Finding solutions

DERELICT FISHING GEAR AND OTHER MARINE DEBRIS IN NORTHERN AUSTRALIA

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DISCLAIMER
This report was prepared for the National Oceans Office and the Department of Environment and Heritage to assist with obtaining an overview of the marine debris issue in Northern Australia, and identify possible solutions. The views expressed in this report are not necessarily those of the Commonwealth. The Commonwealth does not accept responsibility for the contents of this report.

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Contents

Acronyms

AFMA	Australian Fisheries Management Authority
AIMS	Australian Institute of Marine Science
AMSA	Australian Maritime Safety Authority
ANZECC	Australian and New Zealand Environment and Conservation Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department of Environment and Heritage (formerly known as Environment Australia)
EA	Environment Australia (now known as the Department of Environment and Heritage)
EEZ	Exclusive economic zone
ESD	Ecologically sustainable development
FAO	Food and Agricultural Organisation
IMO	International Maritime Organisation
IUU fishing	Illegal, unregulated and unreported fishing
MARPOL	International Convention for the Prevention of Pollution from Ships 1973
MOU	Memorandum of Understanding
NOO	National Oceans Office
NPF	Northern prawn fleet/fishery
NT	Northern Territory
RAN	Royal Australian Navy
SPREP	South Pacific Regional Environment Program
WA	Western Australia
WWF	World Wide Fund for Nature Australia

Tables

Scope of the Report

This report was prepared by the Key Centre for Tropical Wildlife Management at Northern Territory University, for the National Oceans Office (NOO) and Department of Environment and Heritage (DEH), with input from Dhimurru Land Management Aboriginal Corporation (Dhimurru) and the World Wide Fund for Nature (WWF). It is intended to provide a basis for planning for the prevention and management of marine debris in the northern Australian marine environment - Arafura Sea and Gulf of Carpentaria (see Annex I).

This report is broadly aimed at policy makers, researchers, natural resource managers, industry, environment and Indigenous groups within Australia who have concerns about marine debris. It should also provide a foundation for future negotiations with neighbouring states in the management of the international dimension of the issue.

This report incorporates a comprehensive summary of existing knowledge on the sources, magnitude and impacts of marine debris. It details existing activities and identifies information gaps, and it provides a set of options for developing a strategic approach amongst key stakeholders towards the prevention and management of marine debris in the northern Australian marine environment. It builds upon the findings and recommendations of the Australian *Marine Debris Status Review (*ANZECC 1995, 1996a), and has been prepared principally through desktop research and consultation with key stakeholders and interests within Australia. Analysis and interpretation of existing (unpublished) data is also incorporated. The project has not involved any new primary research, or analysis of arrangements beyond Australian waters.

At its broadest definition, marine debris can include any human-generated waste that enters the marine environment, including leachates from landfill sites and spoil from dredging operations. For the purposes of this report, however, the primary concern is with solid debris that can be sourced to, or associated with, marine-based activities such as fishing and shipping.

Executive Summary

Magnitude of marine debris in the northern Australian marine environment

Northern Australia is especially vulnerable to marine debris given the proximity of intensive fishing operations, difficulties in surveillance and enforcement of existing management arrangements, and ocean circulation patterns that are likely to concentrate floating debris before dumping it on the coast.

The amounts, characteristics and impacts of debris disposed of or lost overboard in the Arafura Sea are largely unknown. A small number of marine debris surveys have been undertaken along northern Australia's coasts and, although they are not yet able to show the precise magnitude of marine debris concerns in the region, they are sufficient to indicate that the impacts of marine debris, whether environmental, economic, cultural or aesthetic, are considerable. They demonstrate that the issue of marine debris spans geographical, cultural, and jurisdictional boundaries, and they suggest that the amount of debris washing ashore in northern Australia is as high as, if not higher than, any other area in Australia or the South-east Asian region.

Areas in northern Australia where debris has been observed at very high densities are mostly sandy shorelines in the following areas:

- north-west corner of the Gulf of Carpentaria – Wessel Islands, the English Companys Islands (especially Wigram and Truant Islands), Gove Peninsula;
- Groote Eylandt and the adjacent mainland coast;
- Sir Edward Pellew Group of islands and adjacent mainland coast;
- Karumba in the southern Gulf of Carpentaria;
- Weipa in the north-east Gulf of Carpentaria;
- Fog Bay near Darwin;
- north-west coastline of Bathurst Island;
- northern coast of Arnhem Land between Maningrida and Milingimbi including the Crocodile Islands.

All areas tend to report an increase in accumulation rates of debris on beaches after wet season storms. However, during the dry season when winds are predominantly south-easterly, south-east facing coastlines generally report periods of higher debris accumulation, while north-west facing coastlines report high debris accumulation during the wet season when the wind direction is reversed.

Despite the large quantities of debris found washed ashore in northern Australia, survey results almost certainly under-represent the actual amounts of marine debris in coastal waters. Many items will never float ashore. Many, particularly nets, become entangled underwater on rocky outcrops and reefs, and marine debris onshore can be washed back out to sea during high winds and tides.

Composition and source of marine debris in the northern Australian marine environment

While it is difficult to conclusively assign origin to all items that wash ashore, the majority of marine debris on northern Australia's coasts is likely to originate from marine sources. Plastics are reported in all locations where debris is reported to accumulate in northern Australia, generally comprising more than 50% and up to 90% of all items observed. Many items washing ashore in north-east Arnhem Land have also been identified as of foreign origin, predominantly Indonesian (68%), Taiwanese (8%), and Chinese (8%). Items manufactured in Australia were found to comprise around 9% of all debris that could be identified, while items manufactured as far afield as Mexico, USA, Spain, Italy, Austria, Germany and Belgium have also been observed.

Other than commercial fishing vessels, other sources of marine-based debris in northern Australia potentially include recreational boats, cargo ships, coastal barges, surveillance vessels, offshore oil platforms, rigs and supply vessels, passenger cruise ships and research vessels. However, fishing debris tends to be the most widely reported type of debris and the debris type of greatest concern to coastal communities in northern Australia.

Coastal surveys of the north-west coast of the Gulf of Carpentaria indicate that a very high number of fishing nets are washing ashore. While they comprise only a small proportion of debris items overall, they are the most significant item by weight and potential impact. Preliminary analysis of fishing nets found at Cape Arnhem on the north-west coast of the Gulf of Carpentaria suggests that foreign fishing nets of South-east Asian manufacture are likely to comprise the greatest proportion (around 80%) of all nets washing ashore. Taiwanese manufactured nets account for 26 – 39% of all nets identified, while Indonesian and Japanese manufactured nets account for 17% and up to 11% of identified nets respectively. Prawn trawl and gill nets of the type used by Australian fishing fleets account for around 12% of identified nets. Nets of South-east Asian origin washing ashore in north-east Arnhem Land tend to be of larger mesh size, and of much greater area and weight than Australian prawn trawl nets that wash ashore there. Foreign manufactured nets (notably Taiwanese, Indonesian and Japanese trawl and drift nets) are also causing some of the greatest harm to marine animals, especially turtles.

Both recreational and commercial fisheries, including aquaculture operations, are also believed to be responsible for debris other than nets (such as general waste, fishing net floats, sorting and settlement baskets, crates, buckets, hand reels, light globes, ropes and gloves, and fishing line) in northern Australian waters. Cargo ships are also likely to be responsible for the loss and disposal of a significant proportion of waste found washed ashore.

Impacts of marine debris in northern Australia

The environmental and physical effects of debris (whether marine or land sourced) may be broadly classified as aesthetic, ecological (impacts on marine organisms and their habitats), economic, public safety and social/cultural.

Since 1996, 205 stranded turtles have been recorded at Cape Arnhem alone, including four marine turtle species listed as endangered or vulnerable under Australian legislation. While it is not possible to accurately compare the impact of active fishing effort and that of derelict fishing gear on marine turtles, fishing debris appears likely to pose a threat of at least a similar order to that posed by prawn trawling prior to the introduction of Turtle Exclusion Devices.

Other than turtles, many other protected species such as whales, dugong, and sawfish have been recorded entangled in fishing debris along other areas of the coastline. Of all debris types responsible for the death and injury of marine wildlife in northern Australia, fishing nets likely to originate from Taiwan, Indonesia and Japan have been responsible for entangling the majority of marine wildlife in northern Australia. There are no known records of wildlife entanglements due to trawl netting of the type used by Australian vessels. Given the quantities of debris washing ashore in northern Australia and the substantial numbers of animals found entangled during highly localised surveys, the number of animals injured and killed by debris in northern Australia is potentially large.

Anecdotal reports suggest that the navigational hazard posed by marine debris in northern Australian waters is significant and increasing. Debris, especially derelict fishing nets, has resulted in the entanglement of rudders and propellers of marine vessels, and there have been reports of smaller items clogging cooling water intakes, causing engine failure. Debris is also a hazard to beach-goers, especially children playing on remote beaches on Cape York who, amongst other things, have been cut badly by broken glass from large numbers of light globes and fluorescent tubes washed ashore there. Hundreds of, often full, rusty gas cylinders, and other potentially hazardous substances such as sump oil, detergents, and fuels are causing considerable concern. The high cost of clean-up operations for polluted beaches is prohibitive for many remote coastal communities, and the tonnes of fishing gear found washed ashore in some areas have resulted in public antagonism towards the fishing industry as a whole.

Executive Summary

Legislative framework and existing marine debris activities

The International Convention for the Prevention of Pollution from Ships 1973 (MARPOL), particularly Annex V of the agreement, is the principal international mechanism regulating at-sea disposal of waste. A range of other legislation, applying at various scales, contains provisions that seek to limit the discharge and impact of persistent debris, especially plastics, in the marine environment. To date, environment and transport agencies have had the principal role in the management of marine debris issues. Fisheries agencies have had a lesser role in the prevention and management of marine debris, and fisheries legislation does not currently allow for direct control of fisheries-generated waste. To date, there have been only two successful prosecutions by Australian authorities for violations of garbage dumping regulations in Australian waters.

Marine debris has a relatively high profile within Australia, as indicated by the range of marine debris focused activities and programs undertaken in recent years. Information on marine debris in the Arafura Sea has generally been provided through community clean-ups and surveys, and limited additional research across small areas of the northern Australian coastline. While these activities have raised awareness of the problem, they have often been ad hoc, isolated, and not sufficiently comparable to enable comprehensive and robust analysis of trends or patterns in data.

Options to address marine debris in the Arafura Sea

Marine debris is a complex issue that requires development of integrated, collaborative solutions among different sectors and across institutional and jurisdictional boundaries. There is a critical need for detailed information on where marine debris in the Arafura Sea comes from, who is responsible for it, why it occurs, what materials are being lost and dumped, and how best to alter the practice of those who are contributing to the problem. Marine debris is principally the result of human behaviour such as littering and dumping. Marine debris is therefore largely a social issue, requiring carefully targeted socio-economic solutions, although good research and monitoring, and investigation of the potential for new technologies in the manufacture and recycling of fishing gear and other items should also be considered.

As a priority and important first step, a mechanism that enables and enhances discussion, coordination and sharing of information on marine debris amongst stakeholders and interested groups should be established. This mechanism will be important in identifying priority actions, responsibilities and funding sources that will assist in the prevention and management of marine debris. Future discussions amongst key stakeholders will be critical in developing a collaborative and strategic approach to this problem. While the scope of this report has not allowed time to develop a comprehensive rationale and prioritisation of options, important activities for further consideration should include:

- Analysis of ocean circulation, wind and drift patterns in the Arafura Sea with a specific focus on identifying accumulation areas of marine debris (Option 1a)
- Development of a network of permanent land-based marine debris monitoring sites involving local communities (Option 3)
- Development of consistent, statistically rigorous data collection protocols and survey methodology for use by different sectors on land and at sea (Option 4)
- Identification of all fisheries (both legal and illegal) operating throughout the Arafura Sea region incorporating analysis, where possible, of gear used, effort, target species, management arrangements, markets, and operational structure (ownership, administration, licensing) (Option 7a)
- Identification of the socio-economic and technical factors influencing the loss and disposal of waste (especially fishing nets) within fisheries likely to be contributing to marine debris (Option 7b)
- Verification of the source of derelict fishing nets in the Arafura Sea through collaboration with surveillance operations in the retrieval of fishing nets and associated information from apprehended vessels (Option 8)
- Clarification of government responsibilities in regard to the management and retrieval of hazardous debris, and establishment of a mechanism to facilitate coordination of national and regional responses to marine debris issues (Option 19)
- Determination of the capacity of ports throughout the Arafura Sea region to handle vessel-sourced waste, particularly derelict fishing gear (Option 21)
- Investigation of the viability of fishing gear tagging, coding and marking to aid identification of the source of marine debris (Option 22)
- Investigation of the viability and potential effectiveness of the introduction of fishing gear repair, reuse and recycling initiatives at key ports throughout the Arafura Sea region (Option 24)

*NOTE – Options are outlined in more detail in Section 6, page 34

1. Introduction

'If one stops to think of it, except for the small amount of plastics incinerated, every little bit of plastic manufactured in the world for the last 50 years or so, still remains in the environment somewhere. It's either in the landfill or it's somewhere in the ocean…' (Andrady, 2000: 142).

Until recently, many viewed oceans as a vast reservoir with an unlimited capacity to assimilate waste. This view is now changing, as marine pollution of many kinds is becoming an issue of global proportions. Marine debris is generally defined as any manufactured or processed solid waste material (typically inert) that enters the environment from any source (Coe and Rogers, 1997). Around seven billion tonnes of debris are estimated to enter our oceans annually (Faris and Hart, 1995), and such debris is now classified as one of the world's five major marine pollutants (ANZECC, 1995). Most synthetic marine debris is durable and therefore accumulates in marine 'sinks' for a considerable period of time. Consequently, in the absence of efforts to control and manage it, the issue of marine debris will only get worse.

Five international conferences have been convened since 1985 to address the issue of marine debris and derelict fishing gear (Shomura and Yoshida, 1985; Alverson and June, 1988; Shomura and Godfrey, 1990; Faris and Hart, 1995; McIntosh, et al., 2000), and numerous studies around the world are beginning to document the impact of synthetic waste on marine environments, species and coastal communities.

Northern Australia is especially vulnerable to marine debris given the proximity of intensive fishing operations, difficulties in surveillance and enforcement of existing management arrangements, and ocean circulation patterns that are likely to concentrate floating debris before dumping it on coastlines and beaches. Northern Australia's coastal environment also supports some of the last remaining global strongholds of species of special interest and concern, such as marine turtles, that are especially prone to entanglement in, or ingestion of, debris (Balazs, 1985; Chan, et al., 1988; Bjorndal, et al., 1994; Chatto, 1995; Laist 1997; Starbird, 2000; Barreiros and Barcelos, 2001; Bugoni, et al., 2001; Tomas, et al., 2002).

The impacts of marine debris in the Arafura Sea region are potentially considerable, whether environmental, economic, cultural or aesthetic, and they span geographical and jurisdictional boundaries. Many people share a concern about the impacts of debris and the threats posed to public safety, navigation, the tourism and fishing industries, and marine habitats and wildlife. Traditional Aboriginal owners of the northern Australian coastline are particularly concerned about the impacts of debris on animals and landscapes for which they have long held cultural and totemic responsibilities, as well as the resources they continue to value for food and cultural purposes (Kennett, et al., 1998).

This report presents a summary of existing information on the sources, magnitude and impacts of marine debris in northern Australia's marine and coastal environment. It details current management arrangements and existing activities relevant to the issue of marine debris, and presents an array of options aimed at finding solutions to the issue of marine debris in the Arafura Sea.

1.1 Aim

To identify options for developing a collaborative, strategic response to marine debris, especially derelict fishing gear, in northern Australia's marine environment.

1.2 Geographic scope

This report focuses primarily on the coastal and marine environment of northern Australia bounded by the Western Australian and Northern Territory borders to the west and the Torres Strait to the east, and includes the waters of the Gulf of Carpentaria and the Arafura Sea.

The Arafura Sea covers a region of significant ecological, economic, social and cultural value with respect to marine living resources, protected species, biodiversity and mineral wealth. Australia, Papua New Guinea, East Timor and Indonesia share both legal jurisdiction of these waters and obligation to achieve ecologically sustainable development of resources. The four nations derive benefits from the fishing, oil and gas, tourism, shipping, mining, aquaculture and other industries active throughout the region, and many Indigenous communities populating the coastline continue to value marine species for food and cultural purposes. The four nations surrounding the Arafura Sea also share ecologically similar marine and coastal environments, significant populations of protected species and significant habitats, as well as concerns about unsustainable resource exploitation and the impacts of marine pollution, including marine debris.

1. Introduction

Much of the land surrounding the Arafura Sea, especially in northern Australia, is very remote and sparsely populated: less than 1% of Australia's population lives in a small number of town centres and smaller townships on a coastline that stretches more than 4600km across the Northern Territory and northern Queensland (Table 1). Over 70% of the coastline in the Northern Territory and northern Queensland is also held under Aboriginal ownership and many Aboriginal communities continue to use coastal resources for subsistence and other customary purposes (Munungurritj 1998; Yunupingu 1998).

Table 1. Population of larger town centres and regions along the northern Australian coastline (ABS, 2002)

Town or regional Centre	Population
Torres Strait	9698
Weipa	2200
Kowanyama	672
Aurukun	1032
Burketown	1431
Carpentaria	4844
Karumba	550
Mornington Is.	942
Numbulwar	500
Gulf	3482
Nhulunbuy	3804
Groote Eylandt	2426
Darwin region	109419
Tiwi Islands	2236
TOTAL	143 236

Large-scale wind and water dynamics and seasonal changes, as well as small-scale water movements and coastal processes, influence the fate of marine debris in the Arafura Sea region. While oceanographic and satellite data have improved understanding of ocean circulation and marine water dynamics in many parts of the world, there is still only very limited understanding of the patterns of water movement throughout the Arafura Sea and Gulf of Carpentaria.

The Gulf of Carpentaria is a semi-enclosed body of water that covers an area of approx 193 000 km², with a maximum depth of less than 70 m (Torgersen, et al., 1983; Wolanski, 1993, Somers and Long, 1994). Depth in coastal waters increases only gradually, on average by about 1 m every 1 km, creating a shallow coastal zone up to 20 km wide along much of the Gulf coast. The boundary between the Gulf and the Arafura Sea is around 50 m deep and 200 km wide, and it lies between Cape Wessel and West Papua. The Gulf of Carpentaria and Arafura Sea are connected with the Coral Sea and the Pacific Ocean through the Torres Strait, a very shallow (approx. 10 m), narrow (100 km wide) passage, scattered with numerous islands and reefs that restrict water movements (Wolanski, 1993).

A major ocean current in the region is the South Equatorial Current that flows westwards from the Pacific Ocean through the Arafura Sea to the Indian Ocean. There is a slow, predominantly clockwise circulation of water around the margins of the Gulf, with water driven into it from the east and an outflow to the west. However currents in the Gulf of Carpentaria tend to be variable and generally reverse seasonally in response to monsoonal wind changes (Forbes and Church, 1983). As a consequence, where floating debris enters waters to Australia's north it is likely be swept eastward between Australia and Indonesia during the monsoon, and westward with the south-east trade winds during the dry season (Forbes and Church 1983; Wolanski 1993).

Northern Australia's tidal range varies, but is generally high to moderate, while mean wave energy is low to moderate except during tropical cyclones. Tides are mostly semi-diurnal between the WA and NT border to Cape Arnhem, but are predominantly diurnal throughout the Gulf of Carpentaria and Island groups (Laughlin, 1997). Coastal relief across northern Australia is generally low with mangrove fringes, extensive tidal flats, and sandy shores.

The region provides critical breeding and feeding habitat to a large number of protected marine species (Annex II). In particular, many protected species that are particularly prone to entanglement in debris breed and feed throughout the Gulf of Carpentaria and Arafura Sea. Turtles breed in substantial numbers throughout the region (Chatto, 1998), Gulf of Carpentaria waters are believed to support one of the last global strongholds of dugongs (Marsh, et al., 2000), and numerous dolphin and whale species have been recorded (Living Planet Analysis, 1993; Chatto and Warneke, 2000; Marsh, et al., 2000).

There are few coastal developments or activities (principally small-scale tourism, aquaculture, mining, recreational and charter fisheries), and much of the marine environment is thought to remain in a relatively natural and healthy condition (Hanley and Couriel, 1992; Morrison and Delaney, 1996). However, commercial shipping and offshore fishing fleets are expanding, and the impacts of their operations are becoming widely apparent (Morrison and Delaney, 1996). Large areas of the Arafura Sea and its coastline are being swamped by tonnes of plastics, metals, rubber and derelict fishing gear (Sloan, et al., 1998; Whiting, 1998; Kiessling and Hamilton, 2001, 2003; Roeger, 2002; White, in prep.).

2. Sources, composition and magnitude of marine debris in the coastal and marine environments of northern Australia

Our current understanding of the sources, magnitude and composition of marine debris in northern Australia has been derived primarily from land-based coastal surveys. Few data are available on debris floating in the sea or present on the seabed. As a consequence, existing survey results almost certainly under-represent the actual quantity of marine debris in northern Australia's marine and coastal environments. Obtaining better data will require a systematic, comprehensive effort involving cooperation among many nations. In the meantime, existing survey results and anecdotal reports are beginning to provide a useful perspective on the areas, species and people most heavily impacted by marine debris.

It should be noted that, in the interests of ensuring a comprehensive overview, a number of summaries of unpublished observations and other unpublished data from a variety of sources have been included in this report. It was not possible for the author to verify personally the accuracy of all of these reports. It is therefore possible that some quantitative detail may require revision when analysis and publication by those informants is complete. However, interpretation has invariably been conservative and conclusions drawn based on the cumulative weight of evidence from a number of reliable (preferably published) information sources.

2.1 Magnitude of debris in the northern Australian marine environment

Past and contemporary legal and policy arrangements do not appear to have prevented the development of a substantial marine debris problem in Australian waters. However, as plastics are highly durable and therefore very long-lived, it is generally very difficult to distinguish those items that recently entered the marine environment from those that have been circulating for months or years.

The fate and movement of debris after it enters the marine environment depends on a number of factors. These include whether it is loose or bagged, and the particular physical and chemical characteristics (especially the density) of the solids (National Research Council, 1995). For example, large, dense items such as glass bottles and metal items tend to sink, while small, light items may remain suspended in the water column or float, often for some time. Debris also has variable retention times in coastal areas depending on several factors including oceanic currents and wind patterns. According to studies undertaken overseas, debris may lodge on exposed beaches for as little as several days up to more than a year before drifting laterally along the coastline or washing back out to sea (National Research Council, 1995). In more protected areas, debris can accumulate indefinitely and be buried in coastal sediments (Gregory, 1999a). Anecdotal reports suggest that along the east coast of the Gulf of Carpentaria the same derelict nets have been washing ashore during the dry season and then washing back out to sea each wet season for the last 10-15 years (Wallin, pers. comm., 2003).

A review of marine debris surveys indicates that parts of the northern Australian coastline are 'hotspot' areas for marine (particularly marine-sourced) debris, and that the amount of debris washing ashore in northern Australia is as high as, if not higher than, any other area in Australia or the region (Table 2). Possibly due to the high density of heavy fishing nets, the average weight of all items washing ashore also tends to be far higher in northern Australia than other areas. Other parts of Australia and the Arafura Sea region where marine debris densities compare with those recorded in northern Australia include the south-west coast of Tasmania, which receives huge quantities of accumulated debris from the Southern Ocean, and highly urbanised areas of the Indonesian archipelago (Table 2). For example, between 902 and 2632 items/km have been recorded at Cape Arnhem, NT (Table 2). Around Tasmania between 282 and 603 items/km have been recorded, and in parts of Indonesia between 507 and 1825 items/km have been documented (Table 2). In contrast surveys in other parts of Australia have recorded between 8 and 455 items/km (Table 2).

Despite the large quantities of debris found washed ashore in northern Australia, survey results almost certainly under-represent the actual amounts of marine debris in coastal waters. Many items will never float ashore. Many items, particularly nets, become entangled underwater on rocky outcrops and reefs. Marine debris onshore can also be washed back out to sea during high winds and tides.

Specific areas along the northern Australian coastline where debris has been observed at very high densities include:

- The north-west corner of the Gulf of Carpentaria - Wessel Islands, the English Companys Islands (especially Wigram and Truant Islands), Gove Peninsula.
- Groote Eylandt and the adjacent mainland coast.
- The Sir Edward Pellew Group of islands and adjacent mainland coast.

- Karumba in the southern Gulf of Carpentaria.
- Weipa in the north-east Gulf of Carpentaria.
- Fog Bay near Darwin.
- The north-west coastline of Bathurst Island.
- The northern coast of Arnhem Land between Maningrida and Milingimbi including the Crocodile Islands.

(Sloan, et al., 1998; Whiting, 1998; Roeger, 2002; Kiessling and Hamilton, 2001, 2003; White, in prep; WWF, unpublished data; Chatto pers. comm., 2003; Limpus, pers. comm., 2003; Nolan, pers. comm., 2003; Yibarbuk, pers. comm., 2003)

Preliminary analysis suggests that onshore 'hotspot' areas tend to be exposed sandy shorelines. South-east facing coastlines report periods of high debris accumulation during the dry season when winds are predominantly south-easterly, while north-west facing coastlines report high debris accumulation during the wet season when the wind direction is reversed. All areas tend to report an increase in accumulation rates of debris on beaches after wet season storms (Sloan, et al., 1998; Whiting, 1998; Roeger, 2002; Kiessling and Hamilton, 2001, 2003; White, in prep.; WWF, unpublished data; Chatto pers. comm., 2003; Limpus, pers. comm., 2003; Nolan, pers. comm., 2003; Yibarbuk, pers. comm., 2003).

Plastics are reported in all locations where debris is reported to accumulate, although derelict fishing nets are the item of most concern amongst coastal communities (WWF unpublished data, Chatto pers. comm., 2003; Munungurritj, pers. comm., 2003; Yibarbuk, pers. comm., 2003). Not surprisingly, general food packaging and recreational fishing litter are reported to occur in the greatest densities near popular recreational fishing locations (eg Fog Bay, McArthur River) (Whiting, 1998; WWF unpublished data). Commercial fishing debris (notably derelict fishing nets) comprises the greatest proportion of debris reported at Weipa, Groote Eylandt, Gove Peninsula, the English Companys Islands and the Wessel Islands (Sloan, et al., 1998; Whiting, 1998; Alderman, et al., 1999; WWF unpublished data).

2.2 Composition and source of debris in the northern Australian marine environment

Information about the composition and sources of marine debris in the Arafura Sea is important in identifying where efforts at finding solutions should be directed. Both the composition and source of marine debris varies considerably depending on where it is found (Table 2). Close to population centres for example, debris will often comprise around 75-80% urban litter, and typically consist of food packaging, plastic shopping bags and six pack rings that have reached beaches via streams and drains (O'Callaghan, 1993; Gregory and Ryan, 1997; Wace, 1994, 1995). In contrast, litter accumulating on coastlines distant from urban centres is more likely to originate from marine sources such as fishing vessels and cargo ships (Slip and Burton, 1991; Sloan, et al., 1998; Whiting, 1998).

An estimate of the amount of debris generated by marine activities and vessels in Australia was done by ANZECC through the Marine Debris Status Review (ANZECC, 1996a). On the basis of the findings of this Review, it was estimated that across Australian waters each year:

- around 13 800 tonnes of waste is generated aboard ships
- around 2 400 tonnes of fishing gear is lost or discarded
- only around 9 800 tonnes of debris are recovered over berths and disposal to landfills, so that
- up to 6 500 tonnes of waste per year is lost or discarded overboard.

The amounts and precise characteristics of debris thrown or lost overboard in the Arafura Sea are unknown. Waste generated by marine activities is difficult to isolate from shore-based litter as it is often very similar and can persist in the marine environment for many years, drifting far from where it entered. Similarly, quantities of debris landed ashore by vessels for disposal is unknown as ports in northern Australia do not tend to keep records of waste volumes and often the task of collection and disposal of waste is subcontracted to private operators (Scanlon, pers. comm., 2003).

A small number of marine debris surveys have been undertaken along northern Australia's coasts. The results of several of these surveys have not been documented (eg Beachwatch, 1994), while others are not yet widely available. Only one study (Whiting, 1998) has been published within the scientific literature. While these studies provide a good basis for better understanding the scope and magnitude of marine debris in northern Australia, the lack of comprehensive, consistent and long-term information is a significant constraint to effective monitoring and management of the issue.

Based on available information, plastics dominate the debris found on beaches in northern Australia, generally comprising more than 50% and up to 90% of all items observed (Table 2). This is consistent with surveys conducted elsewhere in the Arafura Sea region and around Australia (Table 2). While many materials in marine debris are persistent (such as glass, metals, foam, and even timber and cloth), plastic is of primary concern as it tends to be the most abundant debris type (by number and weight) found on beaches and in sediments (Table 2), and it tends to have some of the most obvious and pervasive impacts on marine species (Section 3.1).

Table 2. Summary of selected marine debris surveys around Australia and Indonesia (after Kiessling and Hamilton, 2001; Kiessling and Rayns, 2001)

Location	*Period over which survey was under-taken*	*Duration of survey*	*Total amount of debris*	*Total survey length/ area*	*Total debris (items and weight)*	*Total no. and proportion of plastic items (incl. fishing nets)*	*Total fish-ing items recorded*	*Proportion of marine sourced items*	*Proportion of land sourced items*	*Reference*
Groote Eylandt, NT	14 Dec 1997-1 June 1998	31 Days	1140 items 61806 kg	137km	8.3 items per km 451kg	≥ 1026 items ≥ 90%	≥ 812 items ≥ 90% 55918 kg	≥ 1026 items ≥ 90% ≥ 55918 kg	? items ≤ 10% ≤ 5888 kg	Sloan, et al., 1998
Fog Bay, NT	June 1996 and June 1997	*	596 items ? kg	4km	141 items per km ? kg	192 items 32%	107 items >18% ? kg	507 items 85% ? kg	89 items 15% ? kg	Whiting, 1998
North-east Arnhem Land, NT	July 1999	24 hrs (over 3 days	>727 items ? kg	100m	>727 items/ 100m ? kg	> 446 items > 62%	≥ 100 items 14% ? kg	Majority	*	Alderman, et al., 1999
Cape Arnhem, NT	10-20 July 2000	10 days	7561 items >3880 kg	8.25km	916 items per km >470kg	4295 items 57%	2027 items 27% 1040 kg	<7553 items <99% <3875 kg	>8 items >1% >5 kg	Kiessling and Hamilton, 2001
Cape Arnhem, NT	24 July - 2 August 2001	10 days	21 714 items >1074 kg (excl. nets)	8.25km	2 632 items per km >130 kg (ex-cluding nets)	16 133 items 74%	6255 items 29% 1040 kg	>21397 items >99% >1074 kg	<317 items <1% ? kg	Kiessling and Hamilton, 2003
Cape Arnhem, NT	30 July – 4 August 2002	5 days	7443 items 1546 kg	8.25km	902 items per km 187 kg	6022 items 81%	*	*	*	White, in prep.
Groote Eylandt, NT (8 Mile & Salt Lake beaches)	27-28 August 2002	2 days	1 603 items ? kg	4.95km	324 items per km ? kg	1226 items 76%	*	*	*	
Groote Eylandt, NT (South Point)	8-10 October 2002	3 days	2597 items 942 kg	4.81km	540 items per km 196 kg	2372 items 91%	*	*	*	
Elcho Island, NT	1-2 October 2002	2 days	425 items 767 kg	3.25km	132 items per km 238 kg	333 items 78%	*	*	*	
Deep Water National Park, Qld	Nov 1992	*	500 items 8.4 kg	1.1 km	455 items per km 7.6 kg	*	*	Majority	*	Woodall, 1993
Far North Great Barrier Reef, Qld	June 1996	*	2262 items ? kg	21.4km	106 items per km ? kg	980 items 43%	≥ 57 items 0.05 % ? kg	*	*	Haynes, 1997
Marmion Park, WA	July 1985	22 days	2189 items 43.5 kg	800m	274 items/100m 5.4 kg/100m	Approx 28%	791 items 36% 14 kg	791 items 32% 14 kg	1398 items 64% 29.46 kg	Cary, et al., 1987
Marmion Park, WA	6-8 July 1992	2 days	2833 items 98.45 kg	800m	354 items/100m 12.3 kg/100m	*	1161 items 41% ? kg	1161 items 41% ? kg	1672 items 59% ? kg	Edwards, et al., 1992
Kanidal Beach, WA	Between 5 Dec1990-30 Oct 1992	12 days	660 items ? kg	1km	≤ 202 items per km ? kg	*	≤ 202 items ? kg	Majority	*	RAOU, 1996
Far North Coast, NSW	On 28 May, 25 June, 6 Aug, 27 Aug, and 23 Sep 1994	5 days	249 items ? kg	22.8km²	11 items/km² ? kg	116 items 47%	> 18 items > 7%	174 items 70% ? kg	75 items 30% ? kg	Frost and Cullen, 1997
Robe, Long Beach, SA	28 – 29 August 1998	2 days	417 items 198.5 kg (excl. wood)	12km	35 items per km 18 kg	141.45kg 71%	?items 31% 61kg	*	*	Edyvane, 1998
Coastal Tas	1990-1993	4 year period	112,939 items ? kg	400km	282 items per km ? kg	? items 74%	25,976 items 23% ? kg	≥25976 items ≥ 23% ? kg	≥ 304935 items ≥ 27% ? kg	Sustainable Development Advisory Council, 1996
Coastal Tas	Jan 1990 and June 1991	18 month period	50 211 items ?kg	177km	300 items per km ? kg	*	10 042 items 20% ? kg	35 097 items 70% ? kg	15 114 items 30% ? kg	Slater, 1991
Southwest Tas	10-15 Jan 1999	4 days	4824 items 3 500 kg	8 km	603 items per km 438 kg	4 287 items 89%	>2 949 items 61% ? kg	*	*	Pryor, 1999
Macquarie Island, Tas	1989	6 month period	182 items ? kg	40km	9 items per km ? kg	132 items 73%	2 items 29% ? kg	182 items 100% ? kg	Nil	Slip and Burton, 1991
Heard Island, Commonwealth Territory	1988	12 month period	317 items ? kg	24.3km	13 items per km ? kg	161 items 51%	5 items 40% ? kg	316 items 100% ? kg	Nil	
Thousand Islands Jakarta Bay, Indonesia	11-20 Sept 1995	10 days	33,903 items ? kg	490km²	69 items/km² ? kg	~12 641 items 37%	≥ 393 items ≥ 1.2% ? kg	*	*	Willoughby, et al., 1997
Hamadi Beach Yofeta Bay, Indonesia	1990?	1 day	507 items ? kg	1km	507 items per km ? kg	243 items 48%	< 10 %	< 10 % < 51 items ? kg	> 90 % > 1643 items ? kg	Nash, 1992
Holtekang Yofeta Bay, Indonesia	1990?	1 day	1825 items ? kg	1km	1825 items per km ? kg	1 107 items 61%	< 10 %	< 10 % < 182 items ? kg	> 90% > 1643 items ? kg	

* Information not available

2. Sources, composition and magnitude of marine debris in the coastal and marine environments of northern Australia

While it is difficult to conclusively assign origin to all items, the majority of marine debris washing ashore on northern Australia's coasts is highly durable synthetic debris that is most likely to originate from marine sources (Table 2). This proposition is supported by the remoteness of the majority of the coastline (and especially the observed 'hotspot' sites) from urban areas, sparse human population, and the substantial proportion of debris items that may be directly attributed to marine-based activities. For example, of the 25 types of debris defined by the US-based organisation Ocean Conservancy as indicators of maritime sourced debris in US waters (ANZECC, 1996a), 18 are found on the northern Australian coastline and comprise the greatest majority of items surveyed by both weight and number (Sloan, et al., 1998; Whiting, 1998; Alderman, et al., 1999; Kiessling and Hamilton, 2001, 2003).

Based on the findings of two surveys conducted at Cape Arnhem (north-east Arnhem Land), it has been possible to identify a proportion of items (21%) washing ashore as being of foreign origin (Table 3). Of this proportion of identified items, South-east Asian manufactured items (including fishing nets) comprise the greatest proportion of all debris surveyed, with most originating from Indonesia (68%), Taiwan (8%), and China (8%). Items manufactured in Australia (but possibly including components sourced from other nations) were found to comprise around 9% of all debris that could be identified. Items manufactured as far afield as Mexico, USA, Spain, Italy, Austria, Germany and Belgium have also been reported (Table 3).

Table 3. Proportion and number of all debris (including fishing nets) identified to country of manufacture from coastal surveys at Cape Arnhem, Northern Territory (2000 – 2001) (Kiessling and Hamilton, 2001, 2003)

Manufacturing origin	Number of items	Proportion (of items of known origin)
Indonesia	3525	68%
Taiwan	415	8%
China	398	8%
Singapore	345	7%
Japan	335	6%
Philippines	78	1%
Malaysia	69	1%
Thailand	26	0.5%
Korea	20	0.3%
Vietnam	6	0.1%
Papua New Guinea	2	<0.1%
South-east Asia	5219	87%
Australia	563	9%
Other (eg. Mexico, New Zealand, Germany, Spain, Italy, USA, Austria, Belgium)	226	4%
TOTAL items known manufacturing origin	6008	21% (of total items surveyed)
TOTAL items of unknown manufacturing origin	23 267	79% (of total items surveyed)

Under international law, all vessels over 400 tonnes are required to develop a waste management plan for collecting, storing, processing and disposing of waste. They are also required to be fitted with compactors and incinerators, and to record details of garbage incineration or disposal in a garbage log with any receipts from port disposal facilities (MARPOL, Annex V; see Section 4). Most vessels operating in northern Australian waters are smaller than 400 tonnes (Gillies, pers. comm., 2003) and are therefore not required to log waste management details, though they are required to display placards detailing waste regulations and requirements in full view of crew and/or passengers (MARPOL, Annex V). Many smaller vessels also use onboard incinerators to dispose of the large amount of waste that accumulates during long sea voyages (Gillies, pers. comm., 2003).

Partially burnt waste, described as incinerator residues, has been observed on remote coastlines in other parts of the world (Torres, et al., 1997; Gregory, 1999b). On at least one occasion, observers have noted dumping of burnt rubbish residues by a fishing crew in Australian waters (ANZECC, 1996a), and clumps of burnt rubber have been found during surveys in north-east Arnhem Land (Kiessling and Hamilton, 2001). Burning is also a method used by many northern Australian communities to remove waste, especially large derelict fishing nets, from beaches (Limpus, pers. comm., 2003; Munungurritj, pers. comm., 2003; Wallin pers. comm., 2003)

In addition to commercial fishing vessels, other sources of marine-based debris in northern Australia potentially include recreational boats, cargo ships, coastal barges, surveillance vessels, offshore oil platforms, rigs and supply vessels, passenger cruise ships and research vessels. Considerable amounts of waste are likely to be generated by most, if not all, of these fleet types, but a complex range of factors must be considered in identifying which fleets pose the greatest challenges in terms of marine debris management. Key factors include amounts of garbage, numbers of vessels, duration of voyages, types of garbage, and the sophistication of waste management regimes employed by the sector and by individual vessels/crew. The following section addresses each fleet type in regard to its potential contribution to marine debris in the Arafura Sea.

2.2.1 Commercial fisheries

Early fishing gear was made from natural fibres such as cotton, hemp or flax (Jones, 1994). However, with the introduction of plastics after World War II, the fishing industry replaced organic net materials with synthetics (Faris and Hart, 1995; Minton, 2000). The preferred materials for nets now tend to be polyethylenes and polypropylenes which float, and nylon monofilament line which sinks. Modern fishing gear constructed of these synthetic fibres is cheaper, more durable, lighter, stronger, and more efficient than most traditional gear, and fisheries operations now comprise the most significant input of debris to the world's oceans from marine sources (Faris and Hart, 1995; Minton, 2000).

Derelict fishing gear occurs in a number of ways – either inadvertently during the course of normal operations (due to storms, entanglements on reefs and rocks, and other mishaps), or through deliberate disposal (Minton, 2000). As many modern synthetic nets are relatively inexpensive, there may also be an economic incentive for fishermen to discard damaged or worn nets and line rather than invest time and energy in repairing them (Mounsey, pers. comm., 2002). The abandonment of illegal gear types (eg drift nets) is another source of derelict fishing gear. For example, a drift net retrieved from Torres Strait waters in 1998 was identified as abandoned by an unauthorised foreign fishing vessel (AFMA, 1998).

While not intense in comparison to other parts of the world, the Arafura Sea is likely to be an area of high domestic and international fishing effort, relative to other parts of Australia. The history of fishing in the Arafura Sea extends at least over several centuries, long before European colonisation, when the Macassans and other Indonesian fishers regularly visited Australian shores and offshore islands for trepang (sea cucumber) and shark (McLoughlin, et al., 1994). Following declaration of territorial waters in 1968, a Memorandum of Understanding was agreed by Australia and Indonesia permitting 'traditional' Indonesian fishing vessels to continue fishing in traditional fishing areas in the vicinity of Ashmore Island. In 1992, the two countries then signed a Fisheries Cooperation Agreement to create a forum for general discussion on fisheries issues in Australian and Indonesian waters, including illegal, unregulated and unreported (IUU) fishing effort. Illegal incursions by foreign fishing vessels in Australian waters is common, perhaps driven by over-fishing of resources within Indonesian jurisdiction (AFFA, 2000). Indonesian fishing boats accounted for 86% of all foreign fishing vessels sighted in Australian waters during 1994 (McLoughlin, et al., 1994), and the majority of apprehended fishing vessels in 1999 (Coastwatch, 2000).

Foreign fishing vessels, the majority originating from Indonesia, continue to be apprehended in northern Australian waters, although all vessels recently apprehended have been long-line fishers targeting shark (Butler, pers. comm., 2003; Mackay, pers. comm., 2003; Nolan pers. comm., 2003). Trawl fishers were last apprehended in Australian waters in November 2001 (Mackay, pers. comm., 2003). Nets have been confiscated from line fishers originating from Merauke (in West Papua), but these nets tend to be small and mostly of organic fibres (Mackay pers. comm., 2003).

IUU fishing is also a significant problem for Indonesia, as it occurs at many different levels and it is resulting in the loss of fish stocks worth up to US$4 billion per annum (Tsamenyi, pers. comm., 2000). With the exception of Australia, the littoral States of the Arafura and Timor Seas have little capacity for monitoring and surveillance. IUU fisheries in Indonesian waters are also potentially an important contributor of marine debris in the Arafura Sea region. The need for development of policy and management frameworks to combat IUU fisheries has been the focus of a collaborative (Australia, Indonesia, Philippines) research proposal (Tsamenyi, pers. comm., 2000), and it is a matter of priority for Australian and Indonesian fisheries managers and the Arafura and Timor Seas Expert Forum (Table 11).

Authorised fisheries in the Arafura Sea region include Australian operations in Australian waters, and Indonesian owned and licensed foreign operations in Indonesian waters. Australian fisheries comprise the Queensland managed Spanish mackerel, barramundi, and mud crab fisheries, the Northern Territory managed barramundi, coastal line fishery, coastal net fishery, offshore snapper, shark, Spanish mackerel, squid, trepang and mud crab fisheries, and the Commonwealth-managed northern prawn fishery. Within the Australian prawn trawl fleet, between 90 and 96 fishing vessels and four mother ships operate out of home ports including Weipa, Karumba and Darwin (Stone pers. comm. 2003). Indonesian-based fisheries operations include a snapper fishery comprising a large industrial-scale trawl fishery of around 700 boats that operates in the Arafura Sea and transfers frozen catches directly to export carrier ships for export overseas without landing in Indonesia. Although about 700 fish net vessels are thought to operate within Indonesian waters of the Arafura Sea, more than 1500 licences have been issued by the Indonesian Directorate General of Fisheries. Many of these vessels are re-flagged Thai trawlers with Thai crews operating under Indonesian flags, joint venture arrangements, or Indonesian licences and endorsements (McLaughlin, et al., 1994). A number of other foreign fleets are known to operate in the region, though little is known of their effort, catch or market arrangements.

Fishing gear loss could be increasing around the world as a result of economic pressures that are influencing changes in fishing operations and effort in a wide variety of fisheries. Carr and Harris (1997) suggest that, in general, changes in modern fisheries tend to promote gear conflicts, greater risk-taking with gear,

and expansion of fishing grounds, each of which tends to contribute to the incidence of derelict fishing gear. Increases in quantities of derelict gear at sea have also been directly linked with advances in equipment handling and materials technology (ie shifts to more durable gear), limitations in solid waste disposal at ports, and poor understanding of and compliance with waste disposal regulations and controls (Carr and Harris, 1997; Topping, et al., 1997).

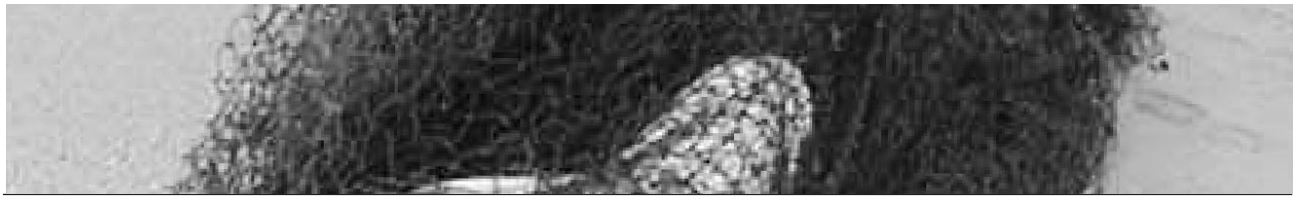
Fishing debris tends to be the most widely reported type of debris and the debris type of greatest concern to coastal communities in northern Australia (Sloan, et al., 1998; Whiting, 1998; Alderman, et al., 1999; Kiessling and Hamilton, 2001, 2003; Roeger, 2002; Limpus, pers. comm., 2003). An aerial survey of the Queensland coastline between Weipa and the Jardine River recorded more than 620 nets over 230km (Limpus, pers. comm., 2003). As this survey only noted beached nets observed from the air, many nets were probably not recorded and the actual number is likely to be far higher. Indeed, Limpus (pers. comm., 2003) estimates on the basis of aerial surveys of the eastern Gulf (between Torres Strait and the NT border), that a total of around 10 000 nets (or around 250kg of fishing net per kilometre) are littering the Queensland coastline.

Land-based surveys of the north-west coast of the Gulf of Carpentaria indicate that derelict fishing nets comprise a relatively small proportion by number but a very high proportion by weight of debris items washing ashore (Table 4). Many of the nets recorded in surveys at north-east Arnhem Land are so large that they are not able to be weighed and so have not been included in survey data (Kiessling and Hamilton, 2003). Fishing net fragments may range from small pieces of less than 1m² to entire nets (including drift nets several kilometres long) to enormous bundles made up of many different types of nets that have amassed and tangled at sea. For example, a large floating bundle of different types of net was sighted and recovered from NT waters in July 1995 (Department of Transport Maritime Policy Division, 1995). The recovered net bundle weighed nine tonnes and required three trucks to remove it once it was ashore. Queensland Boating and Fisheries Patrol officers retrieved an abandoned one-kilometre-long drift net (containing entangled fish) from waters near Kerr Islet in the Torres Strait after it was spotted during a Coastwatch surveillance flight (AFMA, 1998). Several transmitters/beacons of Taiwanese manufacture, used to track long-lines and drift nets, have been found on beaches in north-east Arnhem Land (Leitch, 1997). One of the transmitters retrieved was still operable and was powered by batteries manufactured in Indonesia (Leitch, 1997).

Table 4. Summary of fishing debris recorded from coastal surveys in northern Australia

Location	Total survey length/ area	Total amount of debris recorded	Total fishing items recorded	Total derelict fishing nets recorded	Total fishing nets	Likely origin of derelict fishing nets (by number of items)	Reference
Groote Eylandt, NT	137km	1140 items 61 806 kg	≥ 812 items ≥ 90% 55 918 kg	812 nets 71% (by no.) 90% (by weight)	6 nets/km 69 kg/km	~ 34 % Australian ~ 66 % SE Asian	Sloan, et al., 1998
Fog Bay, NT	4km	596 items ? kg	107 items 18% ? kg	*	*	*	Whiting, 1998
North-east Arnhem Land, NT	100m	>727 items ? kg	≥ 100 items 14% ? kg	33 nets (2997m²) 5% (by no.)	33 nets/100m ? kg	~ 15% Australian ~ 85 % SE Asian	Alderman, et al., 1999
Cape Arnhem, NT	8.25km	7561 items >3880 kg	2027 items 27% 1040 kg	502 nets 7% (by no.)	60 nets/km ? kg	~ 5% Australian ~ 93% SE Asian	Kiessling and Hamilton, 2001
Cape Arnhem, NT	8.25km	21 714 items >1074 kg (excluding nets)	6255 items 29% 1040 kg	590 nets 3% (by no.)	72 nets/km ? kg	~ 14% Australian ~ 86% SE Asian	Kiessling and Hamilton, 2003
Cape Arnhem, NT	8.25 km	7443 items 1546 kg	*	482 nets 6% (by no.)	58 nets/km ? kg	~ 4% Australian ~ 96% SE Asian	White, in prep.
Groote Eylandt, NT (8 Mile & Salt Lake beaches)	4.95km	1603 items ? kg	*	55 nets 3% (by no.) 432kg	11 nets/km 87 kg/km	~5% Australian ~95% SE Asian	White, in prep.
Groote Eylandt, NT (South Point)	4.8km	2597 items 942 kg	*	60 nets 2% 691kg 73%	12 nets/km 144 kg/km	~8% Australian ~92% SE Asian	White, in prep.
Elcho Island	3.25km	425 items 767 kg	*	32 nets 8% (by no.) 655kg 85.4% (by weight)	10 nets/km 202 kg/km	~3% Australian ~97% SE Asia	White, in prep.

*Information not available



Derelict fishing nets provide valuable clues to their origin via their mesh and twine size, colour, knots, number of strands and type of fibre. Existing studies in northern Australia have tended to identify nets in regard to their probable country of origin, based on known use and manufacture of the complete net (Kiessling and Hamilton, 2001, 2003; WWF, 2002; White, in prep). However, as fishing net mesh and materials are often made in one country and purchased by another, and completed nets may then be used by fishing vessels flagged somewhere else, the probable country of origin of a net does not necessarily indicate those who are responsible for its loss or disposal. Analysis and identification of probable use and manufacturing origin of complete fishing nets (versus mesh) nevertheless provides a starting point in ultimately determining accountability for fishing debris.

Preliminary analysis of fishing nets found at Cape Arnhem on the north-east coast of the Gulf of Carpentaria suggest that foreign fishing nets of South-east Asian use and manufacture are likely to comprise the greatest proportion (around 80%) of all nets washing ashore (Table 5).

Nets used by and manufactured in Taiwan account for 26 – 39% of all nets identified, while nets used by and manufactured in Indonesia and Japan account for 17% and up to 11% of identified nets respectively. Prawn trawl and gill nets of Australian use and manufacture account for around 12% of identified nets, and approximately 9% of nets found have not been reliably identified (Table 5).

South-east Asian nets washing ashore in north-east Arnhem Land tend to be of larger mesh size, and of much greater area and weight than Australian prawn trawl nets that wash ashore there (Sloan, et al., 1998; Alderman, et al., 1999; Kiessling and Hamilton 2001, 2003). Foreign nets (notably Taiwanese, Indonesian and Japanese trawl and drift nets) are also causing some of the greatest harm to marine animals, especially turtles (Table 8).

Table 5. Summary of probable use and origin of derelict fishing nets recorded at Cape Arnhem, Northern Territory (Alderman, et al., 1999; Kiessling and Hamilton, 2001, 2003; White, in prep)

Country of manufacture	Net type		Number of nets	Proportion of total nets
South-east Asia	**Subtotal**		**621**	**79%**
Taiwan	Trawl	108	202	26%
	Gill (Drift net)	94		
Indonesia	Trawl	131	137	17%
	Gill	6		
Taiwan/Korea	Trawl		99	13%
Japan	Trawl		63	8%
Philippines	Trawl		52	7%
Japan/Korea	Trawl		25	3%
Thailand	Trawl		23	3%
Korea	Trawl	19	20	2%
	Gill	1		
Australia	Trawl		68	
	Gill		26	
	Subtotal		**94**	**12%**
Unknown	Trawl		7	
	Gill		3	
	Unknown		59	
	Subtotal		**69**	**9%**
TOTAL			**784**	**100%**

Commercial fisheries are also believed to be responsible for debris other than nets in northern Australian waters. Glass bottles believed to be from Japanese longline and purse seine tuna fisheries are common on cays in the Coral Sea (Smith, 1992; Wace, 1995). Indonesian fishing vessels are believed to be the source of quantities of thick rubber and plastic sheeting from which the soles of handmade thongs have been cut. Both the thongs and residual 'blanks' wash ashore on many parts of the northern Australian coastline, including the beaches at Cocos (Keeling) Islands (Wace, 1995). Numerous other items such as fishing net floats, sorting baskets, crates, buckets, hand reels, light globes, ropes and gloves which may also be directly attributed to fishing activities are also found in large quantities (Sloan, et al., 1998; Whiting, 1998; Alderman, et al., 1999, Kiessling and Hamilton, 2001, 2003).

There are numerous aquaculture operations throughout the coastal waters of northern Australia. Pearl farming, in particular, is common and is responsible for creating marine debris in the region, as well as suffering its effects. For example, one pearl farm is known to have lost 200–300 buoys in one incident alone during 1999 (Butel, pers. comm., 2000) and pearl baskets (used for nucleation of the oysters) have been found washed ashore in various parts of the northern Australian coast (Rayns, pers. comm., 2000). As floating debris can cause considerable damage to pearl farm operations, pearl farm workers have also been reported to clean up beaches and retrieve nets observed at sea (Stevens, pers. comm., 2000).

2.2.2 Recreational boating and fishing

Recreational boating and fishing is a popular pastime throughout northern Australia. Recreational fishers tend to produce relatively small amounts of waste per person and per vessel in comparison to commercial vessels, in part due to the short duration of voyages (National Research Council, 1995). However, studies in parts of Australia have found a positive correlation between litter on beaches and numbers of recreational boats (Widmer, 2002). The types of litter most frequently reported as associated with recreational boats are plastic bags, aluminium cans and glass bottles (Widmer, 2002). Recreational fishers are also responsible for the loss or disposal of lines, lures, and nets in northern Australia (Whiting, 1998; Thompson, 2000; Kiessling and Hamilton, 2001, 2003; Chatto, pers. comm., 2003).

Monofilament line that has been lost and discarded by recreational fishers is of particular concern as it presents an entanglement threat to marine wildlife such as sea turtles. For example, recreational fishing line was responsible for the death of a green turtle at Magnetic Island in Queensland during 2000 (Thompson, 2000). Derelict amateur bait nets have also been responsible for killing two rare sawfish near Darwin (Chatto, pers. comm., 2003), and amateur gear has been recorded at beaches in north-east Arnhem Land (Whiting, 1998; Kiessling and Hamilton, 2001, 2003).

Recreational vessels are not required to be registered in the NT, but there are believed to be around 12 000 recreational fishing boats owned by NT residents (Harrison, pers. comm. 2003). Boat-based recreational fishing accounts for the majority (70%) of all recreational fishing activity in the NT, unlike elsewhere in Australia where shore-based fishing accounts for the bulk of fishing effort (Henry and Lyle, 2003). It has been estimated that there are also around 100 000 fishing visitors to the Queensland portion of the Gulf each year, who together spend up to 30 000 days per year fishing from boats (Bateman, pers. comm., 2003). Each year several major recreational fishing tournaments are held out of locations such as Nhulunbuy, Groote Eylandt, Borroloola, Burketown, Normanton, Karumba and Weipa, and fishing charter companies operate from places such as Weipa, Mornington and Sweers Islands, Nhulunbuy, and Darwin, visiting remote locations such as the Wessel and English Companys Islands.

More fishing charter and hire boats operate in the NT and Queensland than elsewhere in Australia (Henry and Lyle, 2003), and there is some concern about the impacts of increased fishing effort in the Queensland charter boat sector on habitats and species within the Gulf of Carpentaria, particularly around the Weipa area. The number of Queensland boats registered for charter purposes in the Gulf has increased from 11 in 1997 to 65 in 2002, and the number of charter fishing days has increased nearly five-fold.

Most recreational boaters and fishers operate within three nautical miles of shore and so are obliged to store all waste for disposal ashore. Actual waste disposal practices at sea are unknown and likely to be variable. As waste generated on board recreational boats is often virtually indistinguishable from that generated on shore, it is difficult to accurately determine debris originating from marine-based recreational fishers. Nevertheless, given the number of recreational vessels and fishers operating in northern Australian waters, a significant proportion of debris found on the northern coastline is likely to be a product of vessel-based recreational fishing activity.

2.2.3 Cargo ships

A large number of cargo ships operate throughout the Arafura Sea. They include Australian flag vessels in domestic or international trade, and an international trade fleet of foreign flag vessels. In terms of tonnage carried and distance travelled, Australia ranks as the fifth largest user of shipping in the world (ANZECC, 1996a). Around 380 million tonnes of freight is transported on 12 000 ships throughout Australian waters each year, although only 50 large vessels involved in overseas voyages are registered in the Australian fleet (Gillies, pers. comm., 2001). In 1998, around 3000 cargo ships passed directly through the Arafura Sea region via the Torres Strait. Approximately 45% of these were bulk carriers, 30% were

tankers and 20% were general cargo vessels. Many of these vessels also visited ports at Darwin, Gove, Groote Eylandt, and Weipa (ANZECC, 1996a).

Some evidence suggests that cargo ships are also likely to be responsible for the loss and disposal of waste in northern Australian waters. For example, a number of items that appear likely to originate from such vessels have been recorded on the northern Australian coastline. A large number of plastic livestock syringes and associated glass antibiotic bottles used to dispense medication to cattle on livestock carriers have been found during surveys on Christmas Island (Environment Australia, 2001) and north-east Arnhem Land. Two syringes were recorded over a 100m stretch in 1999 (Alderman, et al., 1999), nine livestock syringes were found at Cape Arnhem in 2000 (Kiessling and Hamilton, 2001), 42 livestock syringes and 161 antibiotic bottles were found at Cape Arnhem in 2001 (Kiessling and Hamilton, 2003), and rangers regularly find livestock syringes washed ashore during beach patrols (Leitch, pers. comm., 2000). Livestock feedbags such as those used in the live cattle trade have also been reported to wash ashore in northern Australia (Leitch, 1997). One of these feedbags (originally containing 'Lucerne Cubes' manufactured in Australia) was responsible for the entanglement of a hawksbill turtle in north-east Arnhem Land during 1997 (Leitch, 1997).

Thirty-four livestock trade vessels make around 300 trips across the Arafura Sea each year (Hughes, pers. comm., 2000), and more than 286 000 head of cattle were transported from ports in the region during 2001/2002 (Scougall, pers. comm., 2003). Darwin, Karumba and Weipa all receive numerous visits from livestock vessels each year, though Darwin is the most heavily visited port (receiving 169 – 289 visits per year since 1997) (Scanlon, pers. comm., 2003; Scougall, pers. comm., 2003).

2.2.4 Coastal barges

There are at least two general cargo barge companies that operate along the northern Australian coast, Perkins Shipping and Tiwi Barge Services. These companies provide regular freight services to coastal communities as well as transporting a small number of passengers. Several other barge companies provide specialised services throughout the area. For example, one vessel, the *MV Kestrel Bay,* run by the Seaswift company, provides mothershipping services (transport of fuel/oil, water stores, spare parts to the fleet and transport of frozen product to port) to the prawn trawling fleets in the Gulf of Carpentaria. Specialised bulk sea transport of lead-zinc product from the MacArthur River mine to ocean-going vessels offshore is undertaken by the Carpentaria Shipping Services company on the *MV Aburri,* and lead/zinc concentrate is carried by the *MV Wunma* from the Century Zinc mine to offshore ore freighters. A number of vessels also service offshore oil and gas operations in the Timor Sea.

Darwin Port receives on average 39 visits per year by coastal barges (Scanlon, pers. comm., 2003).

Coastal barges operating throughout the Indonesian archipelago have been observed deliberately dumping large quantities of litter at sea. For example, in 2001 a supply ship was observed dumping rubbish overboard while docked at port on the island group of Kepulauan Babar, off Timor L'Este (Newell, pers. comm. 2003). Given the potential for ocean currents to transport debris long distances, dumping from barges in Indonesian waters may be a source of debris washing ashore on northern Australian coasts.

A number of coastal barges in northern Australia have been entangled in fishing and other plastic debris while at sea, though no formal records have been kept of incidents (James, pers. comm., 2003). Perkins Shipping has also provided significant assistance in the transportation and disposal of debris collected during marine debris surveys at Cape Arnhem (Kiessling and Hamilton, 2001).

2.2.5 Surveillance and patrol vessels

Ten Royal Australian Navy (RAN) patrol boats and two landing craft are based in northern Australia (Darwin). However, no more than three of those vessels are likely to be operational in the Arafura Sea region at any one time (Cole, pers. comm., 2003). While sovereign warships are generally exempt from compliance with MARPOL regulations, many IMO member governments have determined that their naval ships will observe the regulations (Polglaze, 2003). This expectation is often extended to visiting foreign warships, even though their country of origin may not have such a requirement (Polglaze, 2003).

Australian Defence vessels are bound to comply with Commonwealth legislation and follow all regulations and requirements of both international and domestic agreements (Cole, pers. comm., 2003). A guide outlining discharge restrictions in Australian waters for waste categories defined by MARPOL (food waste, garbage, plastics) was produced by the RAN in December 1995, and the RAN fleet implements a strict waste management, minimisation and recycling strategy (Cole, pers. comm., 2003).

RAN patrol boats engaged in fisheries patrols regularly observe derelict fishing gear floating in northern Australian waters (Moffitt, 1996). Reports of these observations are limited to a brief description, location and an estimation of drift rate and direction for broadcast as Radio Navigation Warnings. No records of these observations are retained over the longer term.

Two Customs patrol vessels are based in the Torres Strait and three operate out of Darwin. These vessels cover all of the Arafura Sea and Gulf of Carpentaria region in their operations, and all are required to conform with both national and international

regulations as well as strict vessel waste management, minimisation and recycling strategies (Butler, pers. comm., 2003). Customs vessels operating throughout the region are actively involved in observing, recording and sampling marine debris, with all records sent to the Department of Environment and Heritage in Canberra for compilation (Butler, pers. comm., 2003; Ferguson, pers. comm., 2003).

2.2.6 Offshore oil platforms, rigs, and supply vessels

All offshore oil and gas exploration in northern Australian waters occurs in the Timor Sea. An offshore rig or platform is typically operated through a contractual arrangement involving the leaseholder who owns the platform, a shoreside base terminal that serves as a 'port', the drilling contractor, and the offshore vessel operator who transports personnel, supplies and waste between the platform and the shore.

Disposal of any garbage from offshore platforms is totally prohibited under MARPOL and, with the exception of food waste, all garbage is sorted on board the platform for disposal on shore. This sector is also subject to various domestic laws and regulations that impose discharge restrictions independent of, but consistent with, MARPOL Annex V, There have been no reports of debris originating from offshore oil and gas operations in the northern Australian marine environment (ANZECC, 1996a).

2.2.7 Passenger cruise ships

During 2002, 18 cruise ships visited Darwin Port, although it is common for more than 30 vessels to visit each year. Many more cruise ships travel through the Arafura Sea without landing in Australia (Scanlon, pers. comm., 2003). Most waste generated by passenger cruise ships is treated on board. However, when waste must be offloaded, cruise ships can put a strain on port reception facilities due to the volume of waste landed, the short port times and congested cruise itineraries, as well as the minimal shoreside treatment capabilities available in northern Australian ports (Scanlon pers. comm., 2003). In recent years, the cruise industry across the world has been working with shipbuilders and equipment manufacturers to install the latest in garbage treatment systems (including compactors, incinerators, pulpers and shredders) on vessels.

2.2.8 Research vessels

A small number of public and private marine research vessels operate in northern Australian waters. For example, CSIRO Marine Research conducts several cruises per year throughout Australian waters aboard the research vessel *Southern Surveyor*. A small number (around two per year) of these voyages focus directly on, or transit through, the Arafura Sea. Floating debris has been recorded during a number of the research voyages. For example, during October/November 2001 marine debris was recorded as common in the vicinity of the high seas fishing areas off the Indonesian EEZ (CSIRO Marine Research, 2000).

3. Impacts of marine debris in northern Australia

Marine debris, especially plastic waste, has emerged as a dominant global marine pollution problem on the basis of its widespread impacts. Plastics pose a particular threat in the marine environment due to their durability. Plastics are functionally impervious to degradation such that every piece of plastic ever produced remains within our environment. Plastics do break down into smaller pieces over time. However, there is no mechanism for biodegradation of conventional plastic, even if it is in very small pieces, 'in any practical time scale' (Andrady, 2000: 142). Once in the marine environment, plastics also tend to break down into smaller pieces even more slowly than plastics on land (Andrady, 1990, 2000).

There are no studies that have comprehensively investigated the impacts of debris in the Arafura Sea region, though a small number of isolated studies do provide an indication as to the nature of the problem in the region. The environmental and physical effects of debris (whether marine or land sourced) may be broadly classified as aesthetic, ecological (marine species, marine habitats), economic, public safety and social/cultural. The following section provides an overview of existing information on the impacts of debris on marine species, habitats and communities in northern Australia.

3.1 Marine organisms

Studies have documented entanglement and ingestion impacts on marine wildlife in all the world's oceans (Eckert and Luginbuhl, 1988; Blight and Burger, 1997; Hucke-Gaete, et al., 1997; Laist, 1997; Baird and Hooker, 2000; Starbird, 2000; Barreiros and Barcelos, 2001; Eriksson and Burton, 2001; Cadee 2002; Sazima, 2002). Many of the species that are impacted by debris are listed as endangered or threatened under national and international conservation conventions (Laist, 1997; Laist and Liffman, 2000), and many in northern Australia are of particular concern to Indigenous people due to their totemic and cultural significance (Kennett, et al., 1998; Mununguritj, 1998; Yunupingu, 1998).

Waterborne litter masquerading as a food source can, when ingested, starve animals by preventing further ingestion, but it can also reduce absorption of nutrients, result in ulceration, and cause animals to become more buoyant thereby inhibiting diving (Beck and Barros, 1991; Bjorndal, et al., 1994; Sloan, et al., 1998; EPA/QPWS, 2000). Tiny fragments of degraded plastic may be consumed by and effectively 'strangle' filter-feeders by inhibiting their ability to feed (Faris and Hart, 1995; Moore, et al., 2001). Research has also demonstrated that there is a strong potential for biological uptake of heavy metals and/or other toxic substances through ingestion of suspended 'microplastics' (Balazs, 1985; Ananthaswamy, 2001; Mato, et al., 2001).

Microplastics are small plastic particles that are introduced to the marine environment through cosmetic additives (plastics are added as abrasives), aeroblasting materials (plastic 'sand' is used to remove paint from ship hulls), and the weathering of larger plastic items. Within marine food webs, plastic debris can serve as both a transport medium and a potential source of toxic chemicals such as polychlorinated biphenyls (PCBs), endocrine-active substances, and chemicals similar to DDT (eg DDE which is an impurity in DDT as well as a biodegradation product of DDT and therefore occurs in the environment as a result of the use of DDT as an insecticide) (Balazs, 1985; Bjorndal, et al., 1994; Ananthaswamy, 2001; Mato, et al., 2001). These chemicals are known to compromise immunity and cause infertility in animals, even at very low levels (Ananthaswamy, 2001; Mato, et al., 2001).

Derelict fishing gear has been identified as the type of marine debris most hazardous to marine species (Laist 1996). Lost fishing gear and gear scraps have been shown to cause declines in populations of species such as northern fur seals (Fowler, 1987,1990, 2000), Australian sea lions and New Zealand fur seals (Pemberton, et al., 1992; Page, et al., in prep.). 'Ghostfishing' (the effect of lost and discarded fishing gear that continues to catch marine species indefinitely) has also been demonstrated to negatively affect commercial fishstocks (Bullimore, et al., 2000; Donohue, et al., 2000; Laist and Liffman, 2000), and result in catch rates approaching that of active gear (Laist, 1996). In the Arafura Sea, records of entangled and stranded marine wildlife are almost entirely limited to land-based observations over a small area of coastline. However preliminary reports (Table 6) suggest that disturbingly high numbers of marine species are being harmed and killed by debris while at sea, or as a result of their injuries on shore (Chatto 1995).

More than 500 entangled turtles have been recorded along the Queensland coast of the Gulf of Carpentaria over the last three years (Limpus, pers. comm., 2003). At Cape Arnhem in the western Gulf, a total of 205 stranded turtles, including four marine turtle species listed as endangered or vulnerable under Australian legislation, have been recorded since 1996 (Leitch, 1997; Alderman, et al., 1999; Fuller, pers. comm., 2001; Roeger, 2002; Kiessling and Hamilton, 2001, 2003). Some species of marine turtles are

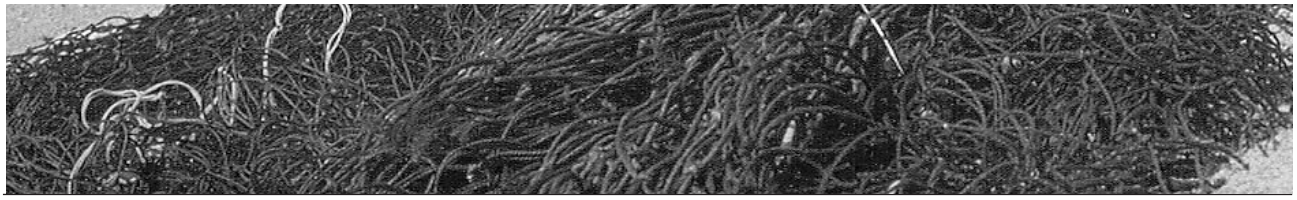
thought to mistake plastic bags and other plastic items for prey (Mrosovsky, 1981; Bjorndal, et al., 1994; Balazs, 1985). Other turtle species, especially hawksbills, eat encrusting organisms that grow on floating plastics and nets, and are likely to become ensnared when attempting to feed (Balazs, 1985).

In 1998 and 1999 (prior to the mandatory introduction of Turtle Exclusion Devices in the Australian Northern Prawn Fishery), the total number of turtles caught by active prawn trawl gear in the Gove fisheries statistical area was 173, of which 31 (18%) were dead when they were hauled aboard (Sharp, et al., 1998). In contrast, the number of turtles found stranded in derelict fishing net over a four-month period at Cape Arnhem (over an area measuring around 10% of the mainland perimeter of the Gove fisheries statistical area) numbered 29, of which 50% were already dead when found (Roeger, 2002). While it is not possible to accurately compare the impact of active fishing effort and that of derelict fishing gear on marine turtles from these figures alone, they suggest that the threat to marine turtles posed by fishing debris is of at least a similar order to the threat that was posed by active fishing effort prior to the introduction of Turtle Exclusion Devices.

Apart from turtles, anecdotal reports suggest that many other protected species such as whales, dugong, and sawfish are being entangled in derelict fishing gear and other debris (Table 6, also Butler, pers. comm., 2003; Mackay, pers. comm., 2003; Mununguritj pers comm., 2003; Yunupingu pers. comm., 2003). For example, in addition to several turtles, Sloan, et al., (1998) also found fish, sharks and seabirds (including a pelican) entangled in derelict fishing nets at Groote Eylandt in the Gulf of Carpentaria. At the very least, more than 794 marine turtles, many sharks, sea-snakes and birds, and several whales, dolphins and dugong have been entangled in derelict commercial and recreational fishing gear, and plastic bags in northern Australian waters since 1994 (Table 6). A large proportion of these records come from a single ongoing study conducted along a comparatively small stretch of beach at Cape Arnhem (Roeger, 2002). Given the quantities of debris washing ashore in northern Australia and the paucity of data on marine debris impacts in northern Australia however, the figures presented in Table 6 clearly record only a tiny fraction of the actual number of animals becoming entangled in marine debris in the Arafura Sea.

Table 6. Summary of incidents of marine wildlife stranded as a result of marine debris in northern Australia (after Kiessling, 2001)

Species	Location	Record Date	Debris Type	Source of information	No. and condition when found
Turtles					
Hawksbill turtle	Darwin Harbour	Feb 1994	Unidentified trawl net	Chatto, 1995	1 dead
	Weipa, Queensland	Oct 2000	Unidentified net type	Read, pers. comm., 2001	1 dead
	Numbulwar, NT	2000	Green net (possibly trawl)	Joshua, pers. comm., 2001	1 dead
	Cobourg Peninsula	Dec 1994	Unidentified net type	Fuller, pers. comm., 2001	2 dead
	North-east Arnhem Land	June 1997	Plastic fodder bag	Leitch, 1997	1 alive
		July 2000	Taiwanese trawl net	Kiessling and Hamilton, 2001	1 dead
		1996-2002	Taiwanese trawl net	Roeger, 2002	2 alive
			Unidentified net type	Roeger, 2002	37 alive 33 dead
		Sept 2000	Taiwan-manufactured gill net of type used by Indonesian fisheries	White, pers. comm., 2003	7 unknown condition
		Oct 2002	Taiwanese trawl net	White, pers. comm., 2003	2 alive
	Groote Eylandt	Aug 2002	Taiwanese drift net	White, in prep.	1 dead
	Ashmore Reef, Timor Sea	9 October 2002	Unidentified trawl net	Butler pers. comm., 2003	2 alive
	Arafura Sea	Dec 2002	Indonesian gill net	White, pers. comm., 2003	20 unknown condition
				Subtotal	**111**



Species	Location	Record Date	Debris Type	Source of information	No. and condition when found
Green turtle	Darwin Harbour	Feb 1994	Unidentified trawl net	Chatto, 1995	1 dead
	Groote Eylandt, NT	1998	Unidentified net types	Hanson, pers. comm., 2001	5 dead
	Magnetic Island, Queensland	Feb 2000	Fishing line	Thompson, 2000	1 dead
	Borroloola, NT	Apr 2000	Collapsible crab pot	Bradley, pers. comm., 2001	1 alive
		Dec 2000	Plastic bag	Quail, pers. comm., 2001	1 dead
	Cobourg Peninsula	Dec 1994	Unidentified net type	Fuller, pers. comm., 2001	4 dead
	Weipa, Queensland	Oct 2000	Unidentified net type	Read, pers. comm., 2001	2 dead 1 alive
	North-east Arnhem Land	1996-2002	Taiwanese trawl net	Roeger, 2002	3 alive
			Indonesian trawl net	Roeger, 2002	2 alive
			Unidentified net type	Roeger, 2002	10 alive 6 dead
			Indonesian/Taiwanese trawl net	Roeger, 2002	3 dead
			Unknown	Roeger, 2002	8 alive 4 dead
	Ashmore Reef, Timor Sea	Jan 2003	Indonesian Trawl net	White, pers. comm., 2003	6 alive
				Subtotal	**58**
Olive ridley turtle	Darwin Harbour	Feb 1994	Unidentified trawl net	Chatto, 1995	2 alive
	Weipa, Queensland	Oct 2000	Unidentified net type	Read, pers. comm., 2001	1 dead
	North-east Arnhem Land	1996-2002	Taiwanese trawl net	Roeger, 2002; Alderman, et al., 1999	3 alive 3 dead
			Indonesian trawl net	Roeger, 2002	1 dead
			Japanese/Korean trawl net	Roeger, 2002	1 dead
			Unidentified net type	Roeger, 2002	18 alive 7 dead
	Timor Sea	Jun 2000	Unidentified net type	White, pers. comm., 2003.	1 alive
		Sept 2002	Taiwanese trawl net	White, pers. comm., 2003	1 alive
	Ashmore Reef, Timor Sea	9 October 2002	Unidentified trawl net	Butler pers. comm., 2003	1 alive
		19 March 2003	Taiwan/Korea trawl net	Butler pers. comm., 2003	1 alive
				Subtotal	40
Flatback turtle	Darwin Harbour	Feb 1994	Woven plastic (hessian) bag	Chatto, 1995	1 alive
	Groote Eylandt, NT	1998	Unidentified net type	Hanson, pers. comm., 2001	1 dead
	Numbuwlar, NT	2000	Green net (possibly trawl)	Joshua, pers. comm., 2001	1 dead
	North-east Arnhem Land	1996-2002	Taiwanese trawl net	Roeger, 2002	1 dead
			Indonesian trawl net	Roeger, 2002	1 alive
			Unidentified net type	Roeger, 2002	8 alive 9 dead
		2001	Taiwanese drift net	Kiessling and Hamilton, 2003	1 alive
				Subtotal	**23**
Leatherback turtle	Bribie Island, Queensland	May 2000	Plastic bags	Thompson, 2000	1 dead
				Subtotal	**1**

Species	Location	Record Date	Debris Type	Source of information	No. and condition when found
Unidentified turtle species	Wigram Island, English Company Islands, NT	May 2000	Unidentified drift net	Butel, pers. comm., 2000	2 dead
	Timor Box	Sept 2000	Indonesian drift net	Perry, pers comm., 2000	7 alive
	Port Bradshaw, NT	Dec 1994	Unidentified net type	Fuller, pers. comm., 2001	3 alive 3 dead
	North-east Arnhem Land	1996-2002	Indonesian trawl net	Roeger, 2002	1 dead
			Unidentified net type	Roeger, 2002	10 alive 16 dead
			Indonesian trawl net	Alderman, et al., 1999	1 dead
	Cotton Island, NT	Feb 2001	Unidentified net type	Yumbulul, pers. comm., 2001	1 dead
	Numbulwar, NT	Mar 2001	Unidentified net type	Joshua, pers. comm., 2001	2 dead
	Northern Cape York	Mar 2001	Unidentified net type	Wallin, pers. comm., 2001	1 alive 13 dead
	Eastern Gulf of Carpentaria	1999-2003	Unidentified net type	Limpus, pers. comm., 2003	500 unknown condition
	Elcho Island	Mar 2003	Unidentified net type	White, pers. comm., 2003.	1 dead
				Subtotal	**561**
Whales and dolphins					
Brydes whale	Trinity Inlet, Queensland	Oct 2000	Plastic shopping bags, food wrappers	Thompson, 2000	1 dead
Indo-Pacific hump-backed dolphin	Lee Point beach, Darwin	Oct 2000	Unidentified net type	Chatto and Warneke, 2000	1 dead
Dolphin species	Cotton Is., English Companys Islands, NT	Oct 2000	Unidentified net type	Yumbulul, pers. comm., 2001	1 dead 1 alive
				Subtotal	**4**
Other					
Dugong	Numbulwar	1996-1998	Unidentified net type	Toldi pers. comm., 2001	Approx. 30 unknown condition
	Northern Cape York	Mar 2001	Unidentified net type	Wallin pers. comm., 2001	Several unknown condition
Sea snake species	North-east Arnhem Land	July 1999	Indonesian trawl net	Alderman, et al., 1999	1 dead
Shark species	Cape Ford, Fog Bay, NT (black tipped sharks)	1994	Unidentified gill net	Valla pers. comm., 2001	7 dead
	North-east Arnhem Land (grey reef shark)	July 1999	Indonesian gill net	Alderman, et al., 1999	1 dead
	Northern Cape York	Mar 2001	Unidentified net type	Wallin pers. comm., 2001	Several unknown condition
Pelican	Groote Eylandt	1998	Unidentified gill net	Sloan, et al., 1998	1 dead
Fish species					
Barramundi	Groote Eylandt	1998	Unidentified gill net	Sloan, et al., 1998	? dead
	Goodameer River, Arnhem Land, NT	1998	Unidentified net type	Jones, pers. comm., 2001	Several dead
Sawfish	Darwin Harbour	Aug 2002	Amateur bait net	Chatto, pers. comm., 2003	1 dead
	Darwin Harbour	Oct 2002	Amateur bait net	Chatto, pers. comm., 2003	1 alive
Various fish species	West of Cape Wessel	April 2000	Unidentified net (possibly Australian)	Harris pers. comm., 2000	? dead
Various fish species	Torres Strait near Kerr Islet	Nov 1998	Unidentified drift net1 km long	AFMA, 1998	? dead

Most stranded turtles found at Cape Arnhem were observed between May and June (Table 7). This period correlates with onshore south-east trade winds when marine debris accumulation is generally recorded to be higher than during other times of the year. The high number of stranded turtles found onshore during the dry season perhaps provides a pointer to the number of turtles that may also be entangled in nets during other times of the year but never wash ashore and are therefore never recorded.

Table 7. Marine turtle entanglement and stranding reports, north-east Arnhem Land 1996 – 2002 (Roeger, 2002; after Kiessling and Hamilton 2001, 2003)

Month entangled turtles found (1996 – 2001)	Number	Proportion
April	19	10%
May	121	64%
June	40	21%
July	9	5%
August	1	<1%
TOTAL	**190**	**100%**

Of all debris types responsible for death and injury of marine wildlife in northern Australia, foreign fishing nets are likely to be of greatest concern, entangling most stranded marine wildlife recorded in northern Australia (Table 8). Of those net types that have been identified, trawl and drift nets of Taiwanese, Indonesian and Japanese manufacture appear to be causing some of the greatest harm to marine wildlife including turtles, sea-snakes, sharks, fish, and birds (Table 8). There are no known records of wildlife entanglements in Australian trawl netting.

There are few records of ingestion of debris by wildlife in northern Australia. In far north Queensland, rangers report bites out of nearly every item of plastic debris they find washed ashore (Blackman pers. comm., 2000), and bite marks have been recorded in white plastic bottles at Groote Eylandt (White, in prep). Based on evidence that loggerhead sea turtles selectively ingest white plastic debris in the Mediterranean (Gramentz, 1988), White (in prep) suggests that several white plastic shampoo/sunscreen bottles found during a survey at Groote Eylandt show evidence of bite marks by hawksbill turtles. However active selection of debris by turtles based on colour is disputed (Tomas, et al., 2002), and it is possible that these bite marks may be caused by a number of species other than turtles. For example, various fish species in other parts of the world have been demonstrated to selectively ingest white plastics (Carpenter, et al., 1972) and seabirds have been shown to preferentially peck and consume floating plastics of particular colour (Blight and Burger, 1997; Cadee, 2002).

3.2 Marine habitats

While the overall ecological effects of marine debris in northern Australia are not known, studies from other parts of the world have shown that marine debris not only causes injury and fatality to marine wildlife through entanglement and ingestion, but it can also:

- smother coastal and benthic habitats, and directly threaten coral reef ecosystems through the abrading and scouring of coral substrates as derelict fishing gear snags on coral outcrops; and
- facilitate the spread and regional introduction of marine pests and weed species

(Faris and Hart, 1995; Willoughby, et al., 1997; Gregory, 1998; Alderman, et al., 1999; Donohue, et al., 2000; Barnes, 2002; Derraik, 2002; Mayell, 2002).

Marine debris poses a direct threat to the coral reef ecosystems in the Pacific (Donohue, et al., 2001). Derelict fishing gear may also pose a significant threat to corals in northern Australian waters, particularly around the Ashmore and Cartier Islands (in the Timor Sea) where large bundles of net entangled around coral outcrops have been observed (Butler, pers. comm., 2003).

Numerous nets and other debris found washed ashore in northern Australia have been found encrusted with crabs, barnacles, oysters, and other crustaceans (Butler, pers. comm., 2003). Preliminary analysis of a very small number of heavily infested debris items has not resulted in the identification of pest species to date (Wallin, pers. comm., 2001; Marshall, pers. comm., 2000-2001).

Research on marine pests associated with marine debris in other parts of the world has found that communities of encrusting organisms on beached plastics are very similar to those associated with drifting seaweeds and other natural 'rafts' (Gregory, 1998). Viable seeds of several exotic plant species (including potential weed species) have been recorded amongst debris at sea and on distant shores, presumably picked up during earlier episodes of stranding (Gregory, 1998).

Given the longevity of synthetic debris, the distances over which it is likely to travel, and the proximity of invasive marine pests to northern Australian waters, the potential for introduction of marine pests is potentially significant.

3.3 Economic, public safety and social/cultural impacts

The aesthetic impact of marine debris on coastal environments in northern Australia is obvious and compelling. Indeed, the aesthetic degradation that is evident on many very remote northern Australian beaches may be more compelling to the general public and policy makers than detailed analyses of animal mortality or other impacts. While the true social and economic costs of marine debris in northern Australia are unknown, marine debris is likely to have significant economic implications for industries such as tourism, shipping and fishing due to a mix of aesthetic impacts, navigational, health and safety hazards, pollution of commercial fish catch, and gear maintenance costs and downtime. The social and cultural impact of marine debris on Indigenous people and communities across northern Australia is also considerable: 'We are the ones on the ground looking out and seeing all this marine debris coming in. We are the ones who are affected. We and our marine species as well' (Mununguritj, pers. comm., 2003).

Anecdotal reports suggest that the navigational hazard posed by marine debris in northern Australian waters is significant and increasing (Jones, Rees, pers. comm., 2001), though incidents remain poorly documented. An operator of a supply vessel for the Northern Prawn Fleet goes so far as to suggest that most people who regularly work in northern Australia's coastal waters have been involved in at least one incident involving floating debris (Rees, pers. comm., 2001).

Debris, especially derelict fishing nets, has entangled rudders and propellers of marine vessels, and smaller items have been reported to clog cooling water intakes, causing engine failure (Nash, 1992; Haynes, 1997; Pooley, 2000). A United States study of the navigational hazards and public safety impacts of marine debris found that during 1999, at least five vessels were damaged by floating debris in Australian waters (Johnson pers. comm., 2000). Many more incidents are undocumented. For example, two vessels were fouled in floating net in April 2001, requiring more than 20 hours each to repair (Rees, pers. comm., 2001). A charter boat operating off the English Companys Islands in May 2000 was stranded after becoming fouled in a derelict fishing net (Miller pers. comm., 2000). In June 2000, an offshore oil and gas operations utility vessel, the *Henrietta,* was stranded north of Cape Wessell when a 200m-long derelict fishing net floating just below the water surface entangled the rudder (Harris pers. comm., 2000). Fortunately, all incidents occurred in good weather conditions and within relatively close range of rescue operations, though they still cost many hours in downtime and repairs. Many fish were found entangled in the net responsible for damaging the oil and gas utility vessel (Harris pers. comm 2000).

In other parts of the world, marine debris results in considerable economic cost through fouling active fishing gear, and polluting commercial catches to such a degree that special trawl gear has been designed specifically to eliminate marine debris through a Bycatch Exclusion Window (Nash, 1992; Faris and Hart, 1995).

Debris can be a hazard to divers and beachgoers. Children playing on remote beaches on Cape York, for example, have been cut badly by broken glass from large numbers of light globes and fluorescent tubes washed ashore there (White pers. comm., 2000). Hundreds of often full, rusty gas cylinders pose a significant explosive threat to beachgoers (Limpus, pers. comm., 2003), and potentially hazardous substances (eg sump oil, detergents, fuels) regularly wash ashore in containers such as 44 gallon drums (Alderman, et al., 1999; Limpus, pers. comm., 2003). Marine debris has also been identified as having a major impact on tourism in other parts of the world, including areas close to urban centres on East Timor (Teixeira, pers. comm., 2002) as well as remote coastal environments (Gregory, 1999a, 1999b).

The high cost of clean-up operations for polluted beaches is prohibitive for many remote coastal communities (Nash, 1992; Faris and Hart, 1995; Wace, 1995; Willoughby, et al., 1997; Sloan, et al., 1998), and the tonnes of fishing gear found washed ashore in some areas has resulted in public antagonism towards the fishing industry as a whole (Sloan, et al., 1998).

Table 8. Summary of known debris types entangling marine wildlife in northern Australia

Debris type	Location and date stranded animal found	Number and species	Reference
Taiwanese drift net	Groote Eylandt, NT; 2002	1 hawksbill turtle	White, in prep
	Cape Arnhem, NT; 2001	1 flatback turtle	Kiessling and Hamilton, 2003
	Subtotal	**2 turtles**	
Taiwanese trawl net	Cape Arnhem; 1996-2002	3 green turtles	Roeger, 2002
	Cape Arnhem; 1996-2002	5 hawksbill turtles	Kiessling and Hamilton, 2001; Roeger, 2002; White, pers. comm., 2003
	Cape Arnhem; 1996-2000	6 olive ridley turtles	Alderman, et al., 1999; Roeger, 2002
	Cape Arnhem; 1996-2000	1 flatback turtle	Roeger, 2002
	Timor Sea; Sept 2002	1 olive ridley turtle	White, pers. comm., 2003
	Subtotal	**16 turtles**	
Indonesian trawl net	Cape Arnhem; 1996-2002	2 green turtles	Roeger, 2002
	Cape Arnhem; 1996-2002	1 olive ridley turtle	Roeger, 2002
	Cape Arnhem; 1996-2000	1 flatback turtle	Roeger, 2002
	Cape Arnhem; 1996-2000	2 unidentified turtles	Alderman, et al., 1999; Roeger, 2002
	Cape Arnhem; July 1999	1 sea snake	Alderman, et al., 1999
	Timor Sea; Jan 2003	6 green turtles	White, ,pers. comm., 2003
	Subtotal	**12 turtles, 1 sea snake**	
Indonesian gill net	Arafura Sea; Dec 2002	20 hawksbill turtles	White, ,pers. comm., 2003
	Cape Arnhem; Sept 2000	7 hawksbill turtles	White, ,pers. comm., 2003
	Cape Arnhem; July 1999	1 grey reef shark	Alderman, et al., 1999
	Subtotal	**27 turtles, 1 shark**	
Indonesian/Taiwanese trawl net	Cape Arnhem; 1996-2002	3 green turtles	Roeger, 2002
Indonesian drift net	Timor Box; Sept 2000	7 unidentified turtles	Perry, pers. comm., 2000
Taiwanese/Korean trawl net	Timor Sea; March 2003	1 olive ridley turtle	Butler, pers. comm., 2003
Japanese/Korean trawl net	Cape Arnhem; 1996-2002	1 olive ridley turtle	Roeger, 2002
Unidentified trawl net (not Australian)	Timor Sea; October 2002	1 hawksbill turtle	Butler, pers. comm., 2003
	Timor Sea; October 2002	1 olive ridley turtle	Butler, pers. comm., 2003
	Numbulwar, NT; 2000	1 hawksbill turtle	Joshua, pers. comm., 2001
	Numbulwar, NT; 2000	1 flatback turtle	Joshua, pers. comm., 2001
	Darwin Harbour; Feb 1994	1 hawksbill turtle	Chatto, 1995
	Darwin Harbour; Feb 1994	2 olive ridley turtles	Chatto, 1995
	Darwin Harbour; Feb 1994	1 green turtle	Chatto, 1995
	Subtotal	**8 turtles**	
Unidentified drift net (not Australian)	English Co. Is, NT; May 2000	2 unidentified turtles	Butel, pers. comm., 2000
	Cape Ford, NT; 1994	7 sharks	Valla, pers. comm., 2001
	Groote Eylandt; 1998	Several barramundi	Sloan, et al., 1998
	Groote Eylandt; 1998	1 pelican	Sloan, et al., 1998
	Torres Strait; 1998	Several fish species	AFMA, 1998
Crab pot	Borroloola, NT; April 2000	1 green turtle	Bradley, pers. comm., 2001
Recreational fishing line	Magnetic Is, Qld; Feb 2000	1 green turtle	Thompson, 2000
Australian bait net	Darwin Harbour; Aug-Oct 2002	2 sawfish	Chatto, pers. comm., 2003
Plastic bag	Borroloola, NT; Dec 2000	1 green turtle	Quail, pers. comm., 2001
	Cape Arnhem; June 1997	1 hawksbill turtle	Leitch, 1997
	Darwin Harbour; Feb 1994	1 flatback turtle	Chatto, 1995
	Bribie Is, Qld; May 2000	1 leatherback turtle	Thompson, 2000
	Trinity Inlet, Qld; Oct 2000	1 Brydes whale	Thompson, 2000
	Subtotal	**4 turtles, 1 whale**	

4. Legislative framework

The International Convention for the Prevention of Pollution from Ships 1973 (MARPOL) is the principal international agreement regulating at-sea disposal of waste. Five technical annexes of MARPOL detail regulations according to the type of pollutant. Annex V specifically relates to the dumping of synthetic wastes (namely plastic) at sea (Table 9). A range of other agreements, applying at various scales, contain provisions that seek to limit the discharge and impact of persistent debris, especially plastics, in the marine environment (Table 10).

To date, environment and transport agencies at the Commonwealth level have had the principal role in the management of marine debris issues (Table 10). Fisheries agencies have had a lesser role in the prevention and management of marine debris, both in the recreational and commercial sectors, because Commonwealth fisheries legislation does not currently allow for direct control of debris within the industry (Galli pers. comm., 2003; Stone pers. comm., 2003).

Table 9. Summary of at-sea waste disposal regulations as defined by MARPOL, Annex V.

Garbage type	All ships except platforms*	Offshore platforms*
All plastics – including but not limited to synthetic ropes, synthetic fishing nets and plastic garbage bags	Disposal prohibited	Disposal prohibited
Floating dunnage, lining and packing materials	>25 n.miles offshore	Disposal prohibited
All other garbage including paper products, rags, glass, metal, bottles, crockery and similar refuse	>12 n.miles offshore	Disposal prohibited
All other garbage including paper, rags, glass, etc. comminuted** or ground	>3 n.miles offshore	Disposal prohibited
Food waste not comminuted or ground	>12 n.miles offshore	Disposal prohibited
Food waste comminuted or ground	>3 n.miles offshore	> 12 n.miles offshore
Mixed refuse types	***	***

* Offshore platforms include all fixed or floating platforms engaged in exploration, exploitation and associated offshore processing of seabed mineral resources, and all ships when alongside or within 500m of such platforms

** Comminuted or ground garbage must be able to pass through a screen with mesh size no larger than 25mm

*** When garbage is mixed with other harmful substances having different disposal or discharge requirements, the more stringent disposal requirements shall apply

4.1 Enforcement and compliance

Under MARPOL, signatories have a general obligation to capture and prosecute those who violate provisions of the agreement within their jurisdiction or their own flagged vessels when they are operating in international and/or foreign waters. However, legislation prohibiting the disposal of waste at sea by vessels is notoriously difficult to enforce. Vessels often spend a significant portion of their time remote from surveillance and monitoring activities. In order to initiate enforcement proceedings, vessels must be observed violating regulations, or there must be some other type of clear evidence to link a particular vessel to a breach of law. Development of methods of identifying debris such as derelict fishing gear could significantly assist the detection of violations of MARPOL.

Non-state entities, such as Taiwan, cannot currently become a party to MARPOL or any of its Annexes. Taiwan has the sixth largest fishing fleet in the world (and the second largest fleet in the central and western Pacific Ocean) (Koehler, et al., 2000), and fishing gear identified as being manufactured in Taiwan is regularly reported on northern Australian coasts (Kiessling and Hamilton, 2001, 2003). Taiwan is currently not a party to the provisions of MARPOL and its Annexes, and this weakens the effectiveness of the agreement in the Arafura Sea. However, Taiwan does recognise marine debris as an issue and has taken steps to address marine debris problems in its own waters. For example, Taiwan has drafted a marine pollution prevention law, which contains provisions that discourage ships from discarding nets and other types of debris within its jurisdiction (Koehler, et al., 2000).

One significant obstacle to States becoming parties to MARPOL or any of its Annexes is institutional capacity (eg in enforcement, administration and infrastructure) required to fully and effectively implement the provisions of the Agreement. As a consequence, in regard to the Arafura Sea region, steps that increase stakeholder participation and the capacity of neighbouring States to comply with MARPOL requirements may not only encourage ratification of Annex V, but also increase its effective implementation.

While Indonesia is a signatory to MARPOL, it is currently not party to Annex V and is therefore not bound by the marine pollution provisions outlined in the Annex. However, of the 125 present parties to Annex V, nearly all of the nations (other than Indonesia) with fishing fleets operating in the Arafura Sea region (or who have been identified as the probable country of origin and/or regular users of derelict fishing gear on Australian coastlines) are party to Annex V. This suggests that effective implementation and enforcement of the provisions of Annex V by parties operating vessels in the Arafura Sea region is as important as, if not more important than, encouraging non-parties to comply with MARPOL Annex V.

Provided that 'all reasonable' precautions are taken to prevent mishaps, accidental losses are not violations of MARPOL Annex V (which addresses deliberate discharges only). However IMO implementation guidelines require all vessels to make every effort to prevent loss and recover all lost and damaged fishing gear. Where fishing gear is lost from Australian vessels operating in Australian waters, the approximate position of, and the reason for, the loss must be reported to the Australian Search and Rescue Coordination Centre (AusSAR) in Canberra. Retrieval and/or monitoring of derelict gear identified by vessels at sea is not currently mandatory and responsibility for responding to reports of potentially hazardous debris is currently unclear. For example, a derelict fishing net too large to be recovered by the vessel who found it had to be abandoned when the government agencies at the state and Commonwealth level to which it was reported would not accept responsibility for its retrieval (Butel pers. comm. 2000).

Compliance with the requirements of MARPOL Annex V and domestic marine pollution legislation is generally monitored in Australia through the AFMA observer program. Almost 100% compliance has been observed amongst domestic vessels while observers are present (Jones, 1994). However, a study of reports from observers on Japanese vessels operating in the Australian Fishing Zone during the early 1990s noted that around half of the vessels carrying observers did not comply with MARPOL provisions. The reasons for non-compliance were recorded as a lack of knowledge of MARPOL regulations, the attitude of the captain and/or crew, and poor waste management practices either due to a lack of facilities on board the vessel or inadequate facilities at port (Jones, 1995).

There have been only two successful prosecutions by Australian authorities for violations under the garbage dumping regulations of MARPOL (Annex V) in Australian waters. The first successful prosecution of a vessel breaching marine pollution requirements in Australian waters took place in January 1997 after a yacht was witnessed disposing of garbage at sea near the Cocos Islands (AMSA, 1999a). The second was prosecution of the cruise-ship *Fairstar* in August 1998 after garbage found off Evans Head in New South Wales was traced to the vessel (AMSA, 1999b). Several other charges have been made but no prosecutions have resulted. The sparsity of charges and prosecutions, despite the volumes of debris reported, graphically illustrates the challenges involved in effectively enforcing obligations under prevailing circumstances.

Table 10. Existing conventions and agreements relevant to marine debris in the northern Australian marine environment

International – global	
International Convention for the Prevention of Pollution from Ships 1973 (MARPOL)	This is the principal international agreement regulating the at-sea disposal of waste. It is promoted and administered by the International Maritime Organization, although implementation of standards and regulations within State waters is the responsibility of individual states directly or indirectly through authorities that are delegated such responsibility. In Australia, the enforcement of MARPOL and other requirements rests with the Australian Maritime Safety Authority (AMSA) and the appropriate authority of the Queensland and NT Governments through relevant legislation (see below). Five technical annexes of MARPOL detail regulations according to type of pollutant. Annex V, which came into force in 1988, applies to all vessels including yachts, fishing boats and dinghies and it totally prohibits the disposal of plastics (including biodegradable plastics) into the ocean. Non-plastic materials that float, food wastes, and other garbage, are permitted to be discharged into the oceans so long as that vessel is a prescribed distance from shore (Table 9). Annex V also requires that all parties to the Convention provide adequate garbage reception facilities at ports and terminals and that inadequate facilities be reported. As at December 2002, 125 States were party to MARPOL (representing 97% of the world's tonnage), including Australia, Indonesia, Japan, Malaysia, the Philippines, and the Republic of Korea. Thailand and Taiwan are not currently signatories to the MARPOL Convention. Most signatories to MARPOL are still developing programs to implement the Convention, as it is generally not binding without domestic implementing legislation. States that are party to MARPOL are not consensually bound to Annex V's obligations unless they also specifically ratify the Annex. Indonesia, although a signatory to MARPOL, is currently not party to Annex V.
London Dumping Convention 1972 (International Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter)	This international Convention contributes to the international control and prevention of marine pollution by prohibiting the dumping of garbage and persistent plastics (generated on land) at sea. "Dumping" is defined in the Convention as the deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other artificial structures, as well as the deliberate disposal of these vessels or platforms themselves. Among other requirements, signatories undertake to designate an authority to deal with permits, keep records, and monitor the condition of the sea. Australia, Japan and Papua New Guinea are currently parties to the Convention. Indonesia, Thailand, Taiwan, Korea, and Malaysia are not currently signatories. The Philippines has signed the Convention but not yet ratified it.
Draft Wreck Removal Convention	The Legal Committee of the IMO is developing a draft Wreck Removal Convention (WRC). It is anticipated that the draft will be ready for consideration by a Diplomatic Conference during 2004-2005. The WRC is intended to provide international rules on the rights and obligations of States and shipowners in dealing with wrecks and drifting or sunken cargo (potentially including derelict fishing nets) which may pose a hazard to navigation and/or pose a threat to the marine environment. The draft Convention currently being considered by the Legal Committee is intended to clarify rights and obligations regarding the identification, reporting, locating and removal of hazardous wrecks/cargo, in particular those found beyond territorial waters.

4. Legislative framework

National	
Protection of the Sea (Prevention of Pollution from Ships) Act 1983 *Navigation (Protection of the Sea) Amendment Act 1983*	These two Acts together give effect to MARPOL in Australian Commonwealth waters. Part IIIC (Prevention of Pollution by Garbage) of the *Protection of the Sea (Prevention from Pollution of Ships) Act 1983* relates specifically to the matter of waste disposal from vessels at sea. Compliance is monitored by the Australian Maritime Safety Authority, and fines of up to $1 million for companies and $200 000 for individuals are possible where vessels are found to be in breach of the legislation. Regulations apply to all Australian vessels wherever they are operating, as well as to foreign vessels anywhere within Australian jurisdiction. Provisions enable foreign ships operating in Australian waters to be detained and inspected if they are suspected of involvement in pollution breaches.
Fisheries Management Act (1991)	Under the Act, the Commonwealth requires that exploitation of fisheries resources and fisheries-related activities under Commonwealth jurisdiction are conducted in a manner consistent with the principles of ecologically sustainable development (ESD) and the precautionary principle. The management and/or prevention of marine debris, while arguably constituting an element of ESD, is not specifically mentioned in the Act and may not be directly managed or controlled under this legislation.
Australian Maritime Safety Authority Act 1990	The *Australian Maritime Safety Authority Act 1990* establishes the Australian Maritime Safety Authority (AMSA), a statutory authority with a role that includes promotion of maritime safety and protection of the marine environment, including prevention and management of ship-sourced pollution in the marine environment.
International - regional	
South Pacific Regional Environment Programme (SPREP)	SPREP is a regional organisation, established by international convention, which works to assist member countries to cooperate on issues affecting shipping and the natural environment. It consists of 26 member countries including Australia, New Zealand and Papua New Guinea. SPREP is funded by government contributions and aid donations, from both national and international sources such as the United Nations and the Global Environment Facility. Australia and New Zealand have had a major role in developing a Strategy and Work Programme for the SPREP/ International Maritime Organization (IMO) Protection of the Marine Environment in the South Pacific Region. This Programme was developed in 1993 with technical assistance from the IMO and primarily addresses shipping-related pollution, and it incorporates the Pacific Ocean Pollution Prevention Program (PACPOL).
Asia Pacific Memorandum of Understanding on Port State Control (Tokyo MOU)	The main objective of this MOU is to establish an effective Port State Control regime in the Asia Pacific region through cooperation among maritime Authorities in the implementation of international regulations for safety and marine pollution prevention. Singapore is one of the founding members of the Tokyo MOU, which also involves Australia, China, Fiji, Hong Kong, China, Indonesia, Japan, Korea, Malaysia, Papua New Guinea, the Philippines, Singapore, Thailand, Vanuatu and Vietnam.
State/Territory	
Queensland Transport Operations (Marine Pollution) Act 1995	This legislation fully incorporates the MARPOL requirements including provisions detailed in Annex V of the Convention. It applies to ships of all sizes, classes and types and is applicable in Queensland's coastal waters. The maximum penalty possible to impose for disposal of waste is $210 000 for individuals and $1 050 000 for corporations.
Queensland Environmental Protection Act 1994	The aims of this Act include the encouragement of ecologically sustainable development of Queensland's natural environment, including coastal waters, through prevention and management of contaminants/pollution from land-based activities. It defines terms including environmental value and contaminant, and it binds everyone including the Queensland Government and its agencies and, as far as legislative power permits, the Australian Government and other state governments.
Queensland Fisheries Act 1994	This Act requires Queensland fisheries to be managed in accordance with ESD principles. Some of the key aspects of the Act are Part 4, Division 2, which requires fishery management plans to be consistent with ESD principles, and Part 6, which provides for protection of fisheries habitat. This Act can be applied retrospectively where fisheries resources or habitats are impacted.
Northern Territory Marine Pollution Act 1999 and Marine Pollution Regulations	This Act is administered by the Marine Safety Branch (Department of Infrastructure, Planning and Environment). Its purpose is to protect the marine and coastal environment of the NT by minimising intentional and negligent discharges of ship-sourced pollutants into coastal waters. Marine pollution regulations are currently being drafted and will outline specific requirements of the Act, details of permitted discharges, and penalties related to breaches of the regulations.
Northern Territory Fisheries Act 1988	This Act is administered by the NT Fisheries agency under the Department of Business, Industry and Resource Development. It includes provisions to control pollution of waters by any substance likely to affect aquatic life.

5. Existing marine debris codes, organisations and activities in northern Australia

Marine debris has a relatively high profile within Australia as indicated by the range of marine debris focused activities and programs undertaken in recent years (Table 11). For example, a number of fishing industry (commercial and recreational) Codes of Practice have been developed, though these are primarily voluntary and mostly fulfil an educative role. Several beach surveys have been undertaken across the northern Australian coastline and many more groups would like to be involved in such activities.

Marine-sourced waste is processed through a number of ports through the Arafura Sea region. Northern Australian ports are located at Darwin, Gove, Groote Eylandt, Bing Bong (MacArthur River), Karumba and Weipa, and a new port is being built at Skaardon River near Weipa. Darwin is the only multi-purpose, multi-cargo, natural deep-water port in the region, while all other ports are largely associated with land-based minerals developments (Scanlon, pers. comm., 2003). During 2001/2002, more than 12 700 vessels visits were recorded at Darwin port, 328 vessels were handled at Weipa, 134 at Karumba, 131 at Gove, 48 at Groote Eylandt, and 17 at Bing Bong (Scanlon pers. comm., 2003).

Northern Australian ports are equipped to deal with dry, non-contaminated waste. However all contaminated (quarantine-controlled) waste tends to be the responsibility of individual vessels/operators and/or is handled privately through contractors (Scanlon, pers. comm., 2003). It is currently not possible to dispose of fishing nets through appropriate facilities in northern Australian ports (Scanlon, pers. comm., 2003).

Table 11. Codes, organisations and activities directly relevant to the prevention and management of marine debris in northern Australian waters

Activity	Lead organisation	Comments
International		
FAO Code of Conduct and Technical Guidelines for Responsible Fisheries	United Nations	This Code has several provisions which assert that States and subregional or regional fisheries management organisations/arrangements should adopt appropriate measures to minimise catch by lost or abandoned fishing gear and its impact on non-target species (Article 7.2 [f][g]; Article 7.6.9), and that fishing activities should be conducted with due regard for the IMO requirements relating to the protection of the marine environment and loss of fishing gear (Article 8.4.1; Article 8.7.1).
	IMO Marine Environment Protection Committee (MEPC)	Marine debris was raised as an agenda item at the 46th session of the IMO MEPC (January 2001). The issue was submitted by the United States and incorporated a summary of conclusions and a declaration of resolve developed at the International Marine Debris Conference on Derelict Fishing Gear and the Environment, held in Hawaii during August 2000 (McIntosh, et al., 2000). Unfortunately, the issue of marine debris has not substantially advanced within the IMO MEPC since that time, although it provides an important context for seeking better implementation of MARPOL Annex V provisions.
IOC Global Investigation of Pollution in the Marine Environment (GIPME) Programme	N/A	GIPME is an international cooperative programme of scientific investigations focused on marine contamination and pollution. GIPME was established in 1974, and is co-sponsored by the Intergovernmental Oceanographic Commission (IOC) of the United Nations Education, Cultural and Scientific Organization (UNESCO), the United Nations Environment Programme (UNEP), and the International Maritime Organization. There is also a close link between GIPME and the marine pollution monitoring and research components of the Regional Seas Programme. Under the GIPME program, manuals and guides have been produced to assist in monitoring and managing marine debris (Ribic, et al., 1992), although the programme has been largely focused on chemical and oil pollution.
Global Marine Litter Information Gateway website	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), clearing house mechanism	The Global Marine Litter Information Gateway is a joint effort of the UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP GPA), the Swedish Environmental Protection Agency, and the UN International Maritime Organization (IMO). It comprises the marine litter (debris) node of the GPA Clearing-House Mechanism, with the aim of providing a gateway for supply and exchange of information on the global, regional and local dimensions of the marine litter problem. The node is largely made of summaries of existing work and projects that have been compiled and presented by people all around the world.
Northern Australian Fisheries Managers' meeting	N/A	The issue of marine debris has been discussed at the Northern Australian Fisheries Managers' meeting, attended by senior Indonesian officials in April 2001 and August 2002. While marine debris issues have received prominence, they remain secondary to illegal fishing issues.

5. Existing marine debris codes, organisations and activities in northern Australia

Activity	Lead organisation	Comments
Australia-Indonesia Ministerial forum	N/A	Marine debris was raised at the Marine Affairs and Fisheries Working Group as part of the Australia-Indonesia Ministerial forum in April 2002. While marine debris issues have received prominence, they remain secondary to illegal fishing issues.
Arafura and Timor Seas Expert Forum (ATSEF)	N/A	ATSEF was established to foster information exchange and scientific collaboration between the littoral States of the Arafura and Timor Seas so as to enhance the capacity of those States to manage marine resources sustainably. It provides a forum for governments, non-government agencies and researchers to collaborate on information gathering and research activities with a view to improving the management of shared ocean waters. Marine debris has been raised a number of times in the context of ATSEF discussions on priority management issues in the region. While IUU fisheries remain of principal concern to many ATSEF participants, marine debris has been acknowledged as an issue that warrants further attention.
National		
Australia's Oceans Policy	National Oceans Office	This Australian Government policy states that the government will: • 'undertake action to enable marine species threatened with extinction to survive and thrive in their natural habitats and prevent additional species and ecological communities from becoming threatened by identifying and managing critical threats', • 'prevent adverse impacts of pollution on the marine environment', and • 'implement monitoring programmes to ensure that fisheries management arrangements achieve long-term sustainability'.
Harmful marine debris listing as a 'Threatening Process'	Department of Environment and Heritage	'Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris' has been listed as a key threatening process under the Australian Government's *EPBC Act 1999*. This listing will now lead to the development of a Threat Abatement Plan for the process. To mitigate the impacts of marine debris, this Plan will build on existing activities such as government programs to improve waste retrieval from watercourses, anti-littering laws, laws controlling disposal of garbage and fishing gear from ships and boats, and plans to reduce litter associated with plastic shopping bags.
Recovery Plan for Marine Turtles in Australia	Department of Environment and Heritage	This Recovery Plan identifies marine debris as a cause of 'death and debilitation of marine turtles and other marine wildlife' and states that 'identifying the sources of marine debris, responding to stranding events and quantifying mortality caused by marine debris' are the 'primary actions to monitor and manage debris as a threat to turtles' (Environment Australia, 2003). Prescribed actions within the Recovery Plan include: A.3.1 Lead agencies to: • Monitor the mortality of marine turtles due to entanglement in marine debris, and • Identify the source of marine debris. A.3.2 Northern Territory agencies to determine the source of nets entangling marine turtles and the magnitude of their mortality in the Cape Arnhem region. A.3.3 Lead agencies to undertake remedial action to prevent/reduce marine turtle mortality in stranding events caused by marine debris.
'Keeping tabs on marine debris' – marine debris survey form and data sheet	Environment Protection and Heritage Council, WWF Australia, AMSA	This brochure provides a marine debris survey form. It also offers guidance on how to conduct marine debris surveys and record results. Completed survey forms may be sent to WWF Australia for compilation.
'Stow it don't throw it' vessel waste management campaign	AMSA	As part of this campaign, AMSA has published brochures on good waste management practices on vessels, and it maintains directories of waste reception facilities in ports.
Marine Waste Reception Facilities Program	Department of Environment and Heritage/ NHT	This Program is designed to assist port and marine facilities to assess their need for waste reception facilities, and to assist in the funding of demonstration projects and development of best practice management guidelines.
Best Practice Guidelines for Waste Reception Facilities at Ports, Marinas and Boat Harbours in Australia and New Zealand	ANZECC	These Guidelines provide practical advice on the implementation of MARPOL obligations. They are to be implemented by state/territory governments and local councils through licensing and approvals, including through Environmental Management Systems. The key principles of the Guidelines include waste avoidance, reduction, segregation, reuse, recycling, treatment and disposal.

Activity	Lead organisation	Comments
Code of Conduct for a Responsible Seafood Industry	Seafood Services Australia	The Australian Seafood Industry Council has developed this voluntary code for all aspects of the seafood industry based on the FAO Code of Conduct for Responsible Fisheries. Specific principles of the Code that relate to debris include: 1.5 Strive to minimise discards and all waste associated with fishing activities 1.12 Record and report the loss and recovery of fishing gear 1.13 Retain material such as derelict fishing gear and other garbage recovered during routine operations for disposal on shore 1.14 Minimise the taking aboard of potential garbage through proper provisioning practices 1.15 Ensure crews of fishing vessels are trained to be aware of and understand proper shipboard procedure in order to minimise garbage discharge.
National Code of Practice for Recreational Fishers	RecFish Australia	RecFish Australia, the national peak recreational fishing body, developed this voluntary code that includes 12 principles for conserving fish stocks. Included also are specific references to the prevention of marine debris such as: • We remove rubbish to prevent pollution and protect wildlife. • Take nylon line, polystyrene from packaging, bottles, sixpack holders, baitbags, cups and packaging etc away from fishing sites. These items must be disposed of correctly to avoid potentially entrapping birds and other creatures. • Don't leave bait to foul rocks, river banks or beaches. • Don't wash rubbish, chemicals and other waste into stormwater systems.
Biodegradable plastics	ANZECC	ANZECC was instrumental in promoting a national approach towards the use of biodegradable materials in bait bag manufacture. A biodegradable bait bag has been made for use in Queensland by Markwell's Bait in collaboration with Jonmar plastics (who are currently using Italian technology under licence). These biodegradable plastic bags are also likely to be introduced to Western Australia. Trials have begun for the development of biodegradable ice bags.
Working Together to Reduce Impacts from Shipping Operations: ANZECC strategy to protect the marine environment	ANZECC	This national strategy aims to enhance the protection of the marine environment through promoting best practice, improving waste management, reducing pollution from shipping, and communicating effectively with shipping interests about environmental values. The action plan detailed by the strategy covers 12 issues: • communicating about areas sensitive to shipping and boating operations; • managing contaminated ballast and hull transfers; • improving port waste reception facilities; • improving anti-fouling practices; • managing marine debris; • involving the community; • promoting education and outreach programs; • promoting targeted and resourced research; • developing industry action; • contributing to IMO and other international activities; • promoting improved shipping standards; and • promoting use of environmental impact assessment Specifically, objective 5 of the Strategy is 'to promote reduction and eventual elimination of ship-sourced marine debris by: • Reviewing the nature and extent of marine debris and waste problems; and • Developing and implementing strategies to (a) monitor waste and debris….and (b) reduce and manage waste…' Three national surveys completed during 1996 provide important baselines for evaluating future improved performance and management on waste reception facilities at ports, boat harbours and marinas and marine debris research and management strategies.
The National Water Quality Management Strategy	ANZECC and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ)	This strategy is guided by the principles of ecologically sustainable development and it aims to deliver a nationally consistent approach to water quality management. Its objective is 'to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development' (ANZECC and ARMCANZ, 2000). This strategy is relevant to Australian fresh and marine waters, and incorporates guidelines specific to debris. These include limits to debris and hazards to health and safety for primary (eg swimming) contact waters, limits to debris for secondary contact waters (eg boating), and limits to floating debris and other objectionable matter that impacts on the visual use of water.
Clean Up Australia Day	Clean Up Australia	Clean Up Australia Day has been operating since 1990, with a focus on urban areas. The program has been very successful at cleaning beaches across much of the Australian coastline, however little information is recorded on the types or quantities of litter collected.

5. Existing marine debris codes, organisations and activities in northern Australia

Activity	Lead organisation	Comments
National - regional		
Strategy and Action Plan for the Prevention of Marine Pollution in the Asia Pacific Region	N/A	The 'Working Together: Regional Workshop on Preventing Maritime Accidents and Pollution in the Asia-Pacific Region' was held in Townsville, Australia, on 20-23 April 1998. It brought together industry, related authorities, academic, and non-government community interests to formulate a strategy and action plan to enhance the protection of the marine environment from ship-based pollution, including marine debris.
The Net Kit: A Fishing Net Identification Kit for Northern Australia	WWF	This fishing net identification guide contains photographs of over 90 net types, with specifications of mesh size, twine size, colour, net use and probable country of origin. The guide is intended to provide a tool for standardised identification and reporting of derelict fishing gear by communities, government agencies, industry and researchers. The development of the guide was funded under a Coasts and Clean Seas (NHT) grant, and the Dhimurru Land Management Aboriginal Corporation and the NT Fisheries agency were partners in the project.
Marine debris database	WWF	WWF is developing a database that is intended to collate information on marine debris in northern Australia obtained through marine debris surveys.
Net coding system to identify derelict fishing nets	WWF	WWF Australia is developing and promoting a fishing gear coding system based on the concept of the 'rogue's yarn'. This method involves the substitution of standard net filaments with those of predetermined coloured filaments during a net's manufacture, to precisely identify manufacturer and type of net.
Various	Australian Institute of Marine Science (AIMS)	AIMS has adopted marine debris as a focus for an element of its research program over the next three years. The principal aim of this research focus is to reduced impacts of ghost fishing through knowledge of the trajectory of gear lost by the offshore fishery in the Timor and Arafura Seas region.
Various	Qld Department of Environment and Heritage, Parks and Wildlife	Qld Parks and Wildlife has coordinated a number of aerial surveys of the northern Australian coastline. One survey flight, focused on identification of marine turtle nesting sites, also noted sightings of marine debris and extended from Papua New Guinea to the NT border. Another aerial survey was undertaken between Weipa and the Jardine River, focused specifically on marine turtle entanglements in debris, and more than 620 nets were observed over 230km (Limpus, pers. comm., 2003).
Various	Sunfish	Sunfish has been involved in marine debris issues through clean-up days at selected estuaries (east coast Qld), in the development of general codes of practice containing anti-litter objectives and training in litter prevention and management through angler education courses. Sunfish has also produced angler education videos and an angler education manual that contain waste management guidelines and promote responsible angling behaviour.
Aboriginal Rangers' Conferences	N/A	Recommendations from the Wuyagiba Aboriginal Rangers' Conference (29-31August 2000) include: • Recommendation 9: This Rangers' Conference recommends that a network of communities interested in marine debris monitoring and research be supported; and • Recommendation 10: This Rangers' Conference recommends that Government needs to adequately resource and implement actions outlined in the "Recovery Plan for Marine Turtles in Australia".'
Sea Ranger Workshop	Northern Land Council	A number of sea ranger workshops have been held during 2003, where marine debris survey and mapping training activities have been undertaken. Dhimurru Land Management Aboriginal Corporation, and WWF are supporting this initiative.
Local		
Marine turtle entanglement monitoring, Cape Arnhem	Dhimurru Land Management Aboriginal Corporation	Dhimurru has conducted monitoring of turtle entanglements in derelict fishing gear at Cape Arnhem since 1996. This survey is the only long-term study of the impacts of marine debris across northern Australia. It is dependent on external funding and the use of helicopters to survey otherwise inaccessible coastline.
Video – Nhaltjan Nguli Miwatj Yolngu Djaka Miyapunuwu; Sea turtle conservation and the Yolngu people of East Arnhem Land	Dhimurru Land Management Aboriginal Corporation	This video documents some of the findings of marine turtle research activities in which Dhimurru has been involved. In particular it details some of the direct impacts of marine debris, especially fishing nets, on coastal communities and marine species and in the coastal waters of north-east Arnhem Land.
Marine debris beach surveys and clean-ups, northern Australia	WWF	WWF is coordinating marine debris surveys in partnership with Dhimurru and Conservation Volunteers Australia at Cape Arnhem, the Anindilyakwa Land Council at Groote Eylandt, and the Mathakal Homelands Resources Centre at Elcho Island. A number of other community groups are also interested in becoming involved in debris surveys.

Activity	Lead organisation	Comments
Coastal surveys (Beachwatch)	NT Parks and Wildlife	Three sites in the NT were surveyed in 1994 as part of a program called Beachwatch. Plastics were found to be the outstanding item on the beaches surveyed (Beachwatch, 1994). Results from these surveys were not published and the surveys did not continue.
Proposal for the removal of ghost nets in the Gulf of Carpentaria	Northern Gulf Resource Management Group	The Northern Gulf Resource Management Group has developed a funding proposal to convene a meeting of all communities and interest groups affected by ghost nets in the Gulf of Carpentaria. The aim of the meeting is to discuss and develop collaborative responses to marine debris issues in the Gulf and to develop monitoring methods and an investment plan for resourcing a 4 – 5 year program aimed at reducing the incidence of ghost nets.
Beach clean-up and monitoring, Pennyfeather Beach (2002)	Cape Projects Group	This project was approved under Coastcare (NHT) but did not occur. The project was intended to involve the clean-up of derelict fishing nets and toxic waste and the preparation of a debris clean-up and monitoring management plan.
Flatback sea turtle inter-nesting habitat research (2001/2002)	Northern Territory University	This project was funded under the Marine Species Program (NHT) and involves analysis of the non-feeding (inter-nesting) areas used by flatback turtles nesting on Bare Sand Island, Fog Bay (NT). Potential threats from fisheries and other activities in the area will also be identified and their management implications assessed.
Marine debris beach survey, Greta Beach, Christmas Island	Christmas Island District High School	This survey has been funded under Coastcare (NHT) and involves a twice-yearly survey of debris that collects on Great Beach, and awareness-raising amongst students, the local community and national/international publicity.
Beach cleanup (Karumba Branch)	Queensland Seafood Industry Association	A 50km length of shoreline adjacent to Karumba is periodically cleaned up by commercial fishers based there.

6. Options to address marine debris in the Arafura Sea

The primary challenge in finding solutions to marine debris, is to achieve a balance between the production of wastes (especially persistent wastes) and their effective and environmentally sustainable disposal. Marine debris is ultimately the result of human behaviour such as littering and dumping and is therefore, at its roots, largely a social issue (Topping, 2000). Polluting behaviour is motivated by an array of economic, regulatory, societal, and technical influences at many different levels. Marine debris has many sources and has complex ecological, economic, public safety and cultural impacts. Consequently there is no single solution to marine debris. Rather, marine debris requires a range of carefully targeted integrated and collaborative solutions that address the socio-economic influences within the community of interest, good communication of sound information to specific audiences, effective legal arrangements, management and enforcement, and adequate technical means for compliance.

Raising awareness to encourage people to change polluting behaviour is an important part of a response to marine debris issues in northern Australia. Community-based initiatives are likely to be one of the most effective means to address marine debris issues in the Arafura Sea region, given remoteness and large Indigenous populations with customary responsibilities and Native Title rights. Community-based initiatives, however, cannot be used as a reason to absolve government of its responsibility. Problems associated with marine debris mostly originate from, or are expressed at, sites distant from its origin and involve numerous people beyond the control, influence and interest of local communities. Whether seen as the perpetrators or victims of regional marine debris issues, communities require support to alter practice, to build and maintain networks, and to have access to sound information.

Community-based beach clean-ups and surveys have played an important role in raising awareness and contributing baseline data and, in the short term, directly reducing the impacts of debris on coastal environments and species in northern Australia. They have also been important in involving local people in prevention of local impacts. However, beach clean-ups are generally resource intensive and they are the last opportunity to intervene in the life cycle of debris. Solutions to marine debris ultimately depend on a reduction in the amount of persistent debris entering the sea in the first place. The involvement of governments and industry at all levels is therefore critical. At the same time, even with a willing public and industry and effective laws and enforcement, marine debris problems cannot be resolved if the technical means for disposing of debris and avoiding impacts are absent.

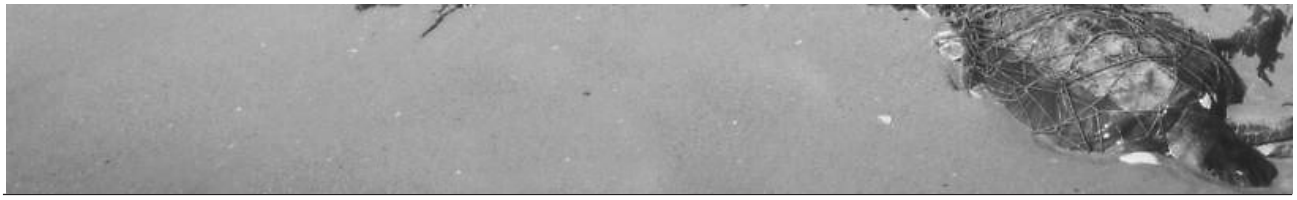
Mitigation of marine debris in the Arafura Sea requires action in all of the following areas:

- coordination of activities and strategies and development of collaborative solutions between governments (national/international), government agencies (State/Territory/Commonwealth), non-government organisations, researchers and industry groups;
- clarification of responsibility/accountability in regard to the management of marine debris in the Australian marine environment;
- education and incentives to encourage changes in polluting behaviour; and
- a focus on long-term monitoring.

Future discussions amongst key stakeholders will be critical in developing a collaborative and strategic approach towards the prevention and management of marine debris. As a consequence, a mechanism that facilitates discussion, coordination, and sharing of information on marine debris amongst stakeholders and interested groups is necessary. The interactions fostered in this way will be important in canvassing options, identifying priorities, allocating responsibilities and sourcing funding for the development of a strategic response to marine debris.

Building on the information provided earlier in this report, the following section connects this with a series of options aimed at addressing the sources and impacts of marine debris. Options are organised under the following categories:

- good information (research and monitoring)
- communication
- moral suasion (education and outreach)
- incentives
- direct control (institutional, legal and regulatory arrangements)
- technical options



6.1 Good information (research and monitoring)

- *Option 1a – analyse ocean circulation, wind and drift patterns in the Arafura Sea with a specific focus on identifying areas of accumulation of marine debris.*
- *Option 1b – investigate the feasibility of undertaking surveillance of 'ghost nets' through the deployment of tracking devices on derelict fishing nets at sea.*

Marine debris becomes part of the physical marine environment and is therefore directly influenced by the interactions of wind, sand and sea. Without some understanding of the dynamic system within which debris is transported and broken down, it is impossible to interpret fully and usefully the results of coastal surveys, or patterns and trends in composition, deposition and magnitude of the problem. In order to determine the movements of marine pollutants, and their interaction with environments and wildlife, the currents and circulation patterns of the nearshore and offshore marine environments of the Arafura Sea need to be better understood. United States oceanographers have recently been developing methods to apply knowledge of oceanographic processes and satellite remote sensing to identify and monitor regions where derelict fishing gear and other forms of debris are most likely to accumulate (Brainard, et al., 2000a, 2000b; Donohue, et al., 2000; Ingraham and Ebbesmeyer, 2000).

Knowledge about ocean circulation patterns cannot provide definitive information on the sources of marine debris. This is because the length of time which an item has been adrift and the distances it has therefore traveled are rarely precisely known, and because variability in ocean currents and wind patterns prevents accurate 'back tracking' to the site where the item was introduced to the marine environment. Nevertheless, as ocean currents and convergence processes can be efficient in accumulating debris into relatively well-defined zones, good knowledge of ocean and wind circulation patterns does provide a basis for targeting removal of fishing gear at sea before it damages wildlife or encounters sensitive coastal environments.

The persistence of lost fishing gear also needs to be better understood in order to determine the movement and potential impact of fishing debris over prolonged periods. By tracking derelict fishing nets at sea through the deployment of tracking devices, it is possible to determine their movement and as a consequence, their longevity in the marine environment, as well as regions of accumulation and potential navigational hazard (Donohue, et al., 2002). Research on the movements of derelict fishing nets could also be linked with the use of locator devices on gillnets.

- *Option 2 – undertake a comprehensive survey of the northern Australian coastline in order to identify marine debris 'hotspots' and determine coastal vulnerability.*

Research suggests that parts of the northern Australian coastline are 'hotspot' areas for marine debris, although survey results almost certainly under-represent the actual amounts of marine debris in Arafura Sea waters. A comprehensive survey of the northern Australian coastline is necessary to verify distribution of debris 'hotspots', and to develop a capacity to predict and assess the impact of debris on marine fauna and habitats. Existing information on debris accumulation in the northern Australian marine environment could be used to develop a statistical model from which a range of predictions could be sampled for validation. Monitoring programs may then be developed in representative areas, focused on areas of high debris accumulation.

- *Option 3 – develop a network of permanent land-based marine debris monitoring sites involving local communities.*

Marine debris surveys have been conducted along parts of the northern Australian coastline, but to date the results have not been sufficient to detect clear trends. The relative strengths/weaknesses of existing and past marine debris surveys conducted in northern Australia are primarily dependent on their original objectives. The surveys that sought to clean up a beach environment and gain community participation have been very successful at achieving educational objectives but have been less successful at producing consistent baseline datasets. More comprehensive, consistent and longer-term information will be required to identify effective solutions to management of marine debris at its source.

To robustly detect and demonstrate significant trends in the composition, quantities and impacts of marine debris, and to determine which types and sources of marine debris require priority attention, will require long-term support for consistent monitoring studies and their refinement and expansion across northern Australia. While beach surveys do not reduce the amount of debris being produced, they can be important in gathering statistical information on the magnitude of the problem as well as baseline data from which to determine the effectiveness of management arrangements. Surveys can also help in reducing accumulated debris and in educating and involving communities, industry and the media, thereby focusing attention on the need for better control and management of the problem.

Beach surveys may be classified as either beach-focused or ocean-focused (Ribic, et al., 1992). Beach-focused surveys estimate the amount of debris on a specific beach at a specific time. Ocean-focused surveys examine trends in marine debris on specific beaches over time as an indicator of oceanic conditions. Ocean-focused surveys

can provide important information on large derelict fishing gear (eg nets) trends (Donohue, et al., 2000). By selecting particular sampling sites and then monitoring certain types of typical marine-sourced debris, it is possible to approximate the level of vessel debris as distinct from other waste.

Given that nations around the Arafura Sea are already participants, it may be most useful to review the Ocean Conservancy's Marine Debris Monitoring Program and assess its relevance to northern Australia. The program involves an annual International Coastal Cleanup in which 77 countries participated in 2001, including Indonesia, Malaysia, Japan, Papua New Guinea, Taiwan, Thailand and the Philippines (Ocean Conservancy, 2003). The Ocean Conservancy uses 28 'indicator items' that correspond to debris produced by maritime and non-maritime activities. This allows international and regional comparisons of debris composition and magnitude. Australia contributed findings to the International Coastal Cleanup in 1992 and again in 2001, but does not have an ongoing involvement in the initiative (ANZECC, 1996a; Ocean Conservancy, 2003). Several surveys around the country have also based their survey design and methodology on the Ocean Conservancy approach including the Beachwatch survey conducted in the NT during 1994 (Beachwatch, 1994), and the surveys conducted at north-east Arnhem Land during 2000 and 2001 (Kiessling and Hamilton, 2001, 2003).

Aspects that should be considered in establishing marine debris monitoring sites across northern Australia include:

- A survey period of at least five years in order to establish a baseline dataset;
- Use of sandy beaches remote from urban stormwater influences;
- Photographs of different items to ensure consistency of classification of debris types;
- Common methods for counting and/or weighing debris items;
- Classification of size classes of items;
- Classification of the source/manufacturing origin of items where possible;
- Identification of indicator items to categorise the source of debris; and
- Recording of the weather and the state of the beach to identify causal conditions.

(Ribic, et al., 1992; Rees and Pond, 1995; Ribic and Ganio, 1996; Velander and Mocogni, 1999; Donohue, et al., 2000).

The collaborative work undertaken by Dhimurru in north-east Arnhem Land has demonstrated the potential of this type of community-based activity to generate useful information while involving those who have the greatest concern in developing solutions (Kiessling and Hamilton, 2001, 2003; Roeger, 2002). There is an opportunity to facilitate communication and sharing of expertise amongst Indigenous and non-Indigenous communities across northern Australia through existing regional management bodies (eg the Northern Gulf Resource Management Group) and the establishment of a network of marine debris monitoring sites. Extending support for those groups who, like Dhimurru, have demonstrated commitment and accrued both expertise and important baseline data, will be an essential element of any monitoring strategy.

- *Option 4 – develop consistent, statistically rigorous data collection protocols and survey methodology for use by different sectors on land and at sea.*

The generally remote nature of northern Australian coasts and waters indicates that extensive resources are unlikely to be available for future marine pollution monitoring. Air and sea-based surveillance activities are, however, likely to continue at significant levels, while fisheries operate extensively throughout the region. There is an opportunity to work with Customs, Coastwatch and the fishing industry to develop standardised survey forms and reporting procedures for recording observations of marine debris through normal operations. Dedicated shipboard trawl surveys may also be conducted opportunistically in association with commercial, experimental, or managed fisheries or with dedicated cruises targeting marine debris.

- *Option 5 – quantify the impacts resulting from the physical and chemical processes that lead to the death and injury of marine species.*

Records of entangled and stranded marine wildlife are almost entirely limited to land-based observations over a relatively small area of the northern Australian coastline. There is therefore a lack of information on the effects of ghostfishing on commercial and non-commercial species (including protected species). Long-term studies to monitor physical interactions between marine life and marine debris (especially derelict fishing gear) are required in order to:

- Document the catch rates by different types of debris in different areas over multi-year periods; and
- Test gear modifications that could make derelict gear less hazardous to marine life (eg the use of biodegradable materials).

There is also a lack of information on how plastics may be incorporated into the food web at levels well down the food chain – eg jellyfish and marine micro-organisms. The physical evolution of lost fishing gear needs to be better understood in order to determine the potential indirect (chemical) impacts of debris on marine environments and species over prolonged periods. Research is required to:

- Establish the nature of degradation pathways of synthetic debris in the marine environment;

- Determine the extent to which degradation products are contaminated by other potentially toxic compounds;
- Determine the potential toxicity of debris types on marine species; and
- Devise means to intercept the pathway of these contaminants into marine species and the environment.

Specific methodologies will depend on the species or population of interest and the source of mortality. However, ecologically, culturally and economically significant species and debris of demonstrated concern should strongly influence priorities. A useful base has been built by a small number of committed groups who recognised the significance of the problem some years ago (eg Anindilyakwa Land Council and Dhimurru). It is important that strategies for refinement and extension of quantitative studies build on existing efforts and commitment as well as the government and private investments already made. Opportunities should be explored for establishing similar programs in other areas.

Fishery observer programs, monitoring and surveillance activities conducted by the Customs Marine Unit, and the expansion of Indigenous ranger/sea ranger programs provide opportunities to collect data on the ingestion of plastics, and consideration should be given to supporting routine collection and analysis of samples from these sources. The possibility of fishing authorities monitoring the ingestion of, and entanglement in, debris by a range of marine fauna and the occurrence of lost and discarded fishing gear should also be considered.

- *Option 6 – develop a systematic sampling procedure and data recording protocol for suspected marine pests found attached to, or associated with, debris.*

The potential for introduction of pests to Australian waters via debris is significant, yet there is currently no systematic sampling procedure and data recording protocol for biota found attached to, or associated with, debris. Existing expertise with NT Fisheries, the Museum and Art Gallery of the NT and the Australian Government could be directed to developing sampling protocols to enable risks of marine pest incursions on debris to be determined.

- *Option 7a – identify all fisheries (both legal and illegal) operating throughout the Arafura Sea region incorporating analysis, where possible, of gear used, effort, target species, management arrangements, markets, and operational structure (ownership, administration, licensing).*
- *Option 7b – identify the socio-economic and technical factors influencing the loss and disposal of waste (especially fishing nets) within fisheries likely to be contributing to marine debris.*

There is a need for regional commitment by governments to tackle the issue of fishing debris. Participation and input by the fishing industry is also critical to developing acceptable and effective solutions.

There is a diverse range of stakeholders in the fishing industry operating in the Arafura Sea region, from owners and operators of large factory trawlers to members of small subsistence fisheries. At all levels, fishing debris results from a mix of intentional disposal and unintentional loss. Measures required to address each reason within each sector are potentially very different. Therefore, in order to devise effective intervention measures that address the reasons behind fishing debris entering the marine environment, a comprehensive knowledge of fishing operations and influences on them is critical.

- *Option 8 – verify the source of derelict fishing nets in the Arafura Sea through collaboration with surveillance operations in the retrieval of fishing nets and associated information from apprehended vessels.*

In order to develop solutions to marine debris, understanding of the source of problems is critical – from the manufacturer to the individual user. Derelict fishing nets provide valuable clues via their mesh size, colour, knot and fibre type, as to the origin of their manufacture and possible source. However, these details do not indicate those who were actually responsible for their loss or disposal. Source identification to a particular fishery and fleet requires a broad and detailed knowledge of fishing equipment and methods. Surveillance activities in northern Australian waters provide an opportunity to retrieve samples of fishing nets from apprehended vessels, obtain information on the nature of their fishing activities, and therefore to validate information on the users of specific fishing net types in the region.

- *Option 9 – determine the contribution of the shipping industry to marine debris in the Arafura Sea region, including the likely causes of debris originating from shipping and any gaps in existing on-board waste management arrangements.*

While the fishing industry in the Arafura Sea is contributing a significant proportion of debris to the marine environment, evidence suggests that cargo ships are also likely to be responsible for waste in northern Australian waters (Leitch, 1997; Kiessling and Hamilton 2001, 2003).

- *Option 10 – assess the economic impacts of marine debris through investigation of the interaction of marine vessels with debris via insurance company records, mechanics and diving companies who repair damaged vessels.*

Navigation hazards posed by marine debris, particularly for small craft, are poorly documented, although anecdotal reports suggest that marine debris presents a significant risk to mariners and their vessels through fouling of vessel propellers, rudders, keels, thrusters, and water intakes. These events result in a financial burden

to vessel operators through lost time and repair. Polluted fish catches and damage of active fishing gear also create difficulties. This problem may be particularly acute in areas where marine debris accumulates due to ocean currents, and where fishing and shipping activity is high.

- *Option 11 – develop a GIS model to allow for analysis of debris accumulation, species and vessel interactions, and coastal vulnerability on a regional scale.*

To facilitate efforts to identify, manage and monitor the impacts of debris in the Arafura Sea region, remotely sensed imagery coupled with information on ocean circulation patterns and wind patterns, field surveys, bathymetry, political boundaries, fisheries areas etc can best be organised and presented within a Geographic Information System (GIS).

6.2 Communication

- *Option 12 – establish a mechanism for government, non-government organisations, industry, researchers, and communities with an interest in marine debris to communicate and share information on the issue, particularly in regard to establishing priority actions and improving coordination of efforts.*

Marine debris is a complex issue that requires collaboration and coordination between many different groups and disciplines, including governments, non-government organisations, industry, researchers, and communities. Many groups are currently involved in marine debris issues throughout the Arafura Sea region, though to date there has been little coordination of effort in mitigation efforts or measures to reduce the problem at its source. A mechanism is required to bring stakeholders and interested groups together to discuss concerns and share information on marine debris, to decide on priority actions for its prevention and management, and to identify responsibilities and funding sources.

- *Option 13a – encourage the publication of survey results from northern Australia and the Arafura Sea region.*
- *Option 13b – develop links with the Global Marine Litter Information Gateway maintained by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA).*

In order to promote understanding of the local impacts of marine debris and to encourage dialogue between nations responsible for marine debris in the Arafura Sea region, publication of survey results should be encouraged, and links with the Global Marine Litter Information Gateway maintained by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) should be established.

6.3 Moral suasion (education and outreach)

- *Option 14 – investigate and develop education and outreach programs aimed at relevant groups contributing to marine debris in the Arafura Sea region in languages appropriate to the target audience, for example;*
  - prepare a targeted marine debris awareness raising video in relevant languages for distribution amongst those groups contributing to marine debris in the Arafura Sea.
  - investigate the effectiveness of supporting exchange visits between Indigenous coastal communities experiencing the impacts of marine debris in Australia and groups contributing to marine debris issues in the Arafura Sea region.

Education and outreach efforts have been viewed as an integral component of virtually all strategies to prevent marine debris. Programs are generally built around themes with the ultimate goal of changing the behaviour of polluters. While the effectiveness of education and outreach programs alone in motivating changes in behaviour has not been proven, the importance of and need for regional management involving education sensitive to local cultures has been reiterated at a number of international conferences and in various research papers (Sutinen, 1997; Laska, 1997; Gregory, 1999b; Morgan and Sheavley, 2000).

Approaches to awareness-raising and outreach need to be matched to the audience and the different groups who contribute to the issue of marine debris. There is scope for increased educational and awareness-raising activity with some sectors of marine-based industry in the Arafura Sea region, however the success or otherwise of past approaches should be reviewed and the feasibility and potential effectiveness of working with South-east Asian industries needs to be examined.

There also needs to be a better understanding of which sectors/groups are responsible for marine debris and why. Once this information is available, there is an opportunity to develop targeted awareness-raising programs based on contact with those who are being directly affected by debris. For example, exposing different groups to the consequences of their actions and those whose resources have been damaged may be an effective way of influencing behaviour, especially where enforcement and/or penalties are ineffective or inappropriate.

6.4 Incentives

- *Option 15 – investigate financial incentives to encourage retrieval, return and recycling of vessel-sourced waste, including derelict fishing gear, such as:*
  - tax credits for gear choice (eg items that can be recycled versus those that cannot),
  - gear/port/vessel inventories, gear deposits and bounty initiatives,
  - insurance for gear removal,
  - industry accreditation of sustainable practice in fisheries with specific reference to gear manufacture, use and handling, and
  - subsidised disposal repair, reuse and recycling initiatives.

There are currently few incentives to retrieve derelict fishing gear or return waste to land for disposal. Incentive-based solutions may be particularly helpful for marine debris issues in fisheries and fishing communities, but need to be carefully tailored to take local socio-economic parameters into consideration.

Studies in the United States have found that tax/subsidy systems are economically viable, but that they should be limited to carefully selected items in the waste stream (Laist and Liffman, 2000). Other potential methods for economic intervention include an explicit accounting for fishing gear use, deposits on new and replacement gear, and insurance (Pooley, 2000). There are also institutional changes that may serve to maximise incentives for gear retrieval, while the economic benefits associated with gear reuse and recycling needs to be investigated further.

- *Option 16 – investigate market/consumer/peer–based incentives such as:*
  - industry accreditation of sustainable practice in fisheries with specific reference to gear manufacture, use and handling; and
  - 'stewardship' arrangements for fishing gear, where the responsibility for proper disposal lies with the manufacturer of the product.

There is the potential for public - private enterprise relationships between fishing gear manufacturers, the plastics and fishing industry, and port authorities to promote the responsible management of waste. For example, there is potential for the Plastics Environment Council (of the Plastics and Chemicals Industries Association) to initiate a 'responsible use' campaign aimed at consumers and linked to educational campaigns. The Plastics Environment Council was formed by Australia's leading resin manufacturers, importers and major converters to educate the government and industry on the environmental aspects of plastics and to help implement sustainable waste management methods through research and development. Similar opportunities exist for the identification and promotion of ethical responsibilities and legal liabilities of gear manufacturers with respect to the impacts of derelict fishing gear on the marine environment.

6.5 Direct control (institutional, legal and regulatory arrangements)

- *Option 17 – analyse the effectiveness of existing legal, regulatory and management regimes with respect to marine pollution, especially marine debris, with a specific focus on opportunities for more effective implementation of MARPOL Annex V in the Arafura Sea.*

In order to encourage ratification of MARPOL Annex V and increase its effective implementation in the Arafura Sea region, there is a need to examine the effectiveness of existing international and domestic agreements and to increase the capacity of neighbouring States to comply with MARPOL requirements.

- *Option 18a – improve surveillance procedures and enforcement of MARPOL Annex V regulations.*
- *Option 18b – AFMA and AMSA to review provisions to enable observers to report on infringements of MARPOL Annex V.*
- *Option 18c – incorporate debris management requirements (return of rubbish, damaged gear etc to port for disposal) into fishery management plans.*
- *Option 18d – seek the introduction of mandatory reporting of lost fishing gear into fishery management plans within Australian waters and throughout the Arafura Sea.*

Within Australian waters, improvements in surveillance and prosecution for infringements of MARPOL Annex V are necessary to deter potential polluters, particularly in regard to fishing fleets and cargo vessels. Monitoring of breaches of MARPOL Annex V and domestic implementing legislation is part of the Australian Observer program on the northern prawn fleet. Useful information is obtained through this system, but cannot currently be used in evidence regarding breaches of the regulations. This situation needs to be reviewed in order to allow observers to have power to report on infringements.

Fisheries management programs are designed to promote sustainability of operations. Given the scale of the marine debris issue, loss or improper disposal of fishing gear has become a significant factor in determining sustainability at a number of levels, including additional mortality of target and non-target stocks, damage to habitats, and society's view of the fishing industry. Management of gear is therefore a legitimate concern of fisheries managers and the management plans they prepare.

- *Option 19 – clarify government responsibilities in regard to the management and retrieval of hazardous debris, and establish a mechanism to facilitate coordination of national and regional responses to marine debris issues.*

There is a need to introduce efficient procedures for at-sea and on-land retrieval of marine debris, especially in regard to debris presenting a navigational, safety and/or environmental hazard. There is also a need to coordinate existing governance and identify inefficiencies and gaps in current arrangements. Within Australia, marine debris interests and activities could be greatly enhanced by such simple steps as the designation of responsible personnel within existing agencies.

- *Option 20 – investigate the need and potential for establishing a regional fisheries organisation/arrangement for the Arafura and Timor Seas region.*

Fisheries that extend beyond the exclusive jurisdiction of one state (straddling ranges of widely distributed stocks or highly migratory fish stocks) are often managed by regional fisheries organisations or commissions established by multilateral agreements. While there are shared fisheries in the Arafura Sea region (eg gold band snapper), there is no regional fisheries organisation that oversees the management of these activities. In other parts of the world, regional fisheries organisations play an important role in managing fishing gear and related debris. The establishment of a similar arrangement in the Arafura Sea region could also embrace responsibility for management of fishing debris. Implementation of MARPOL requirements through an Arafura Sea regional fisheries organisation could also capture the activities of fishing vessels that otherwise would not be legally bound by the provisions of MARPOL (eg Taiwan).

6.6 Technical options

- *Option 21 – determine the capacity of ports throughout the Arafura Sea region to handle vessel-sourced waste, particularly derelict fishing gear.*

Despite MARPOL requirements for nations to provide adequate port disposal activities, many ports do not have reception facilities suitable for waste, including derelict fishing gear. Many land-based disposal sites discourage, or even prevent, disposal of fishing gear in landfills, and in some areas the costs of dumping at ports are prohibitive. Some research has been done on port reception facilities across Australia (ANZECC, 1996b), however little information exists on the capacity of ports to handle fishing related debris and even less information exists on the capacity of ports to receive wastes beyond Australian waters. Given that a significant proportion of the debris generated in the Arafura Sea is likely to be from sources outside Australian waters, the waste management facilities and arrangements at fishing vessels' home ports and international trading ports throughout the South-east Asian region need to be better understood.

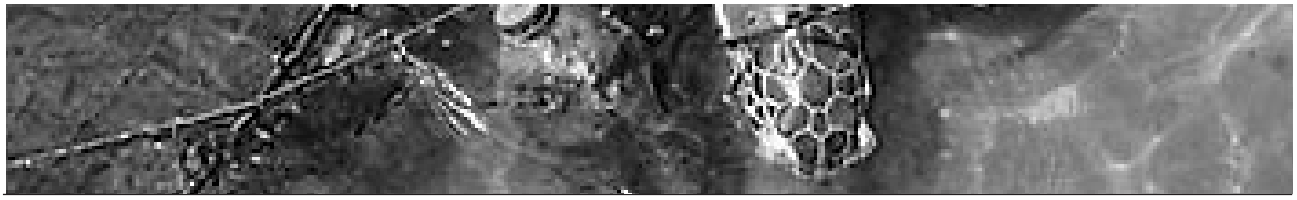
- *Option 22 – investigate the viability of fishing gear tagging, coding and marking to aid identification of the source of marine debris.*

Gear marking is a potentially useful tool to help focus prevention, reduction and enforcement efforts on specific domestic and international sources of derelict fishing gear. Unique marking of fishing gear has progressed little in northern Australia beyond the introduction of tags to the head and ground ropes of Australian commercial fishing nets used by the Northern Prawn Fleet (Sachse, 2000; Carne, 2001; Stone, pers. comm., 2003). This method does not enable the identification of scraps of webbing or other gear fragments that become detached from the headrope.

Easy identification of a manufacturer of fishing gear requires unique elements to be introduced during construction of the particular webbing, net, or other gear. These may be intentional tracers introduced to function as a trademark, or may be particular aspects of construction that result from the manufacturer's design. Identification to individual user and/or fleet requires insertion or application of unique identifiers after the gear has been purchased from the manufacturer or supplier (Henderson and Steiner, 2000).

Identification of net fragments also requires an unobtrusive marking system that does not affect the performance or durability of the gear (Henderson and Steiner, 2000). A range of tagging systems and methods are available (Jefferts, 1988). One such system is a coded wire tag (CWT) that was developed for biological applications but has been suggested as suitable for use as a gear tag (Henderson and Steiner, 2000). The advantages of the CWT are that it has enormous code capacity, tags are inexpensive and there is potential for automatic scanning of large samples. Limitations of the CWT include the fact that tags must usually be implanted in the line or webbing and are therefore usually not externally visible, and they must be removed from the item for reading.

Another identification system is that known as 'rogue's yarn', a name given to a yarn of a different twist and colour from the rest, which is inserted into rope or mesh, to enable identification and tracing (Webster Dictionary, 1913; Kemp, 1988). The advantages of rogue's yarn in the identification of fishing gear are that it is relatively inexpensive, there is no alteration to the net structure and efficiency, the coding is present throughout the entire net, and there are potentially thousands of unique colour-codings that can be attributed to individual fisheries (White, pers. comm., 2003). WWF is currently developing a project proposal that incorporates the concept of rogue's yarn as a method for identifying the origin of fishing nets (White, pers. comm., 2003). This method is currently only



suitable for multi-strand twines, and further development is necessary for implementation of similar coding systems in monofilament nets and lines (White, pers. comm., 2003).

Although, using this technology, it is potentially possible to identify derelict fishing gear down to the user level, application of the appropriate technology requires careful consideration of many factors (Henderson and Steiner, 2000). For example, providing uniquely marked gear is likely to add to costs of manufacture, resulting in higher costs to the consumer. A database of registered gear types and owners would also need to be established and maintained, on an international scale. The potential variables in identifying gear to the individual user/fleet are also considerable. For example, during the lifetime of a net, it may be sold, traded, loaned and thus used by multiple vessels. Another consideration is the longevity of derelict fishing gear in the marine environment – recovery of fishing gear may not occur until many years after its loss or disposal. Furthermore, if fishing gear identification is to be practical, it must contribute substantially to reducing debris at its source (Henderson and Steiner, 2000).
A central issue is to determine how source identification might contribute to debris reduction and the viability of its introduction in commercial fisheries around the world.

- *Option 23 – investigate the feasibility and effectiveness of gear modifications such as the introduction of sound reflecting materials and beacons, to minimise the impact of ghost nets on marine wildlife.*

Monofilament nets are usually extremely efficient though not very discriminating and, underwater, the thin nylon line used in their construction is nearly invisible. Derelict monofilament gillnets and driftnets in the Arafura Sea are responsible for a significant proportion of entangled species (Table 8). Research has been done on minimising the impact of monofilament gillnets on echo-locating animals such as whales, dolphins and porpoises. For example, a new type of net, developed by Atlantic Gillnet of Massachusetts, USA, contains a substance – barium sulphate – added to the nylon net during production, that reflects sound (Schueller, 2001). The additive does not affect the performance or the look of the net in any way, but it reflects sound waves in ranges used by echo-locating animals. Tests in both the United States and Denmark have confirmed the effectiveness of the wave-reflecting nets in preventing entanglement of non-target marine species (Schueller, 2001). Acoustic beacons have also been introduced to nets in parts of Australia, which prevent sharks, dolphins and seals approaching fishing nets (Crawford, 2000).

- *Option 24 – investigate the viability and potential effectiveness of the introduction of fishing gear repair, reuse and recycling initiatives at key ports in the Arafura Sea region.*

The Florida Fish and Wildlife Conservation Commission coordinates a monofilament recovery and recycling program aimed principally at recreational fishers. This program aims to encourage recycling of monofilament (high density, nylon fishing line that is used in fishing reels and the manufacture of fishing nets) through a network of line recycling bins (Berkely line recycling receptacles) and drop-off locations (Florida Fish and Wildlife Conservation Commission, 2003). A similar initiative is underway in Queensland (White, pers. comm., 2003). Rangers in north-east Arnhem Land have been using derelict fishing nets found on the coast to harden coastal tracks for vehicles and are also keen to explore options for reusing/recycling marine debris as a means of providing cost offsets and incentives for clean-up programs (Mununguritj pers. comm. 2003).

Several other areas in the United States have also implemented a fishing net/debris collection and recycling program for larger scale commercial fisheries. For example, monofilament net recycling has proven to be an economically viable operation and a benefit for more than 20 ports in the Pacific north-west where a program involving fishermen, government and port authorities has been implemented (US EPA, 1994; Minton, 2000). Skagit River Steel and Recycling, located in Washington, is the only company currently involved in net recycling in the United States. The company deals almost exclusively with nylon nets (gillnets and driftnets), through ports in the North-west US and Alaska. The principal markets for items made from the recycled nets (eg bicycle seats) are in Hong Kong, Taiwan, China and Japan (Minton, 2000). In some parts of the US feasibility studies have also been undertaken to assess the potential for burning used nets for power generation (Minton, 2000).

Trawl net reuse is also promoted in a number of US ports, However the synthetic materials (polypropylene and polyethylene) used to construct trawl gear are problematic for recycling because they degrade. Also, due to the low value of polypropylene nets and the presence of gear such as chains and rollers, recycling of these net types tends to be very labour intensive (Minton, 2000). The economic costs and benefits associated with fishing gear repair, reuse, and recycling initiatives therefore need to be investigated further to determine their feasibility in the Arafura Sea region.

- *Option 25 – investigate the costs, benefits and feasibility of application of biodegradable materials in the manufacture of fishing gear.*

It is impossible to completely eradicate fishing debris and other waste from the marine environment, and therefore it is important to consider alternative technologies in the manufacture of fishing gear.

There are hundreds of different types of plastics and plastic compositions, but of these, only four or five types are commonly used in the manufacture of fishing gear (Andrady, 2000). Synthetic fibres currently used in fishing gear construction can perish, albeit very slowly, with exposure to UV radiation and microbial degradation (Minton, 2000). However, research has shown that plastics (notably plastics used in fishing nets and rope) floating at sea tend to break down at a much slower rate compared to the same plastic material exposed outdoors on land (Andrady, 1990, 2000).

While the technology currently exists to chemically modify plastics to accelerate degradation and decomposition, little is known about the effectiveness of these techniques in the marine environment. In regard to the fishing industry there is an important question regarding the trade-off between durability of the gear and its degradability in the ocean, as well as the performance and safety of degradable plastics in fishing gear construction (Minton, 2000). The cost of degradable materials remains significantly higher than synthetic fibres currently used, and they may actually encourage polluting behaviour if people perceive them to be harmless to the environment. Perhaps most importantly however, while conventional biodegradable plastics are effective at converting large pieces of plastic into smaller pieces, the powdery residues of degraded products do not 'disappear' but persist in the environment, where they may affect species such as filter feeders and birds.

Recently, new plastics, sometimes referred to as 'true degradables' or biodegradable polymers, have been developed (eg Mater-Bi). These are plastic, or plastic-like, materials that are not modified to encourage their breakdown but are inherently degradable and so leave no polymer or toxic residues (Hall, pers. comm., 2001). They include starch-based plastics blended with a biodegradable polymer. These new materials may be suitable as alternatives to the non-degradable polymers now being used in sheet or film form (plastic bags etc but not fishing nets), or in small components of conventional fishing gear (eg biodegradable float releases to minimise ghostfishing by reducing the vertical profile of a net). They are most widely known in Australia in their use in disposable cutlery, waste collection bags and frozen fishing bait bags. Biodegradable polymers are not currently used in the manufacture of entire fishing nets or line, although polymers such as Mater-Bi do have the necessary physical properties to be used in these applications (Hall, pers. comm., 2001).

Degradable and biodegradable, 'controlled lifetime' fishing gear may significantly assist in reducing impacts on marine mammals and other species. Research on biodegradable plastics also provides an important basis for identifying plastic compounds appropriate to easy recycling (Andrady, 2000). However, much work needs to be done before technical solutions such as biodegradable fishing gear will provide a practical solution to minimising the impacts of debris on marine environments and species. In the meantime, more may be gained in directing efforts at developing targeted incentives to encourage the return of damaged and unwanted gear to shore, where it may be efficiently recycled.

Table 12. Summary of Options

Category	Option	Option no.
Good information	Analyse ocean circulation, wind and drift patterns in the Arafura Sea with a specific focus on identifying areas of accumulation of marine debris	1a
	Undertake a comprehensive survey of the northern Australian coastline in order to identify marine debris 'hotspots' and determine coastal vulnerability	2
	Develop a GIS model incorporating information on debris accumulation, species and vessel interactions, and coastal vulnerability as a planning and assessment tool on a regional scale	11
	Identify all fisheries (both legal and illegal) operating throughout the Arafura Sea region incorporating analysis, where possible, of gear used, effort, target species, management arrangements, markets, and operational structure (ownership, administration, licensing)	7a
	Identify the socio-economic and technical factors influencing the loss and disposal of waste (especially fishing nets) within fisheries likely to be contributing to marine debris	7b
	Verify the source of derelict fishing nets in the Arafura Sea through collaboration with surveillance operations in the retrieval of fishing nets and associated information from apprehended vessels	8
	Determine the contribution of the shipping industry to marine debris in the Arafura Sea region, including the likely causes and any gaps in existing waste management arrangements	9
	Develop consistent, statistically rigorous data collection protocols and survey methodology for use by different sectors on land and at sea	4
	Develop a network of permanent land-based marine debris monitoring sites involving local communities	3
	Quantify the impacts resulting from the physical and chemical processes that lead to the death and injury of marine species	5
	Assess the economic impacts of marine debris through investigation of the interaction of marine vessels with debris via insurance company records, mechanics and diving companies that repair damaged vessels	10
	Investigate the feasibility of undertaking surveillance of 'ghost nets' through the deployment of tracking devices on derelict fishing nets at sea	1b
	Develop a systematic sampling procedure and data recording protocol for suspected marine pests found attached to, or associated with, debris	6
Communication	Establish a mechanism for government, non-government orgnisations, industry, researchers, and communities with an interest in marine debris to communicate and share information on the issue, particularly in regard to establishing priority actions and improving coordination of efforts	12
	Encourage the publication of survey results from northern Australia and the Arafura Sea region	13a
	Develop links with the Global Marine Litter Information Gateway maintained by the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)	13b
Moral suasion	Investigate and develop education and outreach programs aimed at relevant groups contributing to marine debris in the Arafura Sea region in languages appropriate to the target audience, for example: - Prepare a targeted marine debris awareness raising video in relevant languages for distribution amongst groups contributing to marine debris in the Arafura Sea - Investigate the effectiveness of supporting exchange visits between Indigenous coastal communities experiencing the impacts of marine debris in Australia and groups contributing to marine debris issues in the Arafura Sea region	14
Incentives	Investigate financial incentives to encourage the retrieval, return and recycling of vessel sourced waste, including derelict fishing gear, such as: - tax credits for gear choice (eg items that can be recycled versus those that cannot) - gear/port/vessel inventories, gear deposits and bounty initiatives - insurance for gear removal - subsidised disposal, repair, reuse and recycling initiatives	15
	Investigate market/consumer/peer based incentives such as - industry accreditation of sustainable practice in fisheries with specific reference to gear manufacture, use and handling - 'stewardship' arrangements for fishing gear, where the responsibility for proper disposal lies with the manufacturer of the product	16

6. Options to address marine debris in the Arafura Sea

Category	Option	Option no.
Direct control	Analyse the effectiveness of existing legal, regulatory and management regimes with respect to marine pollution, especially marine debris, with a specific focus on identification of the opportunities for more effective implementation of MARPOL Annex V in the Arafura Sea region	17
	Improve surveillance procedures and enforcement of MARPOL Annex V regulations	18a
	AFMA and AMSA to review provisions to enable observers to report on infringements of MARPOL Annex V	18b
	Incorporate debris management requirements (return of rubbish, damaged gear etc to port for disposal) into fishery management plans	18c
	Seek the introduction of mandatory reporting of lost fishing gear into fishery management plans within Australian waters and throughout the Arafura Sea	18d
	Clarify government responsibilities in regard to the management and retrieval of hazardous debris, and establish a mechanism to facilitate coordination of national and regional responses to marine debris issues	19
	Investigate the need and potential for establishing a regional fisheries organisation/arrangement for the Arafura and Timor Seas region	20
Technical means	Determine the capacity of ports throughout the Arafura Sea region to handle vessel sourced waste, particularly derelict fishing gear	21
	Investigate the viability of fishing gear tagging, coding and marking to aid identification of the source of marine debris	22
	Investigate the feasibility and effectiveness of gear modifications such as the introduction of sound reflecting materials and beacons, to minimise the impacts of ghostnets on marine wildlife	23
	Investigate the viability and potential effectiveness of the introduction of fishing gear repair, reuse and recycling initiatives at key ports throughout the Arafura Sea region	24
	Investigate the costs, benefits and feasibility of application of biodegradable materials in the manufacture of fishing gear	25

7. Conclusions

Marine debris is a serious issue on the undeveloped coastline and in the seas of northern Australia.

As many of the items lost or dumped at sea persist for extended periods and the entry of new material appears to be continuing or accelerating, the problem will continue to grow unless decisive action is taken. Impacts are numerous, including aesthetic degradation of coasts and seas, loss of marine life, damage to marine habitats of intrinsic and commercial value, damage to infrastructure and equipment and consequent loss of production, and threats to public safety. Indigenous owners of much of the coastline who remain economically dependent on coastal waters are particularly affected.

Most debris is likely to originate from commercial fishing activity with a significant proportion also originating from shipping activities. Much debris found in Australian waters is also likely to come from overseas vessels.

Options to reduce the problem and its impacts can be divided into two broad classes: those directed at modifying the behaviour of fishers and other mariners, and technical options to reduce the persistence and impact of debris once it has entered the sea. In both cases there is a great need for good information on the extent and magnitude of marine debris issues, improved national policy and legislation and enforcement of existing and new law, and a critical role for education and training. A mechanism that enables exchange of information on marine debris, and provides a forum for discussion and agreement on strategic responses amongst stakeholders and managers, is also necessary.

Greatest short-term gains are likely to come from modification of behaviour, working through both incentives for better practice and increased disincentives (penalties) for, and probability of detection of, poor practice. In regard to incentives, provision of improved and easily accessed facilities for disposal of waste at both north Australian and Indonesian ports will be an important step. Other options include the introduction of fishing gear repair, reuse and recycling initiatives at key ports throughout the Arafura Sea region.

In regard to penalties for poor practice, a basic requirement is to increase the capacity to connect items of debris to the activities of particular nations, sectors, companies, vessels and/or individuals operating in or near Australian waters. This should include mapping of wind and drift patterns throughout the Arafura Sea region, mapping of all fishing operations in the region including identification of gear types, management arrangements and operational structures, careful analysis of the socio-economic drivers of polluting behaviour in the Arafura Sea, and verification of the source of derelict fishing gear through collaboration with gear experts and surveillance operations in the apprehension of illegal fishing vessels. Surveillance requirements face the same logistic constraints as other attempts to prevent illegal operations in the huge expanses of the sparsely populated north, compounded by the difficulty of pinpointing the exact origin of nets and other debris that may have been at sea for many years. Improvements to permanently mark or otherwise reliably identify fishing gear would be a significant step towards mitigating the problem. Clarification of government responsibilities in responding to marine debris concerns such as reports of hazardous debris at sea is also critical.

In regard to long-term management of marine debris issues, a comprehensive (or at least representative) monitoring program is required that provides good baseline data from which to determine the effectiveness of future management arrangements. A monitoring program should incorporate the development of rigorous data collection protocols for use by different sectors on land and at sea, as well as a series of permanent marine debris monitoring sites across northern Australia operated in collaboration with local communities.

While we ignore marine debris, or otherwise fail to respond effectively, marine debris in the northern Australian marine environment will get progressively worse. Reducing marine debris is a complex challenge requiring a multi-faceted approach and involving the collaboration of an array of researchers, industries, coastal managers, governments and the perpetrators themselves. The information and analysis provided in this report is intended to identify options and to promote some initial steps towards broad solutions to marine debris from marine sources in northern Australia.

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Finding solutions to derelict fishing gear and other marine debris in northern Australia

Project Proposal
November 2002

1. Objective

To identify strategic actions and key information necessary to implement solutions to marine debris, especially derelict fishing gear, in northern Australia's marine environment.

2. Background

Marine debris is a navigational hazard, a health risk and is significantly impacting Indigenous coastal communities in northern Australia. Marine debris is also threatening the abundance and survival of native marine species and ecological communities. In particular, significant numbers of marine turtles including all five marine turtle species listed as endangered or vulnerable under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), have been found stranded as a result of derelict fishing nets, fishing line and plastic waste in northern Australia. Evidence indicates that fishing debris is at least a similar order threat to marine turtle populations as active trawling effort was prior to the introduction of Turtle Exclusion Devices (Kiessling and Hamilton 2001).

Northern Australia is especially vulnerable to marine debris given the proximity of intensive fishing operations, remote and largely inaccessible coastlines, and the existence of some of the last remaining global strongholds of threatened species such as marine turtles and dugong.

Survey work indicates that the majority of debris washing ashore on northern Australian coasts is likely to have originated from southeast Asian fishing operations (Sloan, et al 1998; Alderman 1999; Kiessling and Hamilton 2001). As a result of its cross-border origins and impacts, finding solutions to marine debris in the northern Australian marine environment requires the coordination of data gathering and targeted action at local, national and international levels. However, while interest and support for marine debris initiatives is growing amongst a range of community and industry groups, researchers and government agencies, there is as yet no strategic framework to ensure coordination and focus to regional responses to the issue.

At the local level, Dhimurru Land Management Aboriginal Corporation represents a number of Indigenous coastal communities that have considerable concerns about the impacts of marine debris on natural, cultural and food resources. Dhimurru and WWF Australia have been working in partnership for over three years. Dhimurru has extensive experience in monitoring marine turtles entangled in marine debris and together Dhimurru and WWF have been involved in monitoring marine debris washing ashore in north-east Arnhem Land (Leitch 2001). WWF is also assisting in the clean-up of debris from remote coastlines in partnership with the Anindilyakwa Land Council (Groote Eylandt) and Mathakal Homelands Resources Centre (Elcho Island). A number of other community groups are also interested in becoming involved in debris clean-ups and monitoring.

At the regional and international level, several research agencies (Australian Institute of Marine Science, Northern Territory University), government agencies (National Oceans Office) and regional committees (Environment and Health Committee, Northern Australian Fisheries Management Workshop, Arafura and Timor Seas Expert Forum), amongst others, have acknowledged marine debris as an issue of critical concern and provide possible mechanisms for pursuing cross-border solutions to a shared problem.

3. Project Outline

The international origins of marine debris in northern Australian waters demands a coordinated, cooperative and targeted approach towards implementing solutions across borders and across seas.

This proposal seeks funds to take stock of existing data, to identify current and proposed activities, and information gaps, and to develop a collaborative and strategic framework for focusing future actions toward the prevention and management of marine debris in the northern Australian marine environment.

The proposed project will involve:

A. Compilation and analysis of up-to-date information on the sources, locations, impacts of marine debris in northern Australia including:
   - sources and manufacture of derelict fishing gear,
   - marine species (especially turtle) entanglement in derelict fishing nets,
   - marine debris 'hotspots', and
   - current activities, both with Australia and in neighbouring states targeting the prevention and/or management of marine debris.

B. Identification of management driven information needs,

C. Development of a framework of strategic actions at multiple scales (including international) to reduce the incidence and impacts of marine debris, especially derelict fishing gear, in the northern Australia marine environment.

4. Methodology

This project will principally involve desktop research and consultation with key stakeholders and interests within Australia. It will not involve new research, or analysis of arrangements beyond Australian waters, but should provide a basis for future negotiations with neighbouring states.

As the project is intended to identify strategic actions aimed at finding and subsequently implementing solutions to marine debris on a regional scale, it is expected that collaboration with regional neighbours in information gathering and implementation of strategic responses will form a critical element of project recommendations.

5. Project Outputs

- Research report detailing the current state of knowledge on the sources and impacts of marine debris in northern Australian waters, and the success of existing arrangements in Australia in tackling marine debris concerns.
- Information basis for future negotiations with South-east Asian fishing nations regarding the prevention and management of fishing debris in the Arafura and Timor Seas.
- Series of feasible, targeted recommendations and implementation approaches for finding solutions to derelict fishing gear and other marine debris in the northern Australian marine environment.

6. Timeframe

The project will be undertaken by a consultant and is expected to require around 20 days to complete.

Listed and protected marine and coastal species found in the Gulf of Carpentaria and Arafura Sea as listed under the Commonwealth EPBC Act 1999 *(EPBC), the World Conservation Union Red List (IUCN), the Queensland* Nature Conservation Act 1992 *(NCA), and the* Northern Territory Parks and Wildlife Conservation Act 2000 *(TPWC)*

Note:

CR Critically Endangered – a taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.

EN Endangered – a taxon is Endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.

VU Vulnerable – a taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.

Rare – Rare wildlife is defined in the *Queensland Nature Conservation Act* 1992 as including native wildlife whose population is represented by (a) a relatively large population in a restricted range; or (b) smaller populations thinly spread over a wider range.

Listed – Listed species are defined under the *EPBC Act* 1999 and include migratory species listed in appendices to the Bonn Convention (*Convention on the Conservation of Migratory Species of Wild Animals*) for which Australia is a Range State under the Convention; the Agreement between the Government of Australia and the Government of the Peoples Republic of China for the Protection of Migratory Birds and their Environment (CAMBA); and the Agreement between the Government of Japan and the Government of Australia for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA). Listed migratory species also include any native species identified in an international agreement approved by the Commonwealth Environment Minister.

LR Lower risk – a taxon is Lower Risk when it has been evaluated, does not satisfy the criteria for any of the categories Critically Endangered, Endangered or Vulnerable.

DD Data deficient – a taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat or Lower Risk. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate.

Scientific name	**Common name**	**Habitat**	**EPBC**	**IUCN**	**NCA**	**TPWC**
Mammals						
Dugong dugon	Dugong	Intertidal and shallow subtidal seagrass meadows, inshore and offshore water columns	L	VU	VU	
Megaptera novaeangliae	Humpback whale	Inshore and offshore water columns	VU	VU	VU	
Balaenoptera physalus	Fin whale	Offshore water column	VU	VU		
Balaenoptera musculus	Blue whale		EN	EN		
Orcaella brevirostris	Irrawaddy river dolphin	Inshore water column, estuaries, rivers		DD	R	
Sousa chinensis	Indo-Pacific humpback dolphin	Inshore water column, estuaries, rivers		DD	R	
Balaenoptera edeni	Bryde's whale	Inshore and offshore water columns		DD		
Mesoplodon densirostris	Blainville's beaked whale	Offshore water column		DD		
Ziphius cavirostris	Cuvier's beaked whale	Offshore water column		DD		
Steno bredanensis	Rough toothed dolphin	Offshore water column		DD		
Kogia simus	Dwarf sperm whale					
Lagenodelphis hosei	Fraser's dolphin	Offshore water column		DD		
Grampus griseus	Risso's dolphin	Inshore and offshore water columns		DD		
Physeter catodon	Sperm whale			VU		
Tursiops truncatus	Bottlenose dolphin	Inshore and offshore water columns		DD		
Stenella attenuata	Pantropical spotted dolphin	Offshore water column		LR		

Annex II

Scientific name	Common name	Habitat	EPBC	IUCN	NCA	TPWC
Mammals						
Stenella longirostris	Spinner dolphin	Inshore water column		LR		
Stenella coeruleoalba	Striped dolphin	Inshore water column		LR		
Feresa attenuata	Pygmy killer whale	Offshore water column		DD		
Orcinus orca	Killer whale	Inshore and offshore water columns		LR		
Globicephala macrorhynchus	Short finned pilot whale	Offshore water column		LR		
Mesembriomys macrurus	Golden backed tree rat	Vine thickets, woodlands, mangroves	VU	EN		
Xeromys myoides	False water rat	Mangroves, wetlands	VU	EN	R	
Sharks and fish						
Anoxypristis cuspidate	Narrow sawfish	Offshore benthic environment; inshore soft-bottom habitats;		EN		VU
Glyphis glyphis	Speartooth shark	Estuarine and river systems, turbid waters of the inshore water column;	CR	EN		EN
Glyphis sp. A	Northern river shark	Shallow freshwater to brackish river reaches	EN			EN
Himantura chaophraya	Freshwater whipray	Fresh and estuarine waters		VU		DD
Pristis clavata	Dwarf sawfish	Shallow coastal and estuarine waters		EN		VU
Pristis microdon	Great toothed/ freshwater sawfish	Estuarine and river systems, inshore water column	VU	EN		DD
Pritis zijsron	Green sawfish	Coastal and estuarine systems, muddy substrates		EN		VU
Reptiles						
Crocodylus porosus	Estuarine crocodile	Rivers	L		VU	
Caretta caretta	Loggerhead turtle	Offshore and inshore water columns	EN	EN	EN	EN
Chelonia mydas	Green turtle	Inshore water column	VU	EN	EN	LR
Dermochelys coriacea	Leatherback turtle	Inshore water column, estuaries	VU	CR	VU	VU
Eretmochelys imbricata	Hawksbill turtle	Inshore and offshore water columns, reefal communities	VU	CR	VU	DD
Lepidochelys olivaceae	Olive ridley turtle	Inshore water columns	EN	EN	EN	DD
Natator depressa	Flatback turtle	Inshore and offshore waters	VU	DD	VU	DD
Hydrophis atriceps	Black headed seasnake	Offshore and inshore water columns			R	
Varanus semiremex	Rusty monitor	Mangroves			R	
Birds						
Cisticola juncidis normani	Zitting cisticola (Normanton subsp.)	Tall grass on coastal plains			R	
Haematopus fuliginosus	Sooty oystercatchter	Beaches, tidal mudflats			R	
Ephippiorhynchus asiaticus	Black necked stork	Coastal wetlands			R	
Esacus neglectus	Beach stone curlew	Beaches, tidal mudflats			VU	
Numenius madagascariensis	Eastern curlew	Estuaries, tidal mudflats		LR	R	
Phaethon rubricauda	Red tailed tropicbird	Sea, islands, coast			VU	
Podiceps cristatus	Great crested grebe	Wetlands, bays			R	
Sterna albirfrons	Little tern	Coastal waters, lakes	EN		VU	
Tadorna radjah	Radjah shelduck	Wetlands, estuaries			R	
Tyto novaehollandiae kimberli	Masked owl (northern subsp.)	Forests, woodlands	VU		VU	