIS vectors and routes

Ballast trim water and bilge water

Coral diseases are spreading as a result of several factors, including increased stress from global warming and exposure to faecal contaminated water (eg. *Serratia marcescens*) as well as other types of pathogens present in bilge water and ballast trim tanks (ISRS 2002, Ruiz *et al.* 2000, Rosenberg and Ben Halm 2002).

While ballast water may be discharged by vessels undertaking tank exchanges when passing as close as 20-30 nautical miles of the Reserves (Section 5.1), the numbers and frequency of any non-indigenous organisms or pathogens managing to survive the open waters and drift into the Reserves can be discounted in terms of producing significant inocula. A similar conclusion can be made for ballast water discharges from crude oil tankers loading the closest oil export terminal, as this is more than 120 kilometres to the east (Jabiru; Fig. 5). No new oil terminals appear likely to be developed closer than this one during the next 10-15 years (ie. the period typically taken from the initial discovery of a significant prospect by seismic survey to the start of oil production).

Patrol vessels and landing craft of the Royal Australian Navy (RAN) carry ballast trim water and occasionally visit Ashmore Reef, but these units should have no need to discharge the contents of these tanks inside the Reserves except in an emergency such as accidental grounding. Some modern yachts also carry ballast trim water. Because the source/s of the trim water may be unclear or unknown and may contain long-lived cysts or pathogens, we recommend that vessels not be permitted to discharge any ballast trim or bilge water within the West Island Lagoon. In the case of RAN vessels, this could be achieved by a departmental 'standing order' that universally applies to any unit entering the Reserves.

The only event leading to a large ballast water discharge at either Reserve would be the grounding of a bulk carrier, crude oil tanker, general cargo ship or livestock carrier on an inbound (ballasted) voyage to collect cargo. This is a very unlikely scenario but cannot be totally discounted. If a grounding occurred when the sea level was high (a 'worst-case' scenario would be a high spring tide or cyclone-produced surge), subsequent tides would not assist efforts to refloat the ship. Whatever tidal assistance was available, the ship's master or salvage team would probably wish to reduce draft by discharging ballast water as soon as possible. This should be allowed since if the ship could not be refloated and became a total loss, all of its ballast water and, more significantly, the ballast tank sediments and fuel oil would eventually escape. The possibility of pumping out the fuel and ballast tank sediments into a reception vessel before the hull is stripped and abandoned should be checked, although this could prove technically impractical and unsafe depending on the distance between the stranded ship and navigable deep water.

Hull fouling

For over 25 years most national and international attention on shipping-mediated marine species introductions has focussed on the ballast water vector, as it was believed that faster voyages, shorter turn-around times and the development of more efficient, longer-life 'self-polishing' anti-fouling coatings in the 1970s had reduced the importance of hull fouling (eg. Carlton 1985). However recent work in Australia, New Zealand and Europe indicates that hull fouling is remaining an equally important vector for a number reasons (Appendix 1; see AMOG 2002 for detailed review). Hull fouling includes all compartments of a vessel, including internal surfaces such as anchor lockers, water intakes and strainers.

In the case of tropical Australian waters, hull fouling on sailing and fishing vessels has caused significant incursions of three NIS into Darwin and Cairns during 1998-2001, whereas very few NIS with known or suspected pest credentials appear to have been vectored into Australia's northern ports in ballast water from merchant ships over the past 30 years (Appendix 1). The significance of the hull fouling vector is recognised by NIMPCG and AQIS, which commenced a study program in 2001 to evaluate hull fouling and practical ways to manage this vector, with the possible future objective of incorporating it as a module of its ballast water 'Decision Support System' (Appendix 1).

From the various vessel type and movement data reviewed in Section 5, it is clear that hull fouling is the most likely vector to transfer unwanted NIS to the Reserves. SIEVs and Type III fishing vessels (motorised) from Indonesia, plus cruising yachts which have not taken a maintenance stop in Darwin, represent the most hazardous vessel types owing to the predicted absence or poor condition of anti-fouling coatings (Section 5; Appendix 1).

In the case of the SIEVs, lack of effective anti-fouling can be expected to be compounded by previous periods of lay-up in one or more distant Asian ports which could be infected with a variety of fouling species not native to the Timor Sea region (Table 5; Appendix 1). No data of formal hull surveys of SIEVs appears to have been published or could be obtained for this study. It can be predicted that, due to the age, design and condition of these vessels, many will have hulls that offer a variety of nooks, inlets and crannies that provide shelter from turbulent flow and are difficult to clean. Even if some in-water scraping was undertaken prior to the start of their journey, such places can be readily missed while the remnant thalli and holdfasts of many scraped algae and colonial animals can remain attached and regenerate during a slow voyage (AMOG 2002).

Although Type I and Type II sailing vessels are not painted with anti-fouling, they are usually removed from the water at the end of each of voyage, and not left on moorings or anchored for extended periods. They are rarely sailed on voyages beyond the Nusa Tengara region. Thus unlike SIEVs and cruising yachts, their routes remain within the SE Archipelago and Timor Sea region where endemic species have had opportunities to disperse to the Ashmore and Cartier Reserves by natural means (Appendix 1).

Australian vessels visiting the reef (ie. ACVs, RAN units, tourist/charter vessels) will not pose a risk unless non-indigenous fouling species become established in their home base or supply port (ie. Darwin, Broome, Wyndham or Cairns). As shown in Fig. 16, port NIS surveys using formal sampling protocols have not yet been undertaken at Broome or Wyndham (Fig. 16). In this context, any survey undertaken of Broome should include careful sampling of the habitats in Willy Creek (north of Broome and beyond port limits), where many SIEVs were held, left derelict and/or sank prior to the adoption of NIS quarantine procedures in 2000.

Marine debris

As demonstrated by the example of the barnacle *Austromegabalanus krakatauensis* found on drift wood at West Island, floating marine debris drifting into the Reserves has the capacity to transfer non-indigenous fouling species that are native or introduced to coastal or port waters in the south-east Indonesian archipelago and Papua New Guinea (particularly discarded fishing gear and wood and plastic items sourced from harbours and estuaries). Some of Indonesia's major trading ports are known to contain fouling pest species, such as the black-striped mussel (*Mytilopsis sallei*) and serpulid tube worms (*Hydroides elegans*, possibly *H. sanctaecrucis*) in Jakarta and Surabaya (C.L. Hewitt and J.L. Lewis, pers comm; URS 2002, in prep.).

The marine debris-monitoring project near Cape Arnhem has collated valuable long-term data on the types, amounts and apparent sources of drifting rubbish and discarded fish gear. No samples or records of associated fouling biota have apparently been taken, although the vector potential of the debris has been recognised by project coordinators (Appendix 1).

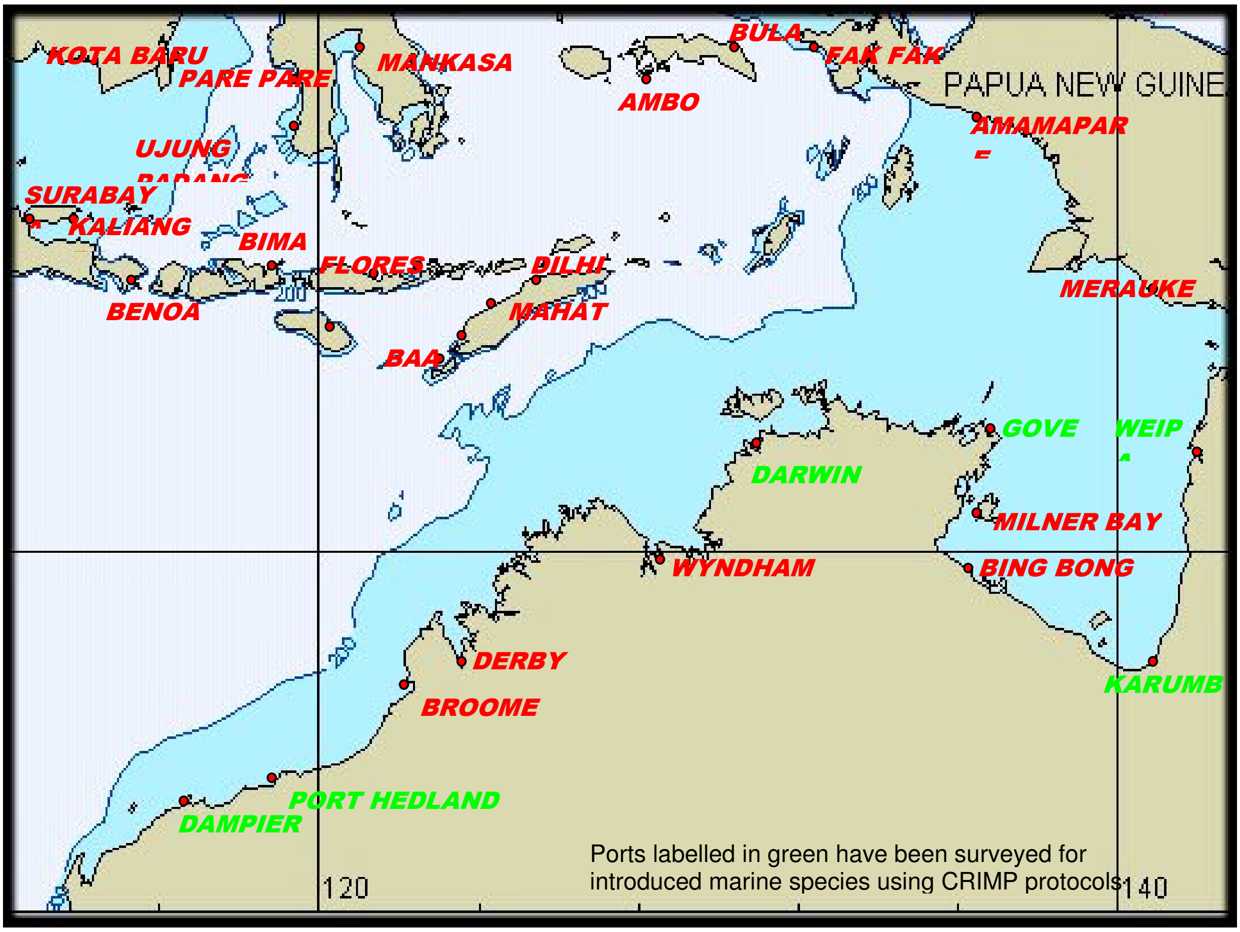

Figure 16: Ports and Fishing-Trading Harbours in the Timor-Arafura Sea Region

The vast majority of the ports, fishing harbours and coastal trading posts in the region have not been surveyed for marine NIS (Fig. 16), and thus present an unknown distribution of fouling NIS originating from north Asia, the Americas and Caribbean. These harbours include Baa on Roti, Kupang in West Timor, Dili in East Timor and Fak Fak, Amamapare and Merauke in Irian Jaya; Fig. 16).

Because of the lack of knowledge regarding the types and sources of marine species attached to marine debris in the Timor Sea - Arafura Sea region, no meaningful risk assessment of this vector is possible.

6.1.4 Analysis of marine NIS – origins and effects

Overview

Of the large number of introduced species now documented for coastal waters in Australasia, Europe and North America, some 5-15% have achieved a 'pest' or 'nuisance' status in most regions (Appendix 1). Many have also spread far from the ports where they were first introduced, and there are no effective ways to eradicate established populations except in

localised sites amenable to closure and intensive management (eg. Pyne 1999, Culver and Kuris, 2000).

Effects on biodiversity, ecosystem processes, fisheries and wildlife stocks are ranging from basin-wide severe impacts in temperate areas (eg. North American comb jellyfish in Black Sea and European zebra mussel across U.S. watersheds), to restricted and as yet unclear effects in tropical regions. Species with a fouling pest status in the tropical Indo-West Pacific such as the black-striped mussel (*Mytilopsis sallei*) and Asian date mussel (*Musculista senhousia*), are reported to have colonised disturbed and polluted harbour habitats in Singapore, Hong Kong, Manila, Jakarta, Mumbai, Vizakhapatnam. In the central Pacific, red macroalgae introduced via hull fouling from the South China Sea – Sea of Japan region (*Acanthophora spicifera, Hypnea musciformis*) have been overgrowing disturbed coral reefs in the Hawaiian Islands (especially Kaneohe Bay), while a 'vacant' niche in the upper intertidal zone of these islands is becoming occupied by a Caribbean barnacle (*Chthamalus proteus*), so far without local biodiversity loss (Appendix 1).

Among some of the infamous introductions of the 20th century, several species did not show signs of their invasive prowess and harmful effects in initial years and even decades following initial establishment (Appendix 1). As there is no reliable way to divide or predict 'harmless' from 'harmful' NIS, a precautionary rather than dichotomous approach is more appropriate for assessments made for Reserves managed for nature conservation and biodiversity protection. The hazard analysis therefore notes NIS which have known, suspected or unknown pest credentials, based on lists compiled in Australia and elsewhere (Appendix 1). It is also important to recognise that the various taxa appearing in Australia's target, 'trigger' and 'next pest' lists (Table 5) do not provide a complete or definitive set of risk species.

Type and effects of tropical marine species incursions in Australia

The majority of marine introductions in Australia are due to hull fouling and have been recorded from its southern waters, with some of these species causing significant ecological and/or economic effects (Appendix 1). Both the number and pest credentials of established NIS decline as one moves northward into subtropical then tropical waters on both sides of Australia (Appendix 1).

In general, 'short-distance' transfers of marine species native to Indonesia and Papua New Guinea into northern Australian waters via hull or debris fouling are unlikely to pose a significant risk for two reasons. Many share the same natural range, while those restricted to the Indo-Malay/ southern Philippine/Papua New Guinea 'triangle of mega-diversity' (ie. naturally absent from north Australia) have had plenty of time and opportunity to extend their range southward, both by natural and historical human-mediated mechanisms (Appendix 1, *Hilliard et al*. 1997).

Although there are no significant biogeographic barriers preventing southward natural dispersals into the Timor Sea, the relatively small latitudinal shift results in marked reductions in cloud cover and annual rainfall, as well as increased average wind strengths, insolation, evaporation and cyclone generation (due to the coriolis effect). The different metaocean conditions experienced by the reefs and islands on the exposed Sahul Shelf, together with the large tidal ranges in the Timor Sea, help explain why many of the marine taxa endemic to the more humid equatorial region have not spread into Australian waters (Appendix 1).

Compared to regions south of the Tropic of Capricorn, most of the fewer NIS recorded in Australia's tropical waters comprise widespread (cosmopolitan) and often cryptogenic foulers which do not appear to have caused any significant ecological or economic impacts following their introduction by historical hull-fouling, 'dry ballast' or aquaculture attempts. The presence of relatively few NIS and apparent invasion resilience of Australia's tropical marine communities have been supported by results of recent NIS surveys at Dampier, Port Hedland, Darwin, Gove, Weipa, Cairns, Mourilyan, Abbot Point and Hay Point (Appendix 1).

Reasons for the apparent dearth of invasive NIS that threaten native biodiversity or habitats in Australia's tropical waters were identified by Hilliard *et al*. (1997) and have been discussed by Hutchings *et al.* (2002), Coles and Eldredge (2002) and Ruiz and Hewitt (2002). They include

the marked differences between Australia's temperate and tropical marine communities in their degree of biogeographic isolation, endemism, tolerance to physical stresses and biological 'defence' capability.

In terms of causing nuisance hull fouling, one of the worst culprits found in Australian tropical ports has been *Hydroides elegans*. This very cosmopolitan and cryptogenic fouling tube worm has a wide temperature tolerance range and was first recorded on Australia's east coast well before the end of the 19th Century, but may have originated from the Mediterranean (AMOG 2002). As noted in Section 3, the record indicating its presence at Cartier Island (Hanley 1993) merits attention. It was not found by the recent survey of Ashmore Reef, the habitats at Cartier Island are atypical for this species, and it is most prolific in brackish harbour and estuarine areas (Section 3; J. Lewis, pers. comm.). Because *H. elegans* has been established for a very long time (it remains an unproven introduction), it is impossible to identify with any certainty the type of ecological effects it may have caused in and near port waters.

There are exceptions to the trend for non-indigenous fouling taxa entering northern Australian waters not to threaten significant economic and/or ecological effects. These include:

- incursion of the black-striped mussel (*Mytilopsis sallei*) into Darwin's lock-gate marinas (since eradicated);
- recent establishment of the Caribbean fouling tube worm (*Hydroides sanctaecrucis*) in Cairns (Trinity Inlet); and
- transfers of Asian green mussels (*Perna viridis*) into Cairns and Darwin (Appendix 1).

The 1998-1999 incursion of *M. sallei* has been followed by its further appearance on the hull of an apprehended Indonesian fishing vessels that was escorted to Darwin in September 2000. Individuals were also reported to have been found on the hull of a SIEV that was apprehended on Ashmore Reef in December 2000 and subsequently scuttled in deep waters off Broome (AMOG 2002). Although *M. sallei* has spread widely among ports in the Indo-Pacific region (from Hawaii and Fiji to India, including Jakarta and Surabaya), these populations appear to remain localised to polluted harbour and sheltered brackish water areas (Appendix 1, Dr A.C. Anil, pers. comm.). That the 1998-1999 incursion at Darwin was restricted to the interior of the lock-gate marinas is also significant, as the marina populations showed no ability to colonise any natural or piling substrate outside the artificial harbours (despite spawning twice and achieving very high densities before discovery and eradication; Hilliard 1999, Pyne 1999, Russell and Hewitt 2000, Ruiz and Hewitt 2002). While the apparent habitat preferences of *M. sallei* in both its natural and introduced range imply little ability to survive in the exposed and tidally-influenced Sahul Shelf reefs, it represents a significant threat to brackish harbours and estuaries where tidal range is lower (eg. Gulf of Carpentaria and NE Queensland).

The fouling Caribbean tube worm *H. sanctaecrucis* was first recorded in 2000 in Trinity Inlet, Cairns, by discovery of recruits that had settled on coastal RAN units that were being slipped to replace worn-out anti-fouling coatings (http://www.env.qld.gov.au/cgi-bin/w3-msql/environment/science/water/msqlwelcome.html?page=marine_pests.html). The source and route of the introduction remain unclear (Appendix 1). This species is presently colonising various artificial and natural hard surfaces in the inlet, but numbers are relatively low and so far show no sign of being able to displace either their congener (*H. elegans*) or other fouling species (J. Lewis, pers. comm.). A reassessment of species collected from Darwin Harbour in 1999 indicates that *H. santaecrucis* also has established there (C. Glasby pers. comm.).

Of the three species listed above, only the green mussel is an Asian native, with an original range centred in the subtropical Indo-West Pacific region. Adults have been found in Darwin on the hulls of small vessels from Vietnam (in 1991) and Indonesia (in 1999, 2000, 2001), and also in Cairns in 2001 on some derelicts moored in Trinity Inlet (http://www.env.qld.gov.au/cgi-bin/w3-msql/environment/science/water/msqlwelcome.html?page=marine_pests.html). This mussel is a popular food source that is cultured in several Asian countries, and its present-day distribution now extends into equatorial areas including Singapore (B. Morton, pers. comm.). As noted in Section 3, it is reported to have altered native shoreline communities in some areas where it has been introduced (Sommerfield *et al.* 2000).

Examples of other non-indigenous, warm-water tolerant fouling species not yet recorded from Darwin or other tropical ports so far surveyed include barnacles and various gastropod and bivalve molluscs with tropical Atlantic origins, plus the Asian date mussel (*Musculista senhousia*). The latter has been an aggressive invader of disturbed estuarine and brackish harbour environments in sub-tropical areas, and its present-day populations indicate remarkable thermal tolerance (ie. from southern Siberia to Singapore and the north and central Philippines, plus the Mediterranean, north-west America, New Zealand, Victoria, New South Wales and the Swan-Canning system at Perth; Appendix 1). As with *Mytilopsis sallei*, however, its propensity for brackish coastal areas implies a low risk for the Reserves. The apparent thermal, salinity and habitat preferences of other north Asian bivalves that have pest credentials indicate only a low chance of establishing a population in northern Australia (Table 5; Appendix 1).

Hull fouling species of concern from the tropical West Atlantic include two barnacles now present in the Central and East Pacific regions, plus several molluscs. The Caribbean star barnacle *Chthamalus proteus* has become predominant on the previously bare upper intertidal zone of the Hawaiian islands, is also present at Midway Atoll (Appendix 1), and was recently found on the cutter-suction arm of a dredger that arrived in Geraldton harbour in October 2002 after a direct voyage from Kingston (Jamaica) via the Suez Canal (R. Hilliard and D. Jones, unpub. data.). This is the first record of its transfer into Australian waters, although it is likely that similar but unnoticed hull-fouling transfers have occurred into Australian East Coast ports via Pacific - Hawaiian routes.

The Atlantic barnacle *Megabalanus coccopoma* is present in the East Pacific region, was also found on the dredger at Geraldton and was recently recorded on a ship inspected at Brisbane (D. Jones, pers. comm.). As with *Austromegabalanus krakatauensis*, it is considered a nuisance fouler (eg. in Brazilian ports near and northward of Rio de Janeiro; URS in prep.).

As international trade and shipping operations continue to globalise, the increase in direct trans-ocean transfers of species vectored by hull fouling and ballast water adds to the problem of quantifying invasion risks. As an example, it is worth noting the following Caribbean molluscs that were also transferred to Geraldton harbour on the dredger (this appears to be their first records of entry to Australian waters; Dr F. Wells, pers. comm.):

- *Thais haemastoma floridana* - a predatory thaid snail and 'serious oyster pest' common in Florida, Puerto Rico and other Caribbean waters;
- *Thais rustica* - another predatory thaid snail whose native range includes Grenada;
- *Crepidula plana* – a hermaphroditic slipper limpet from the Caribbean and already established in San Francisco Bay. This species can live on various artificial and natural hard substrates, such as rocks, bottles, piers and on or in shells of other species.
- *Brachidontes exustus* - this bivalve is tentatively identified (*B. citrinus* is very close to *B. exustus* and may be its synonym).

Whether or not any of these or other taxa from the Caribbean-tropical Atlantic regions has the ability to establish viable populations at Ashmore Reef and Cartier Island, and which of these might subsequently displace native species, remains unclear. What this review is showing is that more port and coral reef survey data are needed from both biogeographically isolated and well-connected tropical regions around the world to confirm some emerging patterns and apparent processes (Hutchings *et al.* 2002, Coles and Eldredge 2002, Ruiz and Hewitt 2002).

In the meantime, there are various fouling species that deserve a watching-brief regarding their potential capability to colonise reefal habitats in open tropical waters, and examples are shown in Table 9. Some of these have and/or appear likely to spread to many tropical and subtropical harbours across the Indo-Pacific region (ie. from Hawaii to Mumbai), including ports where SIEVs and Type III fishing vessels may originate or undergo lay-up periods.

Table 9: Examples of hull-fouling species potentially capable of surviving at Ashmore Reef or Cartier Island Reserves

Species	Native Range	Nearest introduced population and ***Record of Entry***	Ability to tolerate open tropical coral reef habitats with large tides	Pest Status
MACROALGAE				
Acanthophora spicifera	NW Pacific	Central Pacific	Probable (subtidal)	Suspected
Hypnea musciformis	NW Pacific	Central Pacific	Probable (subtidal)	Suspected
TUBE WORMS				
Hydroides elegans	Cryptogenic	Darwin *Cartier Is?*	Possible	Fouling pest
Hydroides sanctaecrucis	Caribbean	Cairns *Darwin*	Low	Fouling pest
Hydroides ezoensis	NW Pacific	Singapore *?*	Low	Fouling pest
BARNACLES				
A. krakatauensis	Indo-Malaya	? *Ashmore Reef*	Unknown	Suspected
M. coccopoma	Trop Atlantic	E Pacific, *Geraldton*	Possible	Suspected
Megabalanus zebra	Cryptogenic	NW Australia *?*	Possible	Unknown
Balanus reticulatus	Cryptogenic	Singapore *Geraldton*	Possible	Suspected
Chthamalus proteus	Caribbean	Midway *Geraldton*	Probable	Suspected
CRABS				
Charybdis japonica	East Asia	Auckland *?*	Unknown	Known pest
Charybdis hellerii	Nth Indo-Pac	Brazil-Florida *?*	Unknown	Known pest
BIVALVES				
Mytilopsis sallei	?	Surabaya *Darwin*	Low tolerance	Fouling pest
Musculista senhousia	?	Singapore *Perth*	Low tolerance	Fouling pest
Perna viridis	NW Pacific	Singapore *Darwin*	Low tolerance	Suspected
Brachidontes exustus?	Caribbean	? *Geraldton*	Unknown	Unknown
GASTROPODS				
Crepidula plana	Caribbean	San Fran. *Geraldton*	Unknown	Unknown
Thais haemostoma	Caribbean	? *Geraldton*	Unknown	Oyster pest
Thais rustica	Caribbean	? *Geraldton*	Unknown	Suspected
OPHISTOBRANCHS				
Cuthona perca	Caribbean	Hawaii, NZ *?*	Unknown	Unknown

6.1.5 Marine risk assessment results and conclusions

Integrating the information from the previous sections allows simple tabulation of a deductive summary that compares the introduction risk associated with each vector and pathway (vessel type and route), and the types of NIS involved (Table 10).

The results in Table 10 show that hull-fouling on Type III fishing boats and SIEVs poses the highest risk, plus any cruising yacht carrying fouling biota from Pacific ports owing to skipping hull-cleaning opportunity in Darwin or Cairns. The risk increases if any fouled vessel undertakes in-water cleaning or is careened or beached within the Reserves.

Inoculation risks posed by Type III fishing vessels and SIEVs are deduced to be much higher than all other visiting vessel types (ie. Type I and II fishing boats, ACVs, RAN vessels, tourist charter vessels and most cruising yachts) for the following reasons:

- hull coating likely to have poor or no anti-fouling properties;
- moored or anchored for long periods instead of stored out of water;
- route history, ie. more distant and wider range ports of call, including NIS infected trading ports (especially SIEVs)
- higher likelihood of pathogen-contaminated bilge water; and
- potential extended stay in West Island Lagoon (SIEVs).

Table 10: Risk of NIS introductions to Ashmore Reef and Cartier Island Reserves

Vector	Route History (previous ports of call)	Types of Non-Indigenous Species	Deduced Inoculation Risk
BALLAST-TRIM AND/OR BILGE WATER	Darwin, Broome	Viral, bacterial and fungi pathogens; [including coral diseases] protozoans; benthic microalgae; dinoflagellate cysts.	Very low
RAN units	Cairns		Low
Cruising yachts	Darwin, Groote Eylandt		Very low
	Kupang, Port Moresby, Cairns, Noumea, Fiji		Low to Moderate
FFV's, SIEVs	South Asian and/or Indo-Malay trading ports		Low to High [various factors]
	Minor Indonesian ports		Low
HULL FOULING			
Type III Fishing Vessels	Surabaya	Serpulid worms, acorn barnacles, molluscs; possibly other taxa.	Low to High [increases with degree of fouling, duration of stay, in-water cleaning, grounding, beaching or sinking at site]
	Minor Indonesian ports	Unknown	
SIEVs	South Asian and/or Indo-Malay trading ports (eg. Colombo, Jakarta, Surabaya)	Serpulid worms; acorn barnacles; molluscs; (+ possibly macroalgae; hydroids, ascidians)	
	Minor Indonesian ports	Unknown	
Cruising Yachts	Darwin – hull cleaned	None at present	None
	Darwin – hull uncleaned	[depends on previous ports]	Low to High [reasons as above, but rarely occurs?]
	Kupang, Port Moresby, Cairns, Noumea, Fiji, Hawaii - hull uncleaned	Serpulid worms; acorn barnacles; molluscs; (+ possibly macroalgae and other taxa)	
ACVs , RAN Units,	Darwin, Broome	None at present	None
	Cairns	*H. sanctaecrucis, P. viridis*	Low
Tourist charter vessels	Darwin, Broome	None at present	None
MARINE DEBRIS	SOURCE: E. Indonesia to Papua New Guinea, plus Ships, Foreign and Australian fishing units		
Discarded fishing gear		Unknown	Unknown
Drift wood, plastics		Unknown	Unknown

The results of this qualitative assessment must be treated as preliminary, since insufficient surveys and studies have been conducted on marine NIS transfers and their consequences in tropical regions to provide a clear picture of invasion patterns and processes. A review and update would be worthwhile within 3-5 years, based on current rates of marine species incursion reports and research studies in the tropical Indo-Pacific.

In the case of Type III fishing boats and marine debris, regular inspections and sampling of these vessels and the shoreline debris at Ashmore Reef would markedly improve the present picture, as would more port surveys in the region. An adequate and cost-effective level of surveillance and sampling could be achieved if 1-2 crew members of ACVs were trained in basic snorkelling, sampling and preserving methods, with pro-forma record sheets and samples transferred to NT Fisheries Aquatic Pest Management Group, Darwin, at vessel turn-around (see Section 7.2; Appendix 5: Protocols for hull inspections and collection of samples of suspected non indigenous marine species at Ashmore Reef).

This would also be adequate for SIEVs, unless their arrival frequency starts rising toward former levels, and/or their management policy involves more than weeklong duration's of stay. In this case, the type and degree of hull-fouling biota on each vessel should be inspected as soon as possible after its arrival. Any policy involving predicted retention of potentially heavily-fouled SIEVs within the Western Lagoon at Ashmore Reef without an explicit fouling survey protocol (ie. thorough sampling and taxonomic identifications) would threaten DEH's management goals and performance objectives and may also be in breach of the EPBC Act.

6.2 Terrestrial species risk assessment

This section provides a qualitative risk assessment for terrestrial species introductions based on the results and information in Sections 4 and 5 and Appendices 3 and 4. The definitions, terms and methods for risk assessment used in this section are similar to those for introduced marine species (Appendix 1), and the term non-indigenous species (NIS) is used throughout to describe those terrestrial plant and animal species considered to have been introduced to Ashmore and Cartier Reefs.

6.2.1 Risk assessment method

Because of limitations of time, the surveys undertaken at Ashmore and Cartier Reefs were necessarily qualitative. Because of taxonomic constraints, particularly for the insects and other terrestrial invertebrates, and incomplete knowledge of the ecology and distributions of many species, the risk assessment methodology adopted here is largely qualitative, and based on past and present survey information (also largely qualitative in nature). Nonetheless, with knowledge of known and potential pest species and of transfer vectors, it is possible to provide qualitative assessments of both risk and current and potential impacts of NIS at Ashmore and Cartier Reefs. The information used in compiling these assessments for terrestrial plants and animals are contained in Sections 4.2 and 4.3 and the detailed survey reports in Appendix 3 and 4 respectively. Sections 6.2.2 and 6.2.3, below, summarise the introduced terrestrial plant and animal respectively for Ashmore and Cartier Reefs. Table 11 lists non-indigenous terrestrial plant and animal species that have established or have a moderate-high risk of establishing at Ashmore and Cartier Islands.

6.2.2 Plants

Eight non-indigenous plant species are presently known from the Islands (Table 11; Appendix 3). At present, none of the non-indigenous plant species found on the islands can be regarded as a major problem. Of these, *Tribulus cistoides* and *Cenchrus brownii* are well established. Although Buffel grass, *Cenchrus ciliaris* is a dominant weed of coastal dunes near Darwin in the NT, it has remained limited in occurrence on West Island. *Cenchrus ciliaris* and Feather grass, *Pennisetum pedicellatum* are both vigorous colonisers, as yet found only in small populations, and should be eliminated from West Island. This was also a recommendation of the NAQS survey (Mitchell in Curran 2003). The presence of Buffel grass in particular, threatens the natural plant communities by replacing almost entirely the understory cover of native grasses and herbs. It also alters the characteristics of the soil and ecology of the islands, and substantially increases the risk of fire.

At present, all except two species of native plant and all of the NIS recorded on the islands are found on the Australian mainland. There is no indication that either of these native species would become serious weeds if introduced to Australia.

The potential impacts of plant species native to the region and dispersing naturally to the Islands may be just as important as impacts of plants introduced by human agencies. There is a need for careful consideration of what type and degree of change in the vegetation is acceptable. This needs to come from a better understanding of the ecology of the Ashmore Islands and other similar islands in the region. The most obvious example is the need to better understand the relationship between vegetation type and the requirements and preferences of different bird species for nesting habitat.

The islands are protected from the arrival of most non-indigenous plants by their distance from land and difficulty of access. The islands appear to offer a hostile physical environment for plant establishment and the human vectors are few.

Under present management regimes, the overall risk of further introduction of non-indigenous plant species to Ashmore Islands and their establishment there are thought to be small. The major potential vector of species from Australia is considered to be through any landing of construction materials, land rehabilitation materials, and equipment (including scientific equipment) to the islands from Australia.

Table 11: Non-indigenous terrestrial plant and animal species established or with moderate-high risk of establishing at Ashmore and Cartier islands

Species	Native range	Nearest introduced population and Record of Entry	Probability of establishing at Ashmore - Cartier islands	Pest status
PLANTS				
Tribulus cistoides (Beach caltrop)	Native to Africa, but now pantropical	Well established on all Ashmore Islands	High	Weed species, impacts on bird nesting areas
Cenchrus brownii (Burr grass)	Native to Central and South America, now widely distributed in SE Asia	Well established on West Island, near old Dept Territories Camp site.	High	Weed species
Cenchrus ciliaris (Buffel grass)	Native to Africa and India	Established only on West Island, near old Dept Territories Camp site.	High	Weed species, with potential to form mono-specific stand
Cenchrus echinatus (Mossman River grass)	Native to North and South America, but now widespread in SE Asia	Previously established on West Island, but apparently eliminated	High	Weed species, apparently successfully eliminated
Pennisetum pedicellatum (Feather grass)	Native to South Africa	Established only on West Island	High	Weed species, vigorous coloniser
Bulbostylis barbata (Watergrass)	World-wide in tropics-subtropics	Established only on West Island, near old Dept Territories Camp site.	High	Weed species, may not pose serious problem
Euphorbia hirta (Asthma weed)	Pantropical	Established only on West Island, near old weather station	High	Weed species, may harbour Poinsettia whitefly pest
Cleome gynandra (Cats whisker)	Native to Africa, but now widespread.	Established on West Island	High	Weed species
Boerhavia erecta (Tar vine)	Native to Americas	Not yet introduced, but 3 native species occur	High	Weed species
Chromolaena odorata (Siam weed)	Native to Central and South America, but now widespread in Indonesia, Papua New Guinea, Queensland	Not yet introduced	High	Weed species, with potential to form monospecific stand
Cleome rutidosperma (Spider weed)	Native to Africa, but now widespread throughout SE Asia	Not yet introduced	High	Weed species
Mikania micrantha (Mikania vine)	Native to Central America, , but now widespread throughout SE Asia	Not yet introduced	High	Weed species
Mucuna pruriens (Cow itch)	Native to Africa, but now pantropical	Not yet introduced	Low-Moderate	Weed species
Paederia foetida (Skunk vine)	Native of Asia	Not yet introduced	Low-Moderate	Weed species
Striga asiatica (Witch weed)	Native of Asia	Not yet introduced	Low-Moderate	Weed species
Indigofera zollingeriana (Zollinger's indigo)	Native to North Africa and India	Not yet introduced	High	Weed species
ANIMALS				
Insects				
Solenopsis geminata (Ginger ant)	North America, but now widespread throughout tropical Pacific, including Indonesia and N. Australia	Established on all three islands at Ashmore Reef	High	Known pest, potentially dangerous to nesting birds

Table 11: continued

Anoplolepis gracilipes (Yellow crazy ant)	Widespread in Indonesia, including Timor	Not yet detected, but has been intercepted in quarantine in Darwin and established in isolated areas in Arnhem Land	High	Known pest, potentially dangerous to nesting birds and other native fauna.
Pheidole megacephala (Big headed ant)	Native of South Africa, established world wide in tropics	Not yet detected, but is established in NT and elsewhere in Australia	High	Potential ecological threat
Teleogryllus oceanicus (Black field cricket)	Pantropical?	Established on West Island, and with potential to spread to other islands	High	Potential pest species
Cryptotermes spp (dry termite)	Widespread in Indonesia	Not yet detected, but found in Indonesian fishing vessels	High	Known pest, with potential to destroy vegetation and bird nesting sites.
Dermestes spp (hide beetles)	Cosmopolitan	Established on all islands at Ashmore Reef. Cartier Island,	High	Mainly carrion feeder, probably with little ecological impact
Necrobia rufipes (Redlegged ham beetle)	Cosmopolitan	Established on all islands at Ashmore Reef and Cartier Island,	High	Mainly carrion feeder, probably with little ecological impact
Aedes aegypti (Dengue mosquito)	Widespread in Indo-W. Pacific	Harmful carrier species not yet detected, but high potential for introduction by Indonesian fishing vessels, together with disease organisms	High	Potential carriers of human and animal diseases such as Malaria, Dengue etc
Molluscs				
Achatina fulica (Giant African snail)	Africa, but introduced into Indonesia, including Timor	Not yet detected, but regularly intercepted in quarantine in Darwin in shipping containers from Timor	High, capable of aestivation over dry season	Known pest, potentially devastating to plants
Parglogenia spp (Land snail)	SE Asia	Not yet detected, but regularly intercepted in Darwin in shipping containers from Timor	High	Known pest, potentially devastating to plants
Reptiles				
Hemidactylus frenatus (Asian house gecko)	SE Asia, but widespread throuout Indo-W Pacific	Established on West Island, not yet detected on East or Middle Islands	High	Potential pest species, may impact on invertebrate fauna
Rodents				
Mus musculus (House mouse)	World wide	Apparently established on East and Middle Islands.	High probability of becoming introduced on West Island	Known pest species, potentially dangerous to nesting birds.
Rattus rattus (Black rat)	World wide	Black rat successfully eradicated in 1980's	High potential for reintroduction from visiting vessels	Known pest species, potentially dangerous to nesting birds.

Indonesian fishing vessels constitute the highest risk of introduction of Asian weeds to the area. Probably of greatest significance for potential introduction of plant species to the Ashmore Islands are *Boerhavia erecta* (Nyctaginaceae), *Chromolaena odorata* (Asteraceae) and *Cleome* *rutidosperma* (Capparaceae). In addition, the Asian native shrub, *Indigofera zollingeriana,* could potentially colonise the Islands. It is a species that occupies sandy beaches and coral strands.

To provide information on the ecology of the terrestrial regions of the Reserves and to allow early detection of any potential invading taxa, thereby facilitating early and rapid response to their presence, regular monitoring of plant species present on the Islands is needed at an appropriate time of year (March-May). Annual monitoring would be ideal, but once every 3-5 years may be a more practical interval.

There is a need to better understand the differences in vegetation between islands, the underlying soil factors and the changes in vegetation taking place on the islands. There is also a need to build a knowledge base on non-indigenous plants invading similar coastal environments in monsoonal northern Australia and in Asia, especially islands used as sea bird nesting sites. Data on responses of individual NIS to the particular conditions associated with bird nesting sites are lacking.

6.2.3 Terrestrial fauna

Most of the terrestrial fauna of Ashmore and Cartier islands comprises species that are widespread in the Indo-West Pacific region. However, several species recorded during the present survey have probably been introduced by man and are of concern; and other species found in the region, but not yet recorded at Ashmore and Cartier islands pose a serious risk of introduction (Table 11; Appendix 4).

Ants

The ginger ant, *Solenopsis geminata* (family Formicidae), is an introduced fire ant to all of the islands of Ashmore Reef. It is a native to North America and has spread throughout much of the tropics including Indonesia and the Top End of the Northern Territory. It is most likely to have been introduced from Indonesia. It is a small aggressive ant that lives in large subterranean colonies, and attacks in large numbers. It feeds on insects and other animals including vertebrates. Sick, vulnerable or tethered animals are particularly susceptible to attack. This ant is an extremely dangerous threat particularly to ground nesting birds, and its impact may already be significant as it has been recorded on Middle and West Islands since at least 1992. During the NAQS survey, Postle (in Curran 2003) observed that this species seemed far more abundant during a survey in 2003 than in 2000, and also noted the potential for its introduction into Western Australia where it is not yet present, via ACVs returning from Ashmore Reef.

Ginger ants have the potential to hinder and deter nesting birds, or even attack and kill hatching young and older surviving hatchlings. They are now widespread on all three islands at Ashmore Reef, and are surviving on dead birds. They may be more abundant in the wet season and could be having an effect on nesting birds and turtles, but neither of these issues could be determined during this visit. These should be followed up, as well as consideration of eradication of the species.

The crazy ant, *Anoplolepis gracilipes* is also a potential threat to Ashmore Reef. This ant causes similar problems to ginger ant, although it does not sting. It is widespread in Indonesia including Timor, and has been intercepted in quarantine in Darwin on a number of occasions. It rapidly moves into new nesting sites such as bags and boxes, and as such could be easily transported to Ashmore Reef. The islands should be monitored for this and other introduced ants at regular intervals.

Borers and termites

The introduction of any insects that will destroy the bird nesting sites will have serious effect on these birds. This applies particularly to boring beetles and termites. None have been found to date, however some species of both groups may remain undetected in wood for many years before their presence is known. Of particular concern are drywood termites, *Cryptotermes* species. These occur in many Indonesian fishing vessels that visit the Reserves, and can live in relatively small pieces of timber for many years before they are noticed. As such, fishing vessels, including boat wrecks and large pieces of driftwood, are possible sources of introduction.

Molluscs

No terrestrial molluscs were found. However, of particular concern for introduction to the Reserves is the herbivorous giant African snail, *Achatina fulica*, which is widespread in Indonesia, including Timor. It occurs in many habitats including vegetated sandy soil at the beach margin, similar to that found on Ashmore. It is capable of aestivating during the dry season. It could survive on Ashmore and, by its presence, have a devastating effect on the vegetation and the ecology, including the re-establishment of native plants such as *Argusia argentea*.

This snail and others such as *Parglogenia* (family Camaenidae) are regularly intercepted in quarantine in Darwin on shipping containers from Timor. Although there is a risk of introduction by Indonesian fishing vessels, there is a much higher risk of translocation through the arrival of people such as illegal immigrants or equipment on the islands.

Asian house gecko

The Asian house gecko, *Hemidactylus frenatus,* was rare at Ashmore Reef in May 1995. It was neither seen nor heard at that time, and its presence was only detected in a Malaise trap on West Island. It is now widespread and abundant on West Island, but was not detected on either East or Middle Islands.

This species is easily spread through the activities of man, and it is most likely that this species originally arrived by boat from Indonesia. This gecko eats large numbers of insects and its presence has the potential to reduce the abundance and diversity of insects currently inhabiting the area and also decreases the chances of any newly introduced insects (both naturally and by man) becoming established. It is likely to be having a significant effect on the invertebrate fauna and this may be indicated by the small numbers of insects seen as well as the presence of very few abundant species. A study on the stomach contents of these geckos could determine the diversity of their prey.

The present abundance of this reptile on West Island probably precludes its eradication.

Rodents

Black rats introduced to West Island probably during the phosphate mining era were successfully eradicated in the 1980's, although fluctuating populations of the House mouse apparently persist on East and Middle Islands (Pike and Leach 1997). No evidence (animals, tracks or scats) of rodents was found during the present survey. However, one noddy (or tern) egg found on East Island showed evidence of predation (Appendix 3: Fig. 2). Damage is similar to that caused by birds such as silver gulls or crows. However, these birds are not present on Ashmore, and the observed damage may have been caused by a rodent. The re-introduction of rats to West Island remains a real threat, with black rats having been found on SIEVs.

Public access area

The insect fauna found in the public access area, the first point of contact of any potential invasive species, did not differ from the fauna found elsewhere within the Reserve area. The risks to public access area are more likely to be botanical rather than entomological, although the landing of equipment here and elsewhere increases the chances of introducing insects such as non-indigenous cockroaches, plant seeds, and other organisms such as reptiles and molluscs. The more equipment that is landed, the larger the risk.

Freshwater sources

Apart from the potential physical danger of well holes to both humans and animals, these, and the pump site on West Island, could possibly provide a source of water for mosquito larvae. The issue of mosquitoes is further discussed below under Quarantine.

As currently found, these sites do not present a physical danger, or provide a source for mosquitoes to breed in.

ACV and other Australian vessels

The presence of the black field cricket, *Teleogryllus oceanicus*, on the ACV *Holdfast Bay* as well on the *Aurelia IV* anchored in the inner lagoon in May 1995 (Brown 1999) demonstrates the risk of transporting insects to the islands from the Australian mainland. Black field crickets are considered to have become established after May 1995 (Brown 1999, Des Pike pers. comm.). The presence of a large nymph on West Island (Table 2 in Appendix 3) supports this. The large size of this cricket precludes it having been blown there.

Similarly, the presence of the arctiid moths, *Amata* sp., on board the ACV *Holdfast Bay* as well as HMAS *Wollongong* in May 1995 (Brown 1999) also indicates how easily insects may be transported to Ashmore Reef. The presence of a noctuid moth on the second night of anchoring may also indicate this, although noctuids are capable of flying long distances well beyond the 5.2 km to West Island from the ACV, and readily fly to lights. As the ACV *Holdfast Bay* was the only visible light from the islands at that time, it is not possible to determine if the moth originally came from the boat or the islands. There were no other insects found on the *Holdfast Bay* despite an extensive search. This was at least partially due to the cleanliness and the cold operating temperature in most parts of the boat.

The presence of cosmopolitan hide beetles, *Dermestes ater* (Brown 1999) and *Dermestes lardarius* on Ashmore Reef and the redlegged ham beetle, *Necrobia rufipes*, on Cartier Island are likely to have come from an Indonesian fishing vessel, as both feed on a variety of dried meats including dried fish, which are the principal catch on Indonesian fishing vessels.

Other animals

Apart from the animals discussed above, there were no other species found during this or previous surveys that are likely to pose an environmental risk to Ashmore Reef or Cartier Island. The continued presence by an Australian Customs vessel at Ashmore Reef will assist in minimising the risks of unnatural and accidental introductions by humans. However, as is outlined below, caution must be exerted when accessing these areas.

Quarantine risks to Australia

Several of the above issues illustrate the importance of quarantine for the islands. The threat of accidentally introducing insects and other organisms from Australia, from Indonesia and from elsewhere is a real one. This is particularly important if illegal arrivals continue to land there.

Because of the proximity of Ashmore Reef and Cartier Island to Indonesia, and the traffic between these reefs and the Australian mainland, there is also an increased quarantine risk to Australia, both from insects and other animals, as well as from the diseases they may carry or transmit. The increased number of people from more diverse parts of the world landing on the islands increases the risk of introducing exotic insects and diseases. It also increases the risk of these being spread from these people to AC personnel and thus to the Australian mainland. One clearly identifiable risk is the possibility of mosquito larvae breeding in drinking water and bilge water on Indonesian fishing boats. Adult mosquitoes transmit diseases such as dengue fever and malaria by biting an infected person and then biting an uninfected person. Mosquitoes biting Indonesian fishermen or illegal immigrants and then AC personnel could easily spread the disease to Australia. Of particular concern is Dengue fever, which is spread by the Dengue mosquito, *Aedes aegypti* (Linnaeus) (family Culicidae). Neither this disease nor the vector mosquitos are established in the Northern Territory, although both have the potential to become established in northern Australia. The NAQS survey (Curran 2003) identified a potential threat to Western Australia of introduction of the ginger ant from Ashmore islands, and also suggested a 'watching brief' on aphids, leafhoppers, thrips, borers and spiders.