APPENDIX II

ENVIRONMENTAL SENSITIVITY INDICATORS

APPENDIX II - ENVIRONMENTAL SENSITIVITY INDICATORS

Contents

II.1 INTRODUCTION

II.1.1 Objective

This appendix provides a simple parameter to indicate the sensitivity of different marine environments to oil spills. Its purpose is to quantify the relative importance of oil spills in different locations, in order to convert the estimates of oil spill frequencies into indicators of environmental risk.

The indicator takes account of the susceptibility of the environment to damage by oil pollution, including the habitats, species present (especially rare or endangered ones), commercial resources (e.g. fishing, aquaculture or tourism), socio-cultural impacts (e.g. on local communities and amenities), and the difficulty of cleanup and recovery after a spill. It is traceable so that it is possible to see the contribution of each aspect of environmental sensitivity to the overall indicator.

II.1.2 Limitations

The study addresses the whole of the Australia's Exclusive Economic Zone (EEZ) and Offshore Territories, including the Australian Antarctic Territory. The risks are presented as average values for approximately 120 sub-regions of the EEZ. These consist of 40 coastal segments, divided into 3 distances offshore:

- Near-shore (0-12nm)
- Intermediate (12-50nm)
- Deep-sea (50-200nm)

Therefore, the environmental sensitivity must be obtained at the same level of granularity, i.e. a single indicator for each of the 120 sub-regions.

In reality environmental sensitivity is extremely diverse and complex, and so the reduction of the entire Australian EEZ to 120 indicators implies extreme simplification compared to the real world. It is therefore important that the necessary degree of simplification is understood, and that the resulting indicators are not used inappropriately outside their intended application.

II.1.3 Previous Studies

Indicators of environmental sensitivity, as used in marine oil spill response planning, are usually based on the vulnerability index developed by Grundlach & Hayes (1978). This allocates shorelines to 10 types, based on characteristics such as shelter from wave action, potential penetration of oil, natural oil retention time and biological productivity. These are given vulnerability indices ranging from 1 to 10. However, this does not attempt to predict how much more sensitive an index of 10 is compared to an index of 9.

In the USA, environmental sensitivity mapping follows a system (NOAA 2002) that combines:

- Shoreline ranking according to their sensitivity to oil, the natural persistence of oil, and the expected ease of clean-up after a spill.

- Biological resources, including oil-sensitive animals and their habitats, and habitats that are themselves sensitive to spilled oil.

- Human-use resources, i.e. resources and places important to humans and sensitive to oiling, such as public beaches and parks, marine sanctuaries, water intakes and archaeological sites.

The same approach is used in several other countries, including Nigeria and several countries in Latin America. The shoreline ranking is a slight modification of the vulnerability index of Grundlach & Hayes (1978), but the biological and human-use resources are not represented as single indices in any way that can be combined with it.

An environmental sensitivity atlas for the coast of Kenya (GEUS 2006) used a simple oil sensitivity index that summed indices for coastal type, biological resource and human use, obtaining an index that varied from 2 to more than 20. The values were based on a stakeholder seminar. It was evaluated along an index line located 500m offshore. It was not considered to be a realistic measure of relative risk, but was used to help select which areas to protect in the event of oil spills.

DNV's previous oil spill risk assessment for Australian ports and waters (DNV 1999) developed a method of applying sensitivity weightings to 16 different types of environmental receptors: world heritage sites, coral reefs/marine parks, mangroves, coastal wetlands, marine mammals, major fishing zones etc. The weightings for each receptor varied from 2 to 25. The total scores for each sub-region varied from 8 to 133. The method did not take account of the size of the receptor, and the weightings were purely judgemental. Their intended purpose was to indicate the relative risk of the different regions.

Various studies have estimated the average costs of oil spills, in a way that may be more suitable as a simplified indicator for the present study. DNV (2001) obtained a cost from the sum of the following elements:

- Clean-up costs - the direct expenditure on recovering oil at sea and cleaning the affected shore.

- Capital losses - the value of the ship and its cargo lost in the accident.

- Business losses - typically losses to business such as fishing and tourism, e.g. the value of fish stocks destroyed. They may include the legal costs associated with compensation claims. They may also include indirect losses to other businesses in the area, e.g. consequent on reductions in tourism.

- Natural resource damage - valuation of damage to the environment that has no market value. In the USA the term "natural resource damage" (NRD) covers direct-use business losses, recreational use losses and "non-use" value. It can be assessed by various methods, including contingent valuation (asking people about their hypothetical willingness to pay to avoid such damage), travel cost (valuing recreational use by means of the expenditure on travel to reach the site) and hedonistic pricing (based on the market value of adjacent property).

This gives quantitative values for each element, which cover the scope of the present study. However, this work only gives average costs, and does not address individual marine environments, so it gives only part of the information needed for the present study.

The US Environmental Protection Agency (EPA) Basic Oil Spill Cost Estimation Model (BOSCEM) sums three cost elements (Etkin 2004):

- Spill response cost, depending on the shore type and response method.
- Socioeconomic damage, depending on the socioeconomic and cultural value of the location.
- Environmental damage, depending on the freshwater vulnerability and habitat/wildlife sensitivity of the locations.

These give quantitative modifiers for each type of environment, which are in principle appropriate for the present study. However, they require the Australian environment to be evaluated in the same terms.

Several approaches are available to quantify the value of marine and coastal ecosystems (UNEP 2011), which could provide a basis for estimating the impact of oil spills, but in order to obtain indicators for the whole of the Australian EEZ a relatively simple approach has been used here.

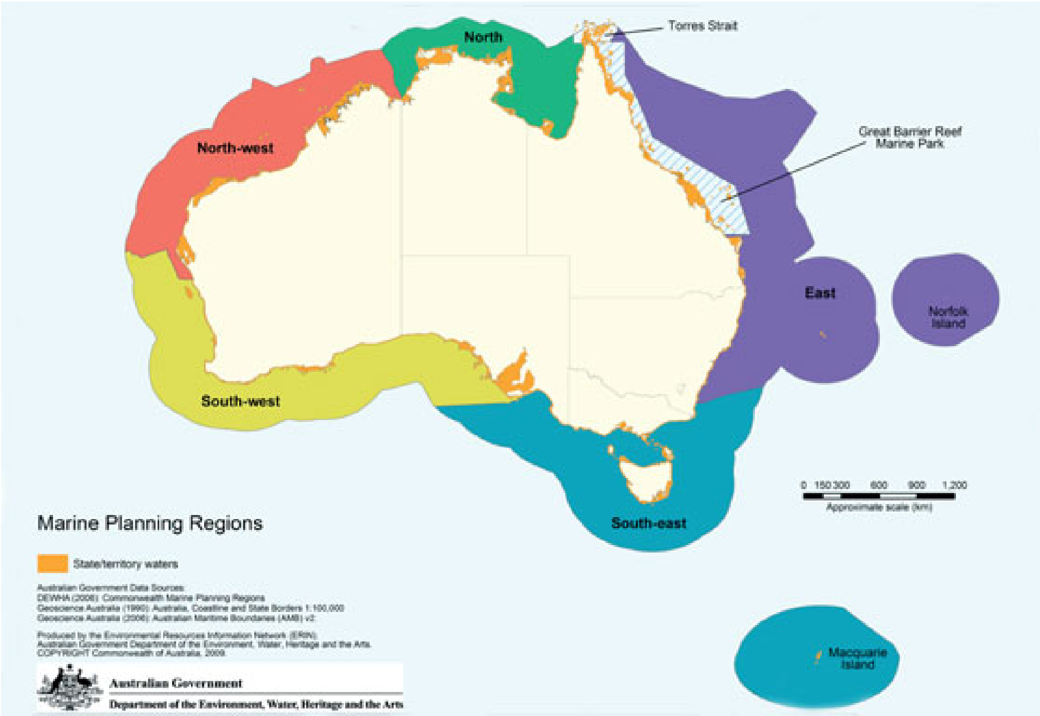
II.1.4 Data Sources for Australian Waters

Bioregional Profiles have been developed for 4 out of 5 regions of Australia's Commonwealth waters (Figure II.1.1). This is the first step in the development of Marine Bioregional Plans (DSEWPC 2011a), which will provide strategic guidance for Government decision-makers and marine users by describing each Marine Region's ecological processes and conservation values, including mapping sites of importance for protected species and communities; identifying regional priorities for action, based on an assessment of threats to conservation values and long-term policy goals; and developing strategic guidance for proponents and decision-makers.

AMSA has developed a computerised Oil Spill Response Atlas (OSRA) for Australia in GIS format. Relevant datasets for the present study include:

- Coastal topography and shoreline sensitivity to oil spills.
- Biological resources, including habitats, fisheries, birds, fish, shellfish, marine mammals, reptiles etc.
- Human-use resources, including recreation, resource extraction and national parks.

Figure II.1.1 Marine Planning Regions in Australia



OSRA provides the most detailed and comprehensive data that is available for oil spill response planning. For the present study, it has some limitations that have been addressed as follows:

- OSRA gives very detailed information on every part of the coastline. The present study requires a reduced level of detail that is appropriate for the small set of sub-regions. This has been achieved by sampling the OSRA data at intervals along the coastline.

- OSRA does not provide the same information in each State. The present study requires a consistent dataset in every State and Territory. Therefore the OSRA data has been supplemented with or replaced by equivalent data from other sources in order to provide consistent data. These data sources are explained below.

- OSRA does not provide all the types of information that are most convenient for the present study. Where other sources provide the necessary information in a more succinct form, these are used as explained below.

In future work, it would be desirable if there could be a more comprehensive connection between OSRA and the environmental sensitivity that is used in the risk assessment. However, it was not practical to develop this in OSRA within the present study.

II.2 METHOD

II.2.1 Definition of ESI

An environmental sensitivity index (ESI) for this study is defined as the average environmental impact of a tonne of oil spilled in a specific location, relative to a spill of the same oil in a defined baseline location (see Section II.2.4 below). ESI is intended to be independent of the oil type and spill quantity, which are considered separately in Appendix VI.

The ESI has a value of 1 in the baseline case, and values higher than 1 for more sensitive locations, and less than 1 for less sensitive locations.

The ESI is intended to be proportional to the cost of the spill, if all cost elements were taken into account (see Section II.2.2 below). Hence an ESI of 10 implies the cost of a spill in the location would be 10 times higher than in the baseline location. Thus the ESI could be called the relative cost of the oil spill. However, it is not at present possible to estimate such costs accurately, and therefore it is appropriate to use the name ESI rather than relative oil spill cost.

II.2.2 Elements of Environmental Sensitivity

The ESI takes account of the following main features of the environment:

- Physical sensitivity, including the environmental characteristics that affect the persistence of the oil and the expected ease of clean-up after a spill.
- Biological resources, including habitats, species (especially rare or endangered ones), and unique or rare natural environments.
- Human-use resources, including commercial fishing and aquaculture, tourism, other recreational activities and amenities, and other sites important to local communities.

The ESI for any location is therefore expressed as a function of separate indices for physical sensitivity (PSI), biological resources (BRI) and human-use resources (HRI) at that location:

$$ESI = f(PSI, BRI, HRI)$$

To some extent, these features overlap, and so are difficult to combine into a single index. However, they can be added by representing them as the following distinct cost elements:

- Physical sensitivity - represented by the clean-up cost for a spill.
- Biological resources - represented by the valuation of natural resource damage caused by a spill.
- Human-use resources - represented by the commercial losses caused by the spill, plus a valuation of the damage to social resources caused by a spill.

This allows previous cost estimates to be used to solve the difficult problem of how to quantify the ESI in units that are meaningful in absolute terms, rather than simply as ranking of different locations. It also helps avoid double-counting of resources that contribute to in different ways to environmental sensitivity.

Although the absolute costs of the three elements above can be added, ESI is an indicator of relative cost, so the three separate indicators must be weighted according to the cost breakdown in the baseline case. The cost breakdown has been obtained from oil tanker spills world-wide during 1992-97 (DNV 2001). This included a collection of all available public-domain information on oil tanker spills world-wide during this period and their cost elements. It included an analysis of the effect of spill size, including the disproportionate effect of the few large spills in the data, and a correction for the effect of missing cost data. More recent data would be desirable, but there is no obvious reason why the breakdown should have changed. The breakdown of cost elements was estimated as follows

- Clean-up cost - 30%, based on actual clean-up costs.
- Valuation of natural resource damage (NRD) - 50%, based on the ratio of NRD to actual costs in 4 cases where this was estimated.
- Commercial losses caused by the spill - 20% based on actual compensated business losses.

Hence, an appropriate weighting of the three indices for this study is:

$$ESI = 0.3\ PSI + 0.5\ BRI + 0.2\ HRI$$

II.2.3 Averaging Methods

Because the calculation sub-regions are large, the indices are each expressed as average values over the region. The averaging method is slightly different, depending on whether the location is on the coastline or at sea. The two types are:

- Coastline - for near-shore sub-regions, which are long thin strips adjacent to the coastline, the indices are averaged along the shoreline length.
- Open sea - for intermediate and deep-sea sub-regions, which are wider segments of open sea with no coastline, the indices are averaged across the sub-region area.

II.2.4 Baseline Case

The ESI is defined as the average environmental impact of spill in a specific location, relative to a spill in a defined baseline location. The baseline location is a hypothetical location that has average characteristics in every respect, such that its ESI is 1. This average should in principle be the average over the Australian EEZ, but because this is not defined at the start of the study, a notional average is adopted instead. This is a spill in the near-shore region, in an area of sandy beach, where fishing and recreational intensity are average for the Australian coast as a whole. If necessary, this notional average location can be adjusted in the future to renormalize the results to Australian average or another baseline sensitivity. This will not affect the ranking of sensitivity between different locations, and so is not critical for the results of the present study.

II.2.5 Limitations

The application of the method described above has led to ESIs that are relatively high for the near-shore sub-regions, and much lower for most intermediate and deep-sea sub-regions. This arises in part from the use of clean-up costs, since clean-up tends to be more intensive on the shoreline than at sea, and in part from the greater definition of environmental receptors on the shoreline compared to at sea. This does not necessarily reflect the sensitivity of the environment. However, at present no more realistic method is available.

Development of ESI has required substantial simplification and averaging across the large sub-regions. For example, PSI was developed by sampling only 10 points in each sub-region. This greatly simplifies reality and cannot reflect the true variation of PSI within the segment. Similarly, the averaging of ESI within each sub-region inevitably result in a loss of detail. Segments are up to 500 linear kilometres (and in some cases may be 1500km of actual coast), with an area of 6000km^2. Such large areas contain diverse environments. Averaging may conceal areas of high sensitivity if they are surrounded by relatively neutral areas. However, this was a choice made in the study specification, and no simple methods of improving the approach were identified during the study. Segments determined by risk factors rather than arbitrary spacing may have been more appropriate for ESI, but were not necessarily appropriate for ship traffic or other risk components. Overall, the ESI is considered a suitable metric, albeit highly simplified. Improvements could be developed in future work.

II.3 INDICATORS OF PHYSICAL SENSITIVITY

II.3.1 Shorelines

The most common classification of shoreline types (NOAA 2002) ranks them according to their sensitivity to damage from spilled oil as in Table II.3.1. This sensitivity ranking is controlled by the following factors:

- Relative exposure to wave and tidal energy
- Shoreline slope
- Substrate type (grain size, mobility, penetration and/or burial, and trafficability)
- Biological productivity and sensitivity

The same classification is in principle used in OSRA, although data samples are not always consistent. For example, shorelines may be classified as “beach” (not specified more precisely) or not classified at all. Nevertheless, it is usually possible to assign a rank to coastal locations based on OSRA. Where necessary, the shoreline types can be identified from the satellite photographs supplied by GoogleMaps.

Table II.3.1 Shoreline Types

RANK	TYPE	EXAMPLES
1	Exposed vertical impermeable substrates	Exposed rocky shores, cliffs Exposed solid artificial structures
2	Exposed non-vertical impermeable substrates	Rocky wave-cut platforms
3	Semi-permeable substrate; low potential for oil penetration and burial; infauna present but not usually abundant	Fine-grained sand beaches
4	Medium permeability; medium potential for oil penetration and burial; infauna present but not usually abundant	Coarse-grained sand beaches
5	Medium to high permeability; high potential for oil penetration and burial; infauna present but not usually abundant	Mixed sand and gravel beaches
6	High permeability; high potential for oil penetration and burial	Gravel beaches Rock breakwaters (riprap)
7	Exposed, flat, permeable substrate; infauna usually abundant	Exposed tidal flats
8	Sheltered impermeable substrate, hard; epibiota usually abundant	Sheltered rocky shores Sheltered artificial structures
9	Sheltered, flat, semi-permeable substrate, soft; infauna usually abundant	Sheltered tidal flats
10	Vegetated emergent wetlands	Marshes, swamps, wetlands, mangroves

The ranking does not indicate the absolute sensitivity of the different types. Available information on cost modifiers for different types of locations (Etkin 2004) indicates relatively small effects, with modifiers such as:

- Rock - 0.5
- Sand - 0.6
- Generic shore/open water - 1.0
- Mudflat - 1.4

- Wetland - 1.6

These small effects result from the fact that in the most sensitive environments the appropriate response is protection by booms, which are relatively low-cost, rather than clean-up, which is often impractical. This indicates that the greatest variation between locations would be in the biological rather than physical sensitivity (see Section II.4 below). However, this practical limitation is not appropriate for a sensitivity index, and so a greater variation would be appropriate.

A simple physical sensitivity indicator (PSI) consistent with this approach can be obtained as follows:

$$PSI_{type} = Rank/5$$

The ranks for each shoreline are taken from Table II.3.1. This in effect defines Rank 5 (mixed sand and gravel beaches) as the average (i.e. with a PSI of 1).

Since most coastal sub-regions include diverse shoreline types, the average PSI is calculated from the lengths of each type:

$$PSI_{region} = \sum_{types} \frac{L_{type}}{L_{total}} PSI_{type}$$

The contributions are estimated by sampling the coast at various points within the sub-region. In this study, approximately 10 sampling points have been used for each sub-region.

Where the coast type has little variation, judgement is used to evaluate the proportion of length in each shoreline type. In some cases, where OSRA does not have the full details of coastal morphology, a smaller set of shoreline types is used, consisting of cliff (Rank 1), beach (Rank 4) and mangroves (Rank 10). In the Antarctic, the ice coast is given a rank of 5.

II.3.2 Ports

The PSI for a port could be taken as equal to that for the adjacent coastline. In reality, ports are usually degraded environments, which are less sensitive than the surrounding region. Furthermore, there is a greater availability of vessels, people and equipment for rapid response.

For river ports, the sensitivity of the river environment could be obtained using a classification similar to that for shorelines. Available data on clean-up costs for spills in ports (Etkin 2000) indicates average costs per tonne 0.88x those in near-shore regions. Therefore the PSI of each port is taken as 0.88x the PSI for the adjacent coastline.

II.3.3 Open Sea

For intermediate and deep-sea sub-regions, which do not include any shoreline, the PSI could be chosen as follows:

- PSI = 1 as given by Etkin (2004) for open water. However, this would imply that open water is more sensitive than many coastal environments, which seems unrealistic.

- PSI = 0.2, based on the lowest shoreline rank.

- PSI = 0.36, based on the average cost per tonne of clean-up in offshore environments (>5km from the shore) compared to near-shore (Etkin 2000).

The latter approach is considered most appropriate.

II.4 INDICATORS OF BIOLOGICAL RESOURCES

II.4.1 General Approach

The general pattern of biological resources in Australian waters is extremely complex, and no simple indicator exists to rank different locations by biological sensitivity. Therefore the present study uses an indicator that is based on sites of acknowledged importance, such as world heritage sites, Ramsar sites, marine protected areas etc. This is supplemented with analyses of specific habitats that are recorded in OSRA.

The chosen biological resource indicator (BRI) is the fraction of the calculation sub-region's area (in the case of an area at sea) or coastal length (in the case of a coastal impact) that is within the specific site or habitat. In order to combine different types of sites and habitats, they are each given a weighting that reflects the overall value of oil damage to them.

$$BRI_{region} = \sum_{sites} \frac{L_{site}}{L_{total}} W_{site}$$

In effect, a weighting W for a specific site implies that a spill affecting 1 km of its length is considered equivalent to a spill affecting W km of a shore with no particular biological resources.

The total coastal length for a sub-region is measured as the shortest distance between its end points along a line that includes all points on the coast. On a concave coast, this is a straight line between the end points of the sub-region. On a convex coast, this is the actual shore length. The aim of this definition is to estimate the length of shoreline subtended towards an oil spill drifting towards the coast. It avoids the need to measure exactly the length of a very indented coastline.

The length of geographically localised sites (e.g. marine parks) can be measured from their furthest extents along the coast. The length of geographically dispersed sites (e.g. shorebird habitats) can be estimated by sampling the coast at various points within the sub-region (see Section II.3.1).

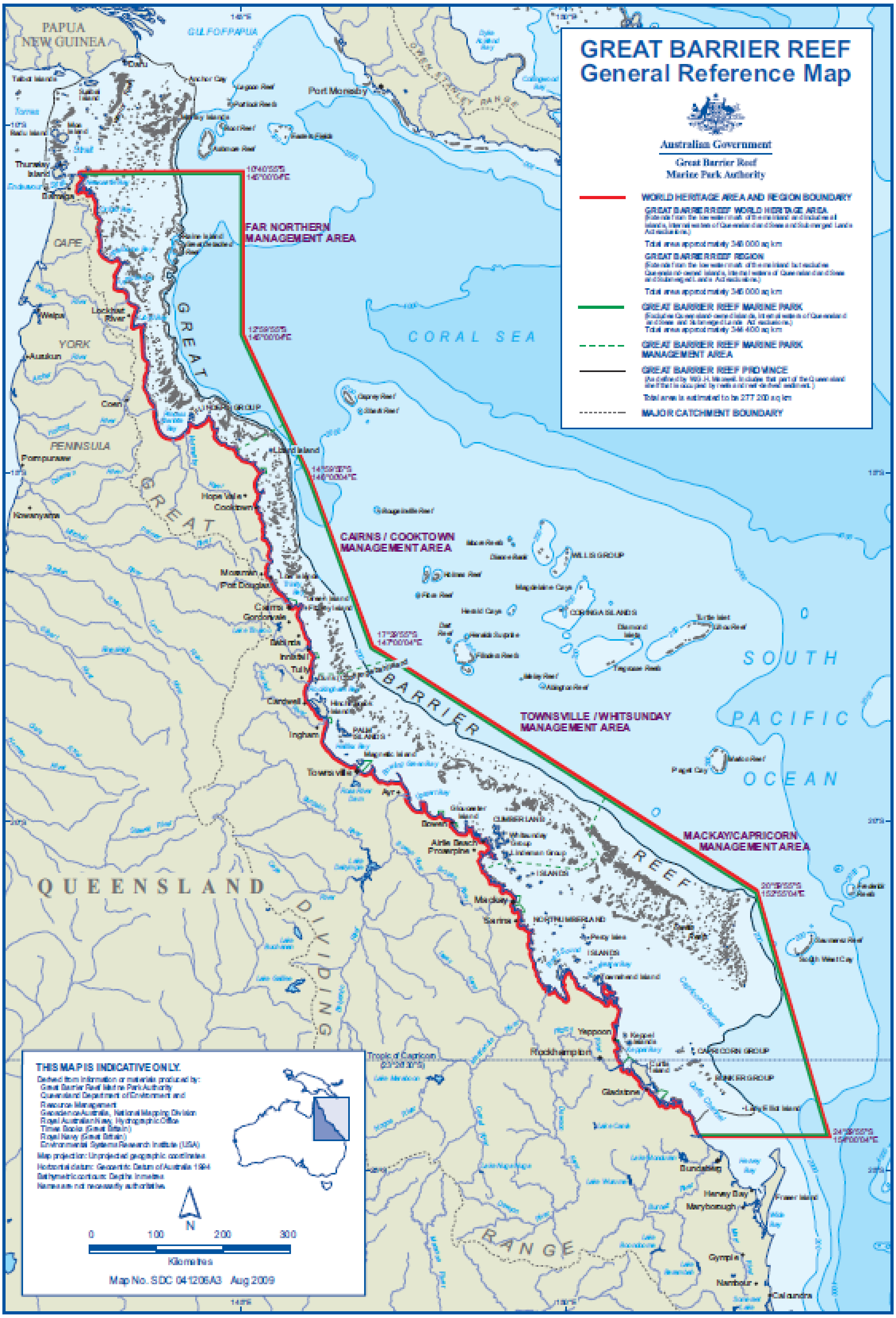
II.4.2 World Heritage Sites

The United Nations Educational, Scientific and Cultural Organization (UNESCO) lists sites of cultural and natural heritage around the world considered to be of outstanding value to humanity. World heritage sites in Australia's EEZ are (UNESCO 2011):

- Great Barrier Reef (Figure II.4.1) - a site of remarkable variety and beauty on the north-east coast of Australia. It contains the world's largest collection of coral reefs, with 400 types of coral, 1,500 species of fish and 4,000 types of mollusc. It also holds great scientific interest as the habitat of species such as the dugong ('sea cow') and the large green turtle, which are threatened with extinction.

- Shark Bay - with its islands and the land surrounding it, has three exceptional natural features: its vast sea-grass beds, which are the largest (4,800 km^2) and richest in the world; its dugong ('sea cow') population; and its stromatolites (colonies of algae which form hard, dome-shaped deposits and are among the oldest forms of life on earth). Shark Bay is also home to five species of endangered mammals.

Figure II.4.1 Great Barrier Reef World Heritage Area



- Lord Howe Islands - a remarkable example of isolated oceanic islands, born of volcanic activity more than 2,000 m under the sea, these islands boast a spectacular topography and are home to numerous endemic species, especially birds.

- Fraser Island - just off the east coast of Australia. At 122 km long, it is the largest sand island in the world. Majestic remnants of tall rainforest growing on sand and half the world's perched freshwater dune lakes are found inland from the beach. The combination of shifting sand-dunes, tropical rainforests and lakes makes it an exceptional site.

- Heard Island and McDonald Islands - located in the Southern Ocean, approximately 1,700 km from the Antarctic continent and 4,100 km south-west of Perth. As the only volcanically active subantarctic islands they 'open a window into the earth', thus providing the opportunity to observe ongoing geomorphic processes and glacial dynamics. The distinctive conservation value of Heard and McDonald – one of the world's rare pristine island ecosystems – lies in the complete absence of alien plants and animals, as well as human impact.

- Macquarie Island - an oceanic island in the Southern Ocean (34 km long x 5 km wide), lying 1,500 km south-east of Tasmania and approximately halfway between Australia and the Antarctic continent. The island is the exposed crest of the undersea Macquarie Ridge, raised to its present position where the Indo-Australian tectonic plate meets the Pacific plate. It is a site of major geoconservation significance, being the only place on earth where rocks from the earth's mantle (6 km below the ocean floor) are being actively exposed above sea-level. These unique exposures include excellent examples of pillow basalts and other extrusive rocks.

- Ningaloo Coast - on the remote western coast of Australia, including one of the longest near-shore reefs in the world. Ningaloo Coast is home to numerous marine species, among them a wealth of sea turtles, and annual gatherings of whale sharks.

World heritage sites are indicators of both biological and cultural resources, but in the present model they are most appropriate as indicators of internationally sensitive biological resources. Because of their rarity, it is difficult to quantify their relative sensitivity. The available data on oil spill costs (DNV 2001) shows a variation of up to a factor of 20 from the median line, and none of these were in world heritage sites. The spill of 4 tonnes from the bulk carrier "Shen Neng 1", which grounded on the Great Barrier Reef on 3 April 2010, was close to the median cost, although possible fines may increase this, and may reflect the physical damage to the reef as well as other factors. In the previous study (DNV 1999), a weighting of 25 was used, based on judgement. A high sensitivity weighting is expected, because of the value and rarity of these sites. Therefore a weighting of 25 is used here. However, in contrast to the previous study, the current method takes account of the size of the site.

II.4.3 Marine Protected Areas

The Australian Government manages an estate of marine protected areas (MPA) that are Commonwealth reserves under the Environment Protection and Biodiversity Conservation Act 1999 (DSEWPC 2011b), as shown in Figure II.4.2. The South-east Commonwealth Marine Reserve Network includes 14 temperate deep sea marine reserves covering representative examples of the diverse seafloor features and associated habitats found in the South-east Marine Region (Figure II.4.3). In other areas, new MPAs will be established to meet national guidelines under which all Australian governments are developing the marine reserve system.

Figure II.4.2 Commonwealth Marine Reserves

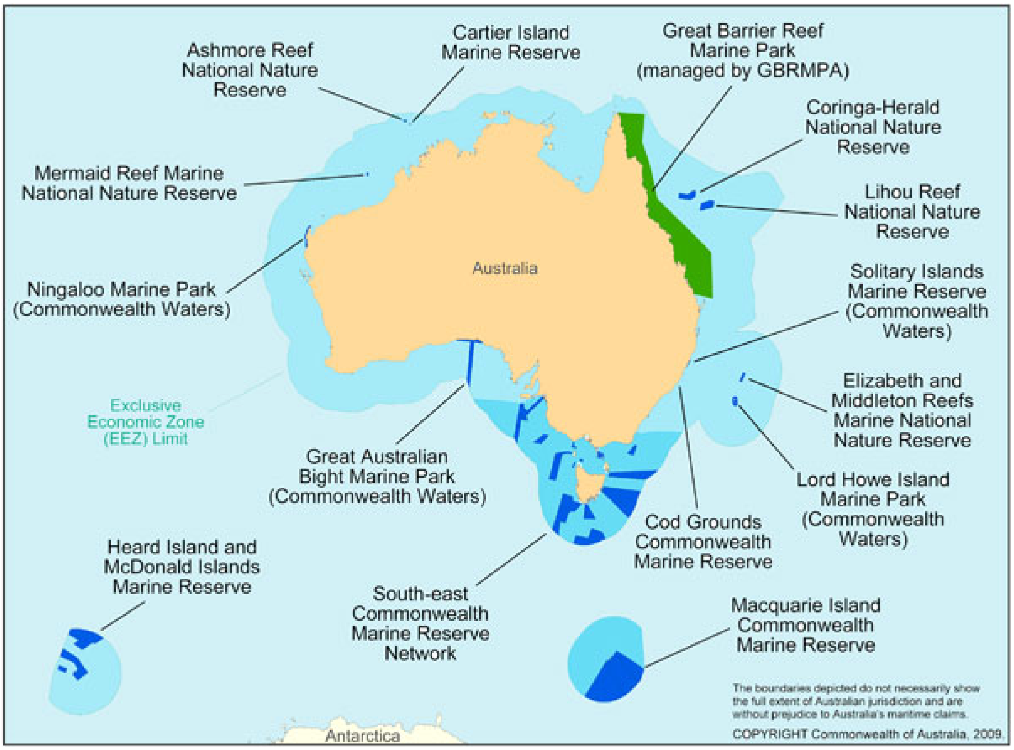
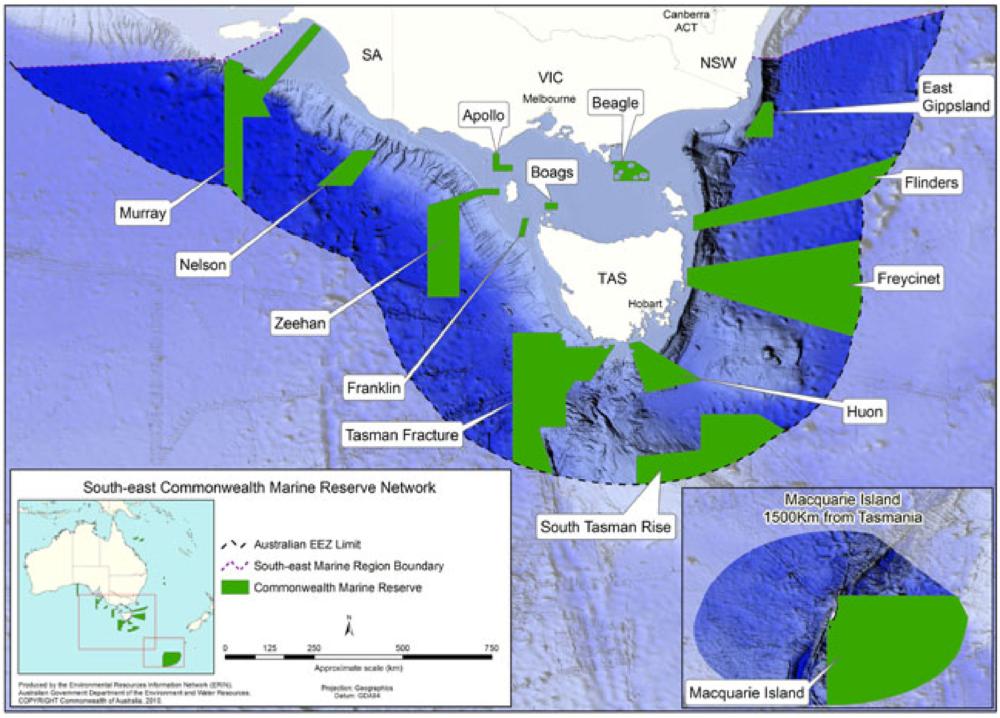
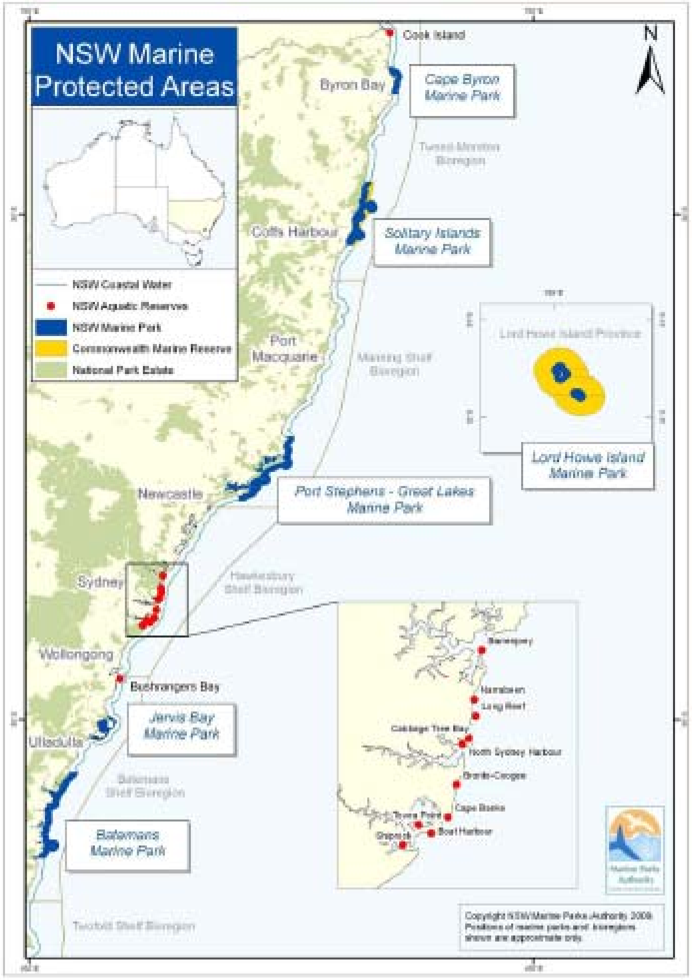


Figure II.4.3 South-East Commonwealth Marine Reserves



Networks of Marine National Parks and aquatic reserves exist to varying degrees around the country in state waters. For example, Figure II.4.4 shows the MPAs in New South Wales (Ocean Planet 2011).

Figure II.4.4 Marine Protected Areas in New South Wales

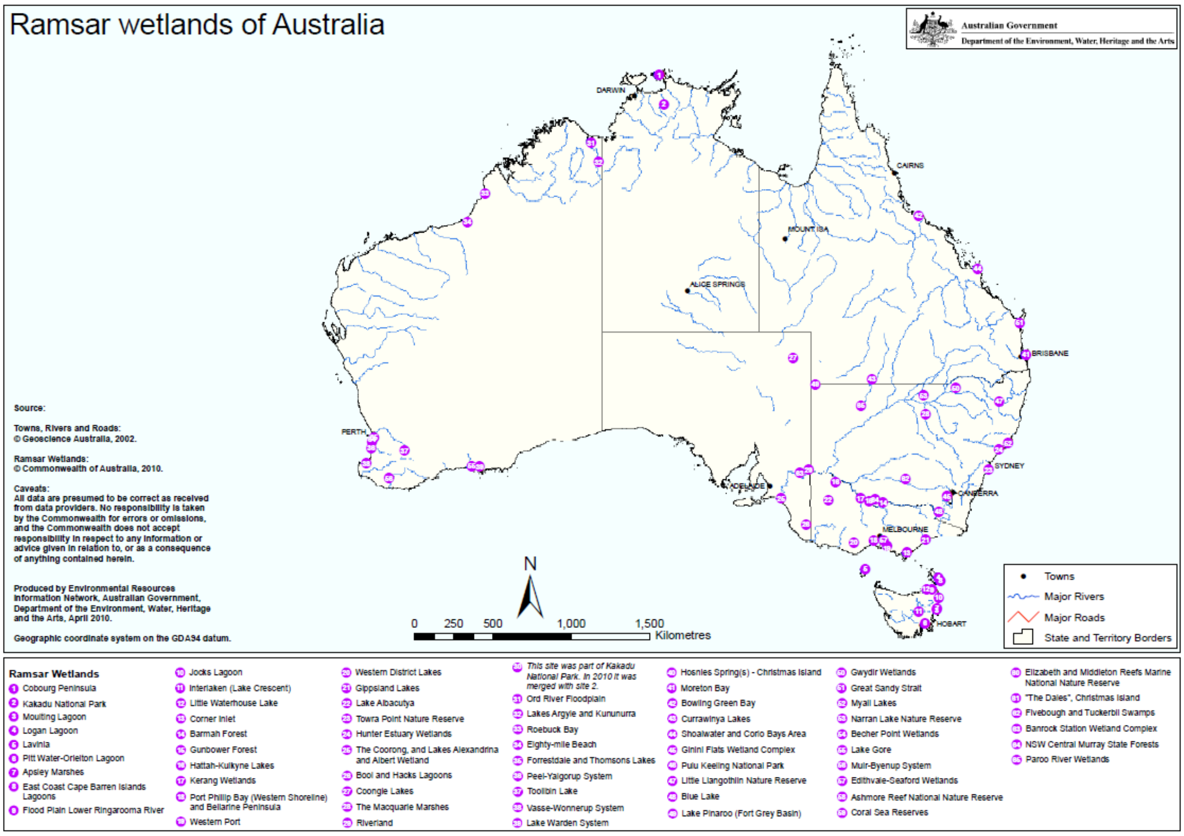


MPAs are sites of regional importance, and so would be expected to have sensitivity indicators lower than that of world heritage sites. The available data on oil spill costs (Etkin 2004) shows a cost modifier of 3.2 for “other sensitive areas”, which is the closest available category. In the previous study (DNV 1999), a weighting of 20 was used, based on judgement. However, the weighting would be expected to be lower than for Ramsar sites (see below), which have international importance. Therefore, a weighting of 10 is used here.

II.4.4 Ramsar Sites

The Convention on Wetlands, known as the "Ramsar Convention", is an intergovernmental treaty to maintain the ecological character of wetlands of international importance. Ramsar sites are wetlands that are representative, rare or unique, or important for conserving biological diversity. In total, there are 1923 sites world-wide, amounting to 187 million hectares (Ramsar 2011). Australia has 64 Ramsar wetlands that cover around 8.1 million hectares. These are shown in Figure II.4.5 DSEWPC (2011c), although many of these have no vulnerability to marine spills.

Figure II.4.5 Ramsar Wetlands of Australia



Ramsar sites have international importance, but would be expected to have sensitivity indicators lower than that of world heritage sites. The available data on oil spill costs (Etkin 2004) shows a cost modifier of 4.0 for “wetland”, but these would be mainly non-Ramsar sites. In the previous study (DNV 1999), a weighting of 15 was used, based on judgement. Therefore, a weighting of 15 is used here.

Ramsar sites are not consistently identified in OSRA, so the Ramsar sites database (DSEWPC 2011c) has been searched for marine/coastal sites. The length of coastline that is within the Ramsar sites is then measured as a straight-line length from the individual site maps.

II.4.5 Coastal Wetlands

Many other coastal wetlands are not included as Ramsar sites. Australia has approximately 11,000 km of mangrove-lined coast, being around 18% of the coastline (Mangrove Watch 2011). The available data on oil spill costs (Etkin 2004) gives a cost modifier of 4.0 for “wetland”. In the previous study (DNV 1999), a weighting of 10 was used, based on judgement. Based on the new data, a weighting of 4 is used here.

Coastal wetlands are identified in OSRA as shorelines backed by mangroves, excluding those identified as Ramsar or World Heritage sites. The length of coastline that is within the coastal wetlands is then estimated as in Section II.3.1.

II.4.6 Shorebird Habitats

Marine oil spills have the potential to affect shorebird habitats, both within and outside the specific protected sites identified above. OSRA identifies the distribution of shoreline bird habitats, and this can be used as a biological sensitivity indicator. The available data on oil spill costs (Etkin 2004) implies a cost modifier between 4.0 for "wetland" and 1.2 for "estuary". In the previous study (DNV 1999), a weighting of 8 was used, based on judgement. Based on the new data, a weighting of 3 is used here.

The International Union for Conservation of Nature (ICUN) Red List of Threatened Species provides a comprehensive approach for evaluating the conservation status of plant and animal species. It uses a scientific approach to identify particular species at risk of extinction. Spatial data is available for 28,000 species among comprehensively assessed taxonomic groups such as amphibians, mammals, threatened birds, reef-building corals, groupers, wrasses, angelfish, butterflyfish, seasnakes, seagrasses and mangroves (ICUN 2010). However, this only identifies areas where these species may be present, and is not possible to obtain a useful metric of species intensity that could be used as an indicator of biological resources.

Therefore, shorebird habitats are identified from OSRA, excluding those identified as coastal wetlands, or Ramsar or World Heritage sites. The length of coastline that is within the shorebird habitats is then estimated as in Section II.3.1.

II.4.7 Marine Mammal Habitats

Marine oil spills have the potential to affect marine mammals, which may arouse particular concern. Dugongs are found in the warm tropical climate off Queensland. Humpback whale migration paths extend from the Southern Ocean to the east and west coasts of Australia. Southern right whales calve in the coastal waters between Perth and Sydney, including Tasmania.

OSRA identifies the locations of sightings of marine mammals, but at present it is not possible to obtain a useful metric of species intensity that could be used as an indicator of biological resources. In the previous study (DNV 1999), a weighting of 8 was used for marine mammals, based on judgement.

II.4.8 High Conservation Status Offshore Islands

The Australian Government commissioned an independent national assessment of the conservation value of Australia's offshore islands, and specific vertebrate pest management issues (Ecosure 2009). Australia has approximately 8 300 offshore islands, including small rocks which are often associated with larger islands. A priority list of 100 islands of high conservation status was prepared to help prioritise investment.

Priority islands over 200 ha in area are distributed as follows:

- 26 in Queensland
- 23 in Western Australia
- 19 in the Northern Territory
- 15 in Tasmania
- 11 in Victoria
- 5 in South Australia

- 1 in NSW (Lord Howe Island).

The selection is based on a combination of biodiversity and potential feral impacts, and so is not directly relevant to oil spills. They are split into top 50 and lower 50, but are not otherwise ranked. Their contribution to coastline length is not recorded, but could be identified from maps of islands in each state. For example, Figure II.4.6 shows the islands in Victoria. At present this does not give a practical indicator of biological resources for this study.

Figure II.4.6 High Conservation Status Islands in Victoria

II.4.9 Australian Antarctic Territory

The Madrid Protocol of the Antarctic Treaty designates Antarctica, including the Australian Antarctic Territory (AAT), as a 'natural reserve, devoted to peace and science'. It establishes a system of Antarctic Specially Protected Areas (entry to which requires a permit) and Antarctic Specially Managed Areas. These provide protection of both biological resources and human-use (i.e. tourism and historic sites), but for the present study the environmental sensitivity of the AAT is represented primarily as an aspect of biological resources.

There is no simple way to represent the complexity of the AAT within the present wide-scale study, or even to compare the AAT as a whole with the rest of Australia. However, because of the international importance of Antarctica, the sensitivity of a typical location is here assumed equivalent to that of a Ramsar site, and given a weighting of 15.

II.4.10 Open Sea

Where intermediate and deep-sea sub-regions include Marine Protected Areas, the BRI is based on the fraction of the sea area that is within them, as defined in Section II.2.3, with a sensitivity weighting of 10 as in Section II.4.3.

For intermediate and deep-sea sub-regions that do not include any of the above sites or habitats, the BRI is assumed to be related to that of the nearest near-shore region, and is taken as:

- For intermediate sub-regions, 0.4x the BRI for the adjacent near-shore region
- For deep-sea sub-regions, 0.1x the BRI for the nearest near-shore region

The Great Barrier Reef extends into several intermediate sub-regions. For the adjacent deep-sea sub-regions, the BRI is taken as 0.1x the BRI for the nearest intermediate region.

II.5 INDICATORS OF HUMAN-USE RESOURCES

II.5.1 General Approach

The general pattern of human-use resources in Australian waters is extremely complex, and no simple indicator exists to rank different locations by the sensitivity of human-uses to oil spills. Therefore the present study uses a combination of three representative indicators:

- The intensity of commercial fishing (CFI)
- The intensity of passenger vessel activity along the coast (PVI)
- The proportion of the coast that is fringed by national parks (NPI)

These indicators are explained and defined in the following sections. In the absence of any estimates of the average costs of oil spill damage to these resources, they are given a subjective weighting as follows, to form the overall human-use resource index:

$$HRI = 0.8\ CFI + 0.1\ PVI + 0.1\ NPI$$

This reflects a judgement that fishing is the resource that is most affected by oil spills.

II.5.2 Commercial Fishing

Commercial fishing, including wild catch and aquaculture, is particularly vulnerable to oil spills. Figure II.5.1 indicates the distribution of commercial fisheries, although this is based on data gathered before 2000. Spatial data from 2002 is available (BRS 2006), but there is no facility to cumulate this in the calculation sub-regions. A more recent distribution of coastal fishing zones can be identified from OSRA.

Figure II.5.1 Commercial Fisheries Catch in Australia

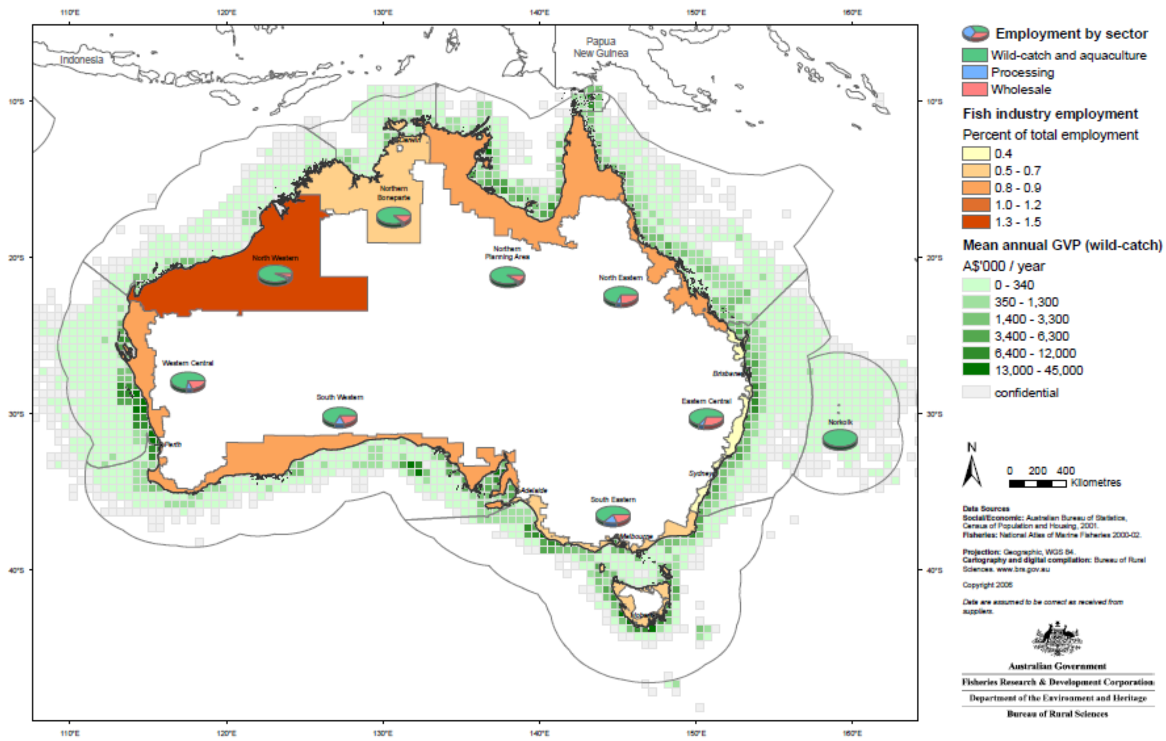


Table II.5.1 gives the total value of fisheries production in State waters in the latest available data (ABARE 2011), which relates to the period 2007-08. Where OSRA provides the value of fisheries, these in general total somewhat less. For example, in NSW it totals $51m, which is less than the values in Table II.5.1. This may be due to older or incomplete data.

Table II.5.1 Commercial Fisheries Catch in Australian State Waters ($m per year), 2006-07

STATE/TERRITORY	WILD CATCH FISHERIES	AQUACULTURE	TOTAL
Queensland	203	76	279
New South Wales	82	48	130
Victoria	68	18	86
Tasmania	157	319	475
South Australia	206	262	468
Western Australia	326	123	448
Northern Territory	33	23	56
Total	1074	868	1943

Table II.5.2 divides the total catches by the length of the mainland coast, to obtain a measure of intensity of commercial fishing. The average estimated for Australia is $54,000 per km of coastline. Dividing the values for each sub-region by this gives an indicator that represents the importance of a given length of coastline to commercial fishing (CFI). This is used to represent the contribution of commercial fishing to human-use resources. The table includes average values for each state, but in practice the values are calculated for each coastal sub-region.

Table II.5.2 Commercial Fishing Intensity in Australian State Waters

STATE/TERRITORY	TOTAL CATCH ($m per year)	MAINLAND LENGTH (km)	CATCH INTENSITY (1000 $/km)	STATE AVERAGE CFI
Queensland	279	6,973	40	0.74
New South Wales	130	2,007	65	1.20
Victoria	86	1,868	46	0.85
Tasmania	475	2,833	168	3.09
South Australia	468	3,816	123	2.26
Western Australia	448	12,889	35	0.64
Northern Territory	56	5,437	10	0.19
Total	1943	35,823	54	1.00

In the previous study (DNV 1999), a weighting of 6 was used for major fisheries and aquaculture, based on judgement. The new data gives a maximum weighting of 3.1 at state level, although greater values occur in some sub-regions.

For some States, OSRA provides sufficient information to modify the State average CFI above to apply to each sub-region. The distribution of catch value by sub-region from OSRA is used, despite the limitations noted above, because this is the only source of such a breakdown. In cases where no values are given, the distribution of catch tonnage is used. In some states, no fisheries data is given, and so the state average CFI is used for each sub-region.

The total value of fisheries production in Commonwealth waters is $288 million per year in the latest available data (ABARE 2011). This is a small fraction of the coastal catch above. The total area of the Australian EEZ is 8.2 million km^2, so the average intensity of commercial fishing at sea is $35 per km^2 per year. Figure II.5.1 shows that the greatest intensity is in inshore waters, but does not give absolute values consistent with the national totals. The relative commercial fishing intensity for the different distances offshore is therefore chosen as follows:

- Near-shore region (0-12nm offshore) = CFI for coast as above
- Intermediate region (12-50nm offshore) = 0.5 x CFI for coast.
- Deep-sea region (50-200nm offshore) = 0.1 x CFI for coast.

II.5.3 Passenger Vessel Activities

Recreational activities, including commercial passenger vessels, recreational boating, sub-aqua and beach use, are vulnerable to oil spills. OSRA identifies locations of various indicators of recreational activities, such as marinas, boat slips and moorings, but the data does not permit any simple summation of the intensity within the sub-regions. Therefore, the level of activity is assumed proportional to commercial passenger vessel activity.

The numbers of commercial passenger vessels in each state have been obtained from data collected in 2008 (AMSA 2009), as shown in Table II.5.3. Dividing by the length of the mainland coast gives a measure of intensity of commercial passenger vessel activity. The average estimated for Australia is 0.1 passenger vessels per km of coastline. Dividing the values for each sub-region by this gives a multiplier that represents the importance of a given length of coastline to passenger vessel activity. This is used to represent the contribution of recreational activities to human-use resources. In the absence of any useful data from OSRA, the average values for each state are applied to each of its coastal sub-regions.

Table II.5.3 Commercial Passenger Vessel Intensity in Australian Waters

STATE/TERRITORY	PASSENGER VESSELS	MAINLAND LENGTH (km)	VESSEL INTENSITY (vessels/km)	STATE AVERAGE PVI
Queensland	1627	6,973	0.23	2.27
New South Wales	597	2,007	0.30	2.89
Victoria	536	1,868	0.29	2.79
Tasmania	56	2,833	0.02	0.19
South Australia	371	3,816	0.10	0.95
Western Australia	409	12,889	0.03	0.31
Northern Territory	85	5,437	0.02	0.15
Total	3681	35,823	0.10	1.00

In the previous study (DNV 1999), a weighting of 2 was used for population sinks, based on judgement. The new data gives a maximum weighting of 2.9, but its importance is reduced when it is combined with the other human-use resource indicators.

In order to estimate the relative level of activity for the different distances offshore, the proportion of passenger vessel registered for operation different distances offshore has been obtained (AMSA 2009), as shown in Table II.5.4.

Table II.5.4 Commercial Passenger Vessel Operating Areas (as Fractions of all Passenger Vessels in State/Territory)

STATE/TERRITORY	TYPE A or B (200 miles or more offshore)	TYPE C (up to 30 miles from sheltered waters	TYPE D or E (smooth or partially smooth waters)
Queensland	0.20	0.49	1.00
New South Wales	0.06	0.20	1.00
Victoria	0.04	0.16	1.00
Tasmania	0.00	0.21	1.00
South Australia	0.00	0.04	1.00
Western Australia	0.02	0.34	1.00
Northern Territory	0.01	0.05	1.00
Australia overall	0.04	0.18	1.00

The relative passenger vessel intensity for the different distances offshore is therefore chosen as follows:

- Near-shore region (0-12nm offshore) = PVI for coast as above
- Intermediate region (12-50nm offshore) = 0.18 x PVI for coast.
- Deep-sea region (50-200nm offshore) = 0.04 x PVI for coast.

These probably over-estimate the recreational activity in the intermediate and deep-sea regions, but no better source of data is available at present. In fact, because of the weighting towards commercial fishing when calculating HRI, this uncertainty has no significant effect.

II.5.4 National Parks

Australia has an extensive system of 516 national parks, covering 25.7 million hectares, or 3.4% of the land surface. In addition, over 2700 designated conservation areas cover a further 3.6% of the land surface. They include fauna and flora reserves, conservation parks, environment parks and Aboriginal areas as well as national parks. National parks are indicators of land that has particular value for recreational use or cultural sensitivity. Where national parks are adjacent to the coast, they are relevant for the present study.

National parks are included within OSRA, so locations where they are adjacent to the coast can be identified. Sampling within each sub-region gives the fraction of the coast that is fringed by national parks, as in Section II.3.1.

The available data on oil spill costs (Etkin 2004) gives a cost modifier for socio-economic and cultural value of 1.7 for national parks. In the previous study (DNV 1999), a weighting of 7 was used, based on judgement. Based on the new data, a weighting of 2 is used here. This refers only to the human-use value of the national park that is additional to the actual recreational use (Section II.5.3) and biological resources (Section II.4).

These are not relevant for the intermediate and deep-sea regions. Marine national parks have been represented separately for biological resources (Section II.4.3).

II.5.5 Commonwealth Heritage Sites

The Commonwealth Heritage List is a list of natural, indigenous and historic heritage places owned or controlled by the Australian Government. The list was established under the Federal Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). It includes places connected to defence, communications, customs and other government activities that also reflect Australia's development as a nation. Places protected include federally-owned telegraph stations, defence sites, migration centres, customs houses, lighthouses, national institutions, memorials, islands and marine areas.

Marine areas and islands include:

- Low Island (QLD)
- Shoalwater Bay (QLD)
- Snapper Island & Cockatoo Island (Sydney Harbour, NSW)
- Jervis Bay Territory (NSW)
- Tasmanian Seamounts (TAS)
- Garden Island (10km in WA)
- Mermaid Reef & Ningaloo Reef (WA)
- Ashmore Reef
- North Keeling and Home Islands (COC)
- Scott and Seringapatam Reefs
- Christmas Island

Several of these are already included in BRI as Marine Protected Areas. Some are already included in HRI as National Parks. The human-use significance of the other heritage sites listed above is included using a weighting of 2 as for National Parks.

There are many other heritage areas that are not listed above because their small size (sometimes just an individual building) means that they are unlikely to be impacted by any one spill. No collected measure of density of such areas along the cost is available. Therefore the places not listed above are not at present suitable to use as practical indicators of human-use sensitivity.

II.5.6 National Heritage Areas

The Australian National Heritage List is a list of places deemed to be of outstanding heritage significance to Australia. The list includes natural, historic and indigenous places.

Marine areas and islands include:

- Great Barrier Reef (QLD)
- Fraser Island (QLD)
- Lion Island & Long Island (NSW)
- Spectacle Island (NSW)
- Bondi Beach (NSW)
- Kurnell Peninsula Headland (NSW)
- North Head, Sydney (NSW)
- Royal National Park (NSW)
- Great Ocean Road (Vic)
- Recherche Bay (Tas)

- Shark Bay (WA)
- Ningaloo Coast (WA)
- Lord Howe Island
- Macquarie Island
- Heard & McDonald Islands

Several of these are already included in BRI as World Heritage Areas. Some are already included in HRI as National Parks. The human-use significance of the others is included using a weighting of 2 as for National Parks.

II.5.7 Coastal Population

Human population could be considered by itself as an indicator of the human-use value of nearby environments, or as a weighting on other indicators such as national parks. However, this would be very sensitive to the distance threshold used in selecting coastal population, or would require an integration taking account of accessibility, which would be too complex for the present study.

II.6 REFERENCES

1. ABARE (2011), “Australian Fisheries Statistics 2008”, Australian Bureau of Agricultural and Resource Economics, http://www.abare.gov.au/publications_html/afs/afs_09/AFS_Production.xls (Accessed March 2011).

2. AMSA (2009), “National Approach to Maritime Safety Regulation: Regulation Impact Statement”, Australian Maritime Safety Authority.

3. BRS (2006), “PILOT - Atlas of Australian Marine Fishing and Coastal Communities”, Bureau of Rural Sciences, http://adl.brs.gov.au/mapserv/fishcoast/index.html

4. DNV (1999), “Risk Assessment of Pollution from Oil and Chemical Spills in Australian Ports and Waters”, Det Norske Veritas Project 9330-3972, December 1999.

5. DNV (2001), “Formal Safety Assessment of Tankers for Oil”, Confidential Internal Report, Det Norske Veritas Project 383184/4, June 2001.

6. DSEWPC (2011a), “Marine Bioregional Planning”, Department of Sustainability, Environment, Water, Population and Communities, http://www.environment.gov.au/coasts/mbp/index.html (Accessed March 2011).

7. DSEWPC (2011b), “Marine Protected Areas”, Department of Sustainability, Environment, Water, Population and Communities, http://www.environment.gov.au/coasts/mpa/index.html (Accessed March 2011).

8. DSEWPC (2011c), “Australian Ramsar Wetlands”, Department of Sustainability, Environment, Water, Population and Communities, http://www.environment.gov.au/cgi-bin/wetlands/alphablist.pl (Accessed March 2011).

9. Ecosure (2009), “Prioritisation of High Conservation Status Offshore Islands”, Report to the Australian Government Department of the Environment, Water, Heritage and the Arts. Ecosure, Cairns, Queensland. http://www.environment.gov.au/biodiversity/invasive/publications/pubs/offshore-islands-0-summary-and-toc.pdf

10. Etkin, D.S. (2000), “Worldwide Analysis of Marine Oil Spill Cleanup Cost Factors”, Arctic and Marine Oilspill Program technical Seminar, June 2000.

11. Etkin, D.S. (2004), “Modelling Oil Spill Response and Damage Costs”, Freshwater Spills Symposium, April 2004.

12. GEUS (2006), “Environmental Sensitivity Atlas for Coastal Area of Kenya”, Geological Survey of Denmark and Greenland, March 2006.

13. Grundlach, E.R. & Hayes, M.O. (1978), “Vulnerability of Coastal Environments to Oil Spill Impacts”, Marine Technology Society Journal, 1978.

14. ICUN (2010), “The ICUN Red List of Threatened Species” International Union for Conservation of Nature, http://www.iucnredlist.org/technical-documents/spatial-data

15. Mangrove Watch (2011), “Mangrove Watch Australia”, http://www.mangrovewatch.org.au/index.php?option=com_content&view=section&layout=blog&id=12&Itemid=300144, (Accessed March 2011).

16. NOAA (2002), “Environmental Sensitivity Index Guidelines” Version 3.0, NOAA Technical Memorandum NOS OR&R 11, National Oceanic and Atmospheric Administration, March 2002.

17. Ocean Planet (2011), “Marine National Parks Around Australia”, http://www.oceanplanet.org.au/national.php (Accessed March 2011).

18. Ramsar (2011), ”About the Ramsar Convention”, The Ramsar Convention on Wetlands, “http://www.ramsar.org/cda/en/ramsar-about-about-ramsar/main/ramsar/1-36^7687_4000_0__(Accessed March 2011).

19. UNEP (2011), “Marine and Coastal Ecosystem Services: Valuation Methods and their Practical Application”, United Nations Environment Programme World Conservation Monitoring Centre.

20. UNESCO (2011), “World Heritage List”, http://whc.unesco.org/en/list (Accessed March 2011).