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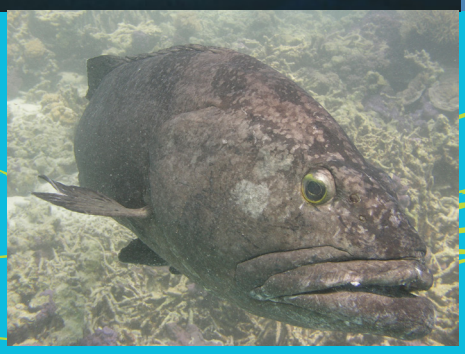

Elizabeth and Middleton Reefs

Ramsar Wetland

Ecological Character Description

Image credits: DEWHA; S. Hartley; DEWHA

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This information does not create a policy position to be applied in statutory decision making. Further it does not provide assessment of any particular action within the meaning of the EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision on any action.

This report is not a substitute for professional advice rather it is intended to inform professional opinion by providing the authors' assessment of available evidence on change in ecological character. This information is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention. Users should obtain any appropriate professional advice relevant to their particular circumstances.

Expert Panel and Peer Reviewers

An expert panel assembled for this project reviewed and contributed to drafts of this report, and the final draft was also peer reviewed. Information on members of the expert panel and peer reviewers is provided below. The draft was also reviewed by officers of the Inland Waters Section of the Australian Government Department of the Environment and Heritage.

Expert Panel

Katrina Jensz (Latitude 42 Environmental Consulting) - *Environment Protection and Biodiversity Conservation Act 1999; threatened species; marine conservation issues; recovery program; threatened seabirds*

Dr Adam Smith (Great Barrier Reef Marine Park Authority) - *fish and fisheries; surveys of habitats, invertebrates, fish and sharks; fisheries assessments under Environment Protection and Biodiversity Conservation Act 1999*

Mary Wakeford (Australian Institute of Marine Science) - *coral taxonomy and coral reef ecology; disturbance impacts on coral communities; reef surveys assessing coral biodiversity and health*

Dr Ashley Williams (CRC Reef Research Centre) - *coral reef fish research, particularly on the Great Barrier Reef; new Management Plan for the Elizabeth and Middleton Reefs Marine National Nature Reserve*

Peer reviewers

Barry Baker (Australian Government Department of the Environment and Heritage) - *threatened species; threat abatement plans for key threatening processes; demographic analyses and modelling of threatened bird populations; long-term seabird monitoring program in National Nature Reserves in the Coral Sea*

Mr Vainuupo Jungblut (Ramsar Officer, Secretariat of the South Pacific Regional Environment Program) - *Samoa's Biodiversity Strategy; marine conservation programs; coral health; coastal zone hazard mapping*

Acknowledgements

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Australian Institute of Marine Research for allowing the reproduction in this report of photographs from their survey report of December 2003.

Cover photographs
Courtesy of the Marine Division, Department of Environment and Heritage

Ecological character of Elizabeth and Middleton Reefs Marine National Nature Reserve Wetland of International Importance

March 2006

Dr Bill Phillips (MainStream Environmental Consulting Pty Ltd), Jennifer Hale and Dr Mathew Maliel, with advice from an expert panel and peer reviewers

Funded by the Australian Government Department of the Environment and Heritage through the Natural Heritage Trust

Australian Government

MainStream Environmental Consulting
Email: mainstream@mainstream.com.au
Website: www.mainstream.com.au

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Executive summary

The need for an assessment of the ecological character of the Elizabeth and Middleton Reefs Marine National Nature Reserve comes from its designation as a 'Wetland of International Importance' under the Ramsar Convention, in October 2002. The act of designating a site as a Wetland of International Importance (Ramsar site) carries with it certain obligations, including to manage the site to retain its 'ecological character' and have procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Understanding and describing the 'ecological character' of a Ramsar site is a fundamental management tool for signatory governments and the local site managers. A good understanding of 'ecological character' should form the baseline or benchmark for management planning and action, including site monitoring to detect negative impacts.

Domestically, the Australian Government has introduced legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), that provides a legal framework for seeing that the 'ecological character' of all Australian Ramsar sites is retained. The EPBC Act establishes a Commonwealth process for the referral, and possible assessment, of proposed actions that may have a significant detrimental impact on 'matters of national environmental significance', which includes Ramsar sites.

The EPBC Act also requires that the Commonwealth *"... use its best endeavours to ensure a plan for managing the wetland in a way that is not inconsistent with Australia's obligations under the Ramsar Convention or the Australian Ramsar management principles is prepared and implemented in cooperation with the State and Territory*" (Section 3.3.3).

The Australian Ramsar Management Principles (provided as Schedule 6 of the Regulations under the Act) set out general principles and the expectations the Commonwealth has for management plans pertaining to Ramsar wetlands. Among these expectations are that the 'ecological character' of the site be described and how it will be both monitored and maintained.

At present there is no globally agreed method for describing the 'ecological character' of Ramsar-listed wetlands. In early 2005, a trial method was documented by the Victorian Department of Sustainability and Environment (DSE, 2005). The DSE framework for describing 'ecological character' applies a step-by-step process using the 'ecosystem services' of the site as the entry point for a structured approach to setting 'condition' benchmarks for the wetland. It does this through identifying and describing the attributes that qualified the site for Ramsar listing, and those underlying ecological components and processes which support the related ecosystem services. The project team for this report on the Elizabeth and Middleton Ramsar site was requested to apply the DSE approach; which it has done with some minor modifications.

A key aspect of describing ecological character is to quantify the significant ecological and biological assets of the site wherever possible and then ascribe to these assets robust 'limits of acceptable change'. Such limits of change can then be used to guide management actions, design monitoring programs and, if necessary, even used to help inform referral-related decisions under the Commonwealth's EPBC Act. In order to set robust limits of acceptable change, a sound understanding of the baselines and natural variability inherent in all populations and ecological communities is needed; the better these are understood, the more robust will be the limits of acceptable change identified.

For this site, setting such limits of acceptable change has proven very challenging due to the lack of long-term, rigorously collected datasets to help set baselines, and document natural variability within the populations and key system parameters. However, on advice from the Department of Environment and Heritage every effort was made to indicate such limits of change so that future management actions had baselines against which to manage and monitor the condition of the site. These, interim limits of acceptable change have been included in this report although it should be clearly understood that they represent

"educated or best guesses" on the part of the project team, and should not be considered as long-term management benchmarks. They are provided as interim indicators of condition pending further surveys, research, monitoring and analyses to allow them to be modified based on these future findings.

For the Elizabeth and Middleton Reefs Marine National Nature Reserve those 'ecosystem services' documented in this report are as follows:

1. It is representative of a unique ecosystem in the bioregion: southern-most open-ocean coral reef platform in the world;
2. It supports threatened species: Green turtle (*Chelonia mydas);*
3. It supports regionally high species diversity:
   (a) fish (see also Black Cod below);
   (b) coral communities;
   (c) molluscs; and,
   (d) bêche-de-mer.
4. It supports animal taxa at a vulnerable or critical stage of their lifecycle: Galapagos Shark (*Carcharinus galapagensis);*and,
5. It supports the last known large population of Black Cod (*Epinephelus daemelii).*

For each of the above, the ecological components and processes that operate at the site, and work collectively to offer habitat suitable for them, are documented. Those ecological components and processes considered most critical for sustaining these communities and species at the site are as shown below (see Tables 8 and 9). Ideally limits of acceptable change would be recommended for each of these, however, lack of data prevented this from being done and remains a priority knowledge gap for future investigations.

1. Available habitats types, geomorphology and substrate;
2. Food sources and productivity; and,
3. Water quality and water temperature.

The summarised and consolidated description of ecological character is provided in Table 10 along with advice regarding priority knowledge gaps and recommended monitoring in relation to each element of the description of ecological character. Table 11 summarises the threats and risks to retaining the ecological character of the site, and again, provides advice regarding knowledge gaps and recommended monitoring. The primary threats are the Crown of Thorns Starfish, illegal fishing, anchor damage from vessels, ballast water and in the future, potentially coral bleaching.

As noted above, while the Elizabeth and Middleton Reefs Ramsar site has been subjected to some surveys and investigations over the years, the lack of long-term data sets was a major obstacle to this project providing strongly supported limits of acceptable change (LAC) in order to benchmark the ecological character of the system. Future investments in surveys and monitoring are urged to consider the findings of this report, and to aim to establish long-term, repeatable survey methods that can help strengthen the interim LACs recommended herein.

1. Introduction

The need for an assessment of the ecological character of the Elizabeth and Middleton Reefs Marine National Nature Reserve comes from its designation as a 'Wetland of International Importance' under the Ramsar Convention, in October 2002. The act of designating a site as a Wetland of International Importance (Ramsar site) carries with it certain obligations, including to manage the site to retain its 'ecological character' and have procedures in place to detect if any threatening processes are likely to, or have altered the 'ecological character'. Thus, understanding and describing the 'ecological character' of a Ramsar site is a fundamental management tool for signatory governments and the local site managers. A good understanding of 'ecological character' should form the baseline or benchmark for management planning and action, including site monitoring to detect negative impacts.

The Ramsar Convention defines 'ecological character' and 'change in ecological character' as shown below, and, while the Convention provides frameworks and guidelines for management planning, establishing monitoring programs and undertaking risk assessments, there is at present no definitive guidance on how to describe 'ecological character'.

At the 9th Meeting of the Conference of the Contracting Parties to the Ramsar Convention held in November 2005, in Kampala, Uganda the following revised definitions of 'ecological character' and 'change in ecological character were adopted:

> *"Ecological character is the combination of the ecosystem components, processes and benefits*/services that characterise the wetland at a given point in time."*
>
> (*Within this context, ecosystem benefits are defined in accordance with the definition of ecosystem services as used by the Millenium Ecosystem Assessment; "the benefits that people receive from ecosystems" – see Section 3.2 of this report.)
>
> *"For the purposes of implementation of Article 3.2 [of the Convention], change in ecological character is the human-induced adverse alteration of any ecosystem component, process, and/or ecosystem benefit/service."*

Domestically, the Australian Government has introduced legislation, the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), that provides a legal framework for seeing that the 'ecological character' of all Australian Ramsar sites is retained. The EPBC Act establishes a Commonwealth process for the referral, and possible assessment, of proposed actions that may have a significant detrimental impact on 'matters of national environmental significance', which includes Ramsar sites.

The EPBC Act also requires that the Commonwealth *"... use its best endeavours to ensure a plan for managing the wetland in a way that is not inconsistent with Australia's obligations under the Ramsar Convention or the Australian Ramsar management principles is prepared and implemented in cooperation with the State and Territory*" (Section 3.3.3).

The Australian Ramsar Management Principles (provided as Schedule 6 of the Regulations under the Act) set out general principles and the expectations the Commonwealth has for management plans pertaining to Ramsar wetlands. Among these expectations are that the 'ecological character' of the site be described and how it will be both monitored and maintained.

Taken together, Australia has obligations under the Ramsar Convention with respect to how designated Wetlands of International Importance are managed. In order to meet these obligations the 'ecological character' of each site needs to be carefully described, and then used to guide management action and ongoing monitoring. Such descriptions of 'ecological character' are also fundamental to the effective implementation of the EPBC Act, which is designed to ensure Australia is not contravening its site management obligations under the Ramsar Convention.

The Elizabeth and Middleton Reefs Marine National Nature Reserve was designated as a Wetland of International Importance under the Ramsar Convention on 21 October 2002. A pre-Ramsar plan of management for the site adopted in 1994 remained in place until 23 March 2004. A draft second management plan has since been prepared, and it was made available for public comment up until 30 August 2005. While the 1994 plan and the draft second plan gave some insights into the ecological assets of the Ramsar area, they did not provide a detailed description of 'ecological character' required of Ramsar sites. The current project is intended to provide such a baseline description so that monitoring of the site and future management actions can be geared toward retaining the unique 'ecological character' of this nature reserve Ramsar site.

2. Approach taken

As part of a broader project brief this report focuses on one of three separate studies aimed at producing the following outputs:

1. A description of the ecological character of Ashmore Reef National Nature Reserve, Coral Sea Reserves (Coringa-Herald and Lihou Reefs and Cays), and Elizabeth and Middleton Reefs Marine National Nature Reserve Ramsar sites based on existing data.

2. Recommendations regarding:
   - any further data required to refine the ecological character descriptions for the three sites; and
   - indicators and limits of acceptable change for monitoring ecological character at the three sites.

Note:	The descriptions and other information relating to Ashmore Reef National Nature Reserve and the Coral Sea Reserves are the subject of separate reports.

As noted in the preceding section, at present there is no globally agreed method for describing the 'ecological character' of Ramsar-listed wetlands. In early 2005, a trial method was documented by the Victorian Department of Sustainability and Environment (DSE, 2005) and pilot-tested on the Barmah Forest Ramsar site. The DSE framework for describing 'ecological character' applies a step-by-step process using the 'ecosystem services' of the site as the entry point for a structured approach to setting 'condition' benchmarks for the wetland. It does this through identifying and describing the attributes that qualified the site for Ramsar listing, and those underlying ecological components and processes which support the related ecosystem services.

The project team for this report on the Elizabeth and Middleton Reefs Marine National Nature Reserve was requested to apply the DSE approach, while noting that in their report the DSE acknowledged that the "*Application of the framework at other Ramsar sites is proposed and may result in further refinement with the aim of producing a standard method for describing ecological character for Ramsar sites in Australia that has national support*."

In preparing the current description of the 'ecological character' of the Elizabeth and Middleton Reefs Marine National Nature Reserve Ramsar site, the DSE method was used with the following minor modifications:

1. This description of 'ecological character' combines steps four and five (in part) of the DSE method so as to provide for a more streamlined presentation;
2. While the DSE method expects knowledge gaps to be noted at each step, this information has been consolidated in Section 3.7 for presentational reasons; and

3. Although the DSE method does not specifically anticipate that threats and risks to the ecological character of the site will be documented, the project team, expert panel and peer reviewers all believed this was an important addition to make (see Section 3.8).

Important note

A key aspect of describing ecological character is to quantify the significant ecological and biological assets of the site wherever possible and then ascribe to these assets robust 'limits of acceptable change'. Such limits of change can then be used to guide management actions, design monitoring programs and, if necessary, even used to help inform referral-related decisions under the Commonwealth's EPBC Act. In order to set robust limits of acceptable change, a sound understanding of the baselines and natural variability inherent in all populations and ecological communities is needed; the better these are understood, the more robust will be the limits of acceptable change identified.

For this site, setting such limits of acceptable change has proven very challenging due to the lack of long-term, rigorously collected datasets to help set baselines, and document natural variability within the populations and key system parameters. However, the advice provided to the project team by the Department of Environment and Heritage was that every effort should be made to indicate such limits of change so that future management actions had baselines against which to manage and monitor the condition of the site. Accordingly, interim limits of acceptable change have been included in this report. It should be clearly understood that these represent "educated or best guesses" on the part of the project team, and should not be considered as long-term management benchmarks. They are provided as interim indicators of condition pending further surveys, research, monitoring and analyses to allow them to be modified based on these future findings.

3. Description of ecological character

This section presents the description of ecological character using the step-wise approach proposed by the Victorian Department of Sustainability and Environment (2005), with some minor modifications - see Section 2.

3.1 Introductory details (Step 1)

Site name	Elizabeth and Middleton Reefs Marine National Nature Reserve.
Location	In the northern Tasman Sea, 630 km east of Coffs Harbour (NSW); 690 km east-southeast of Brisbane (Queensland); and 150 km north of Lord Howe Island. See Figure 1, *Location of Elizabeth and Middleton Reefs Marine National Nature Reserve* on page 10. Elizabeth Reef is at latitude 29°56'S and longitude 159°05'E. Middleton Reef is at latitude 29°27'S and longitude 159°07'E. See Figure 2 on page 11 for boundaries and relative locations of the two reefs. The coordinates of the corner points of the Reserve are as follows, starting with the most north-westerly point and moving clock-wise: 158° 59'E and 29° 21'S; 159° 14'E and 29° 21'S; 159° 10'E and 30° 03'S; 158° 55'E and 30° 03'S.
Area	Approximately 188,000 ha
Date of listing as a Ramsar site	21 October 2002
Date for which the description of ecological character applies	October 2002
Status of description	This is the first detailed description of the ecological character of this site.
Name of compiler	Dr Bill Phillips (MainStream Environmental Consulting), Jennifer Hale, Dr Mathew Maliel and associates. Contact: Dr Bill Phillips Email: mainstream@mainstream.com.au
Date of compilation	March 2006
Reference for Ramsar Information Sheet	Information Sheet on Ramsar wetlands (see Appendix A). Also available at the Australian Wetlands Database website, http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=60#
Reference for management plan	The first management plan for the Elizabeth and Middleton Reefs Marine National Nature Reserve came into force on 24 March 1994 and remained in place until 23 March 2004. A draft second management plan, titled 'Elizabeth and Middleton Reefs Marine National Nature Reserve Draft Management Plan 2005–2012' was made available for public comment until 30 August 2005. Further information can be found at http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=60#

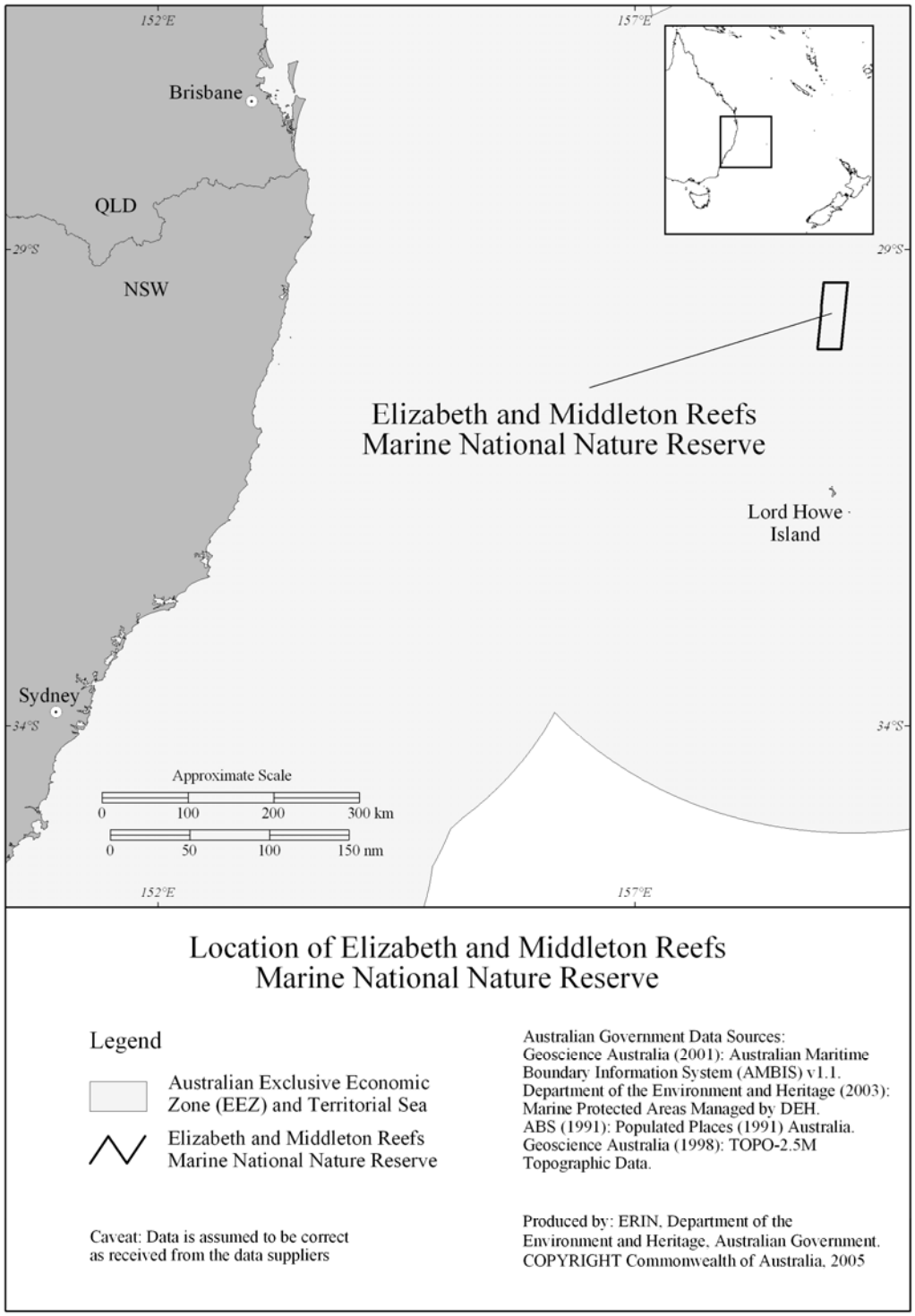


Figure 1: Location of Elizabeth and Middleton Reefs Marine National Nature Reserve
: Department of the Environment and Heritage, Australian Government
http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=60#

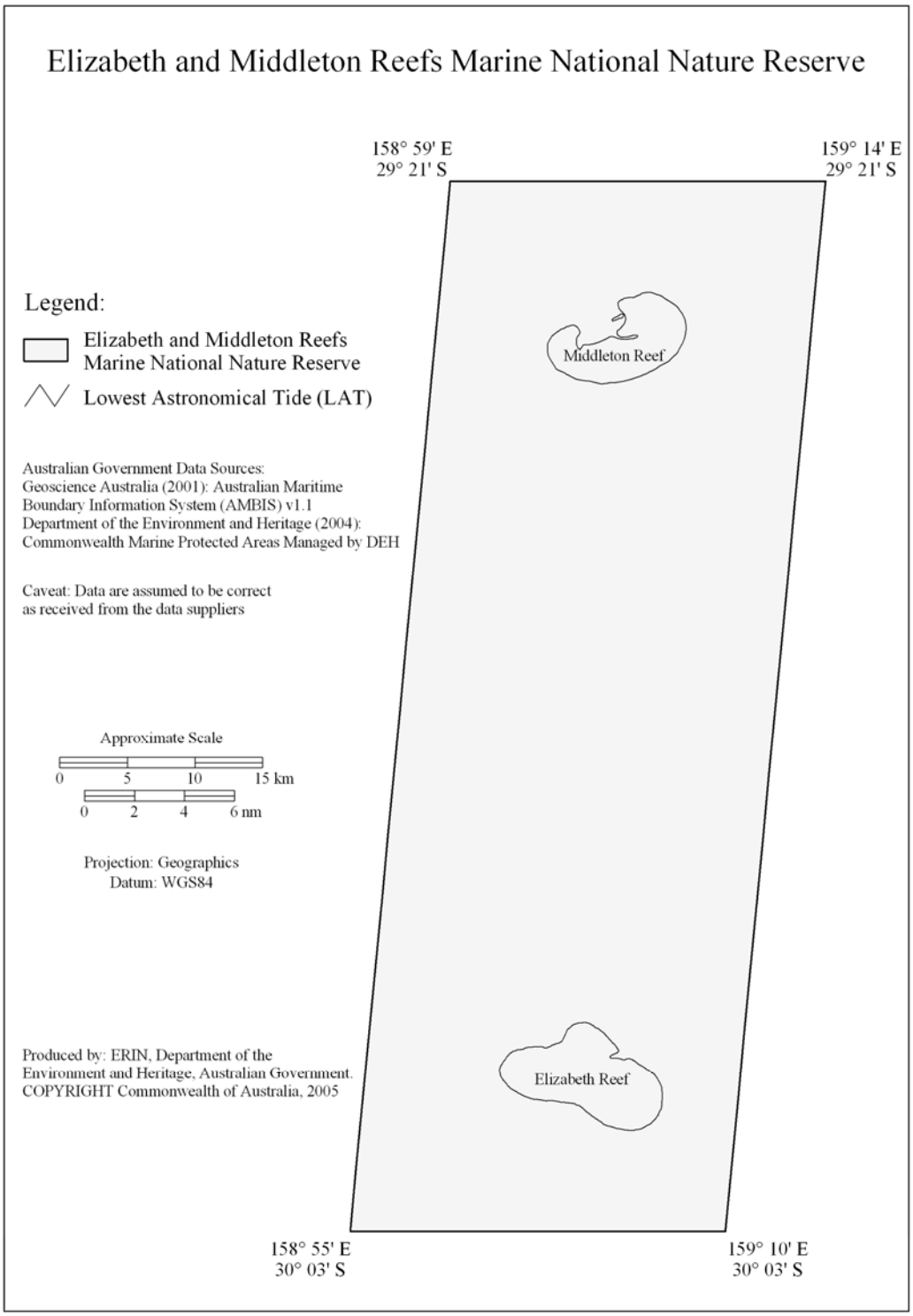


Figure 2: Boundaries of the Elizabeth and Middleton Reefs Marine National Nature Reserve and Ramsar site

Source: Department of the Environment and Heritage, Australian Government
http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=60#

3.2 Ecosystem services of the site (Step 2)

The Elizabeth and Middleton Reefs Marine National Nature Reserve Ramsar site provides the following ecosystem services.

Table 1: Ecosystem services of the Elizabeth and Middleton Reefs Marine National Nature Reserve Ramsar site

Ecosystem service	References*
Provisioning services	
Nursery habitat for open-water fish (commercial and recreational species)	7
Regulating services	
Local climate regulation	12
Cultural services	
Nature observation	8
Scenic / aesthetic values	8
Recreational activities (snorkeling, scuba diving)	8
Large number of shipwrecks protected under the *Historic Shipwrecks Act, 1976*	8
Supporting services	
Representative of a unique ecosystem in the bioregion – situated atop separate volcanic sea mounts and are the southern-most open-ocean coral reef platform in the world	8
Supports threatened species	8
Supports high species diversity with notable occurrences of fishes, benthic communities (soft and hard corals, sponges and thallous algae), molluscs and bêche-de-mer.	2, 8
Supports animal taxa at a vulnerable or critical stage of their lifecycle (breeding, migration)	2, 7, 8
Supports the last remaining large population of Black Cod (*Epinephelus daemelii)*	2, 7

*see Section 5

3.3 Ecosystem services to be used as the basis for the ecological character description (Step 3)

The Elizabeth and Middleton Reefs Marine National Nature Reserve was listed as a Wetland of International Importance under Ramsar criteria 1, 2, 3, 4 and 8 (see below). The nominating document specified Criterion 4 as being the most significant (see Appendix A).

- Criterion 1: Contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate bioregion.
- Criterion 2: Supports vulnerable, endangered or critically endangered species or threatened ecological communities.
- Criterion 3: Supports populations of plant and/or animal species important for maintaining the biological diversity of the region.
- Criterion 4: Supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
- Criterion 8: Is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Note: At Ramsar's 9th Meeting of the Conference of the Contracting Parties held in November 2005, in Uganda, an additional criterion was adopted, as follows:

> Criterion 9: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

Based on the information currently available it is possible that this site could qualify against this new criterion for the role it plays in supporting a population of Black Cod (*Epinephelus daemelii*) – see Ecosystem Service 5 in Section 3.4. However, there is insufficient known about the population size of this species across its full range to know if the population at Elizabeth and Middleton Reefs represents 1% or more.

The ecosystem services listed in the table below (as selected from the table in Section 3.2 above) are those that relate to the above criteria and have been used as the basis for the ecological character description of the Elizabeth and Middleton Reefs Marine National Nature Reserve Ramsar site.

Table 2: Relating ecosystem services to the Ramsar criteria for this site

Ecosystem service	Ramsar criteria
1. Representative of a unique ecosystem in the bioregion – southern-most open-ocean coral reef platform in the world	1
2. Supports threatened species	2
3. Supports regionally high species diversity with notable occurrences of fishes, coral communities, molluscs and bêche-de-mer.	3
4. Supports animal taxa at a vulnerable or critical stage of their lifecycle (breeding, migration)	2, 4, 8
5. Supports the last remaining large population of Black Cod (*Epinephelus daemelii)*	8

3.4 Define the selected ecosystem services in specific terms (Step 4)

AND

Link the selected ecosystem services with the critical ecological components and processes that support them, and select those components to be further specified (Step 5a – see Section 3.5 for Step 5b)

In this section (and Section 3.5 following) two steps from the DSE method have been combined (in part) to streamline the presentation of information. In addition, one of the five ecosystem services referred to in the preceding steps have been sub-divided as shown below. This is to allow for greater resolution in the analysis.

Table 3: Ecosystem services selected for detailed consideration

Ecosystem service	Ramsar criteria
1. Representative of a unique ecosystem in the bioregion: southern-most open-ocean coral reef platform in the world.	1
2. Supports threatened species[#]: Green turtle (*Chelonia mydas)*	2
3. Supports regionally high species diversity: (a) fish (see also Black Cod below); (b) coral communities; (c) molluscs; and, (d) bêche-de-mer.	3
4. Supports animal taxa at a vulnerable or critical stage of their lifecycle: Galapagos Shark (*Carcharinus galapagensis*) Note: the Ramsar Information Sheet (see Appendix A) refers to the presence of small populations of seabirds, 12 migratory waterbird species and a small breeding colony (30 pairs) of Common Noddy on one of the shipwrecks at the site. It was decided that in the context of this description of ecological character these did not warrant detailed consideration.	2, 4, 8
5. Supports the last known large population of Black Cod (*Epinephelus daemelii)*	8

[#] The draft second management plan titled *Elizabeth and Middleton Reefs Marine National Nature Reserve Draft Management Plan 2005–2012* identifies a number of EPBC-listed species as 'known or likely to occur in the reserve'. These are shown in Section 4. However, most of these species are likely to only occasionally occur in, or pass through, the Elizabeth and Middleton Reefs area, and as such these reefs do not form critically important habitat for them. On this basis, it was concluded that these species do not warrant consideration in the context of describing the ecological character of the Elizabeth and Middleton Reefs reserve.

Note: The term 'limits of acceptable change' used below is intended to indicate the tolerance that is considered acceptable without indicating a change of 'ecological character' is occurring, or has occurred (also see 'Important note' in Section 2, page 8).

Ecosystem service 1: Representative of a unique ecosystem in the bioregion – southern-most open-water platform reef in the world

Qualitative description

Elizabeth and Middleton Reefs are a pair of isolated oceanic platform reefs separated from one another by 45 km of deep oceanic waters. They are unique in that they represent the southern-most platform reefs in the world. Despite their high latitude, both reefs display a rich and diverse marine flora and fauna, aided by their location in an area where tropical and temperate ocean currents meet.

The two reefs are of similar size and shape with Elizabeth measuring 8.2 km by 5.5 km and Middleton Reef slightly larger at 8.9 km by 6.3 km (See Figures 3, 4, 5 and 6). The reefs are largely awash, with only two small sand cays being emergent at high tide. The largest cay, Elizabeth Island, found on Elizabeth Reef measures around 400m in length and up to 400m in width. The smaller cay, known as The Sound and located on Middleton Reef, measures 100m by 70m. Both barely emerge 1m above the high water level. At low tides much of the reef flat is exposed by the receding waters. Elizabeth and Middleton Reefs are physically and biologically similar to one another and both contain unique assemblages of tropical, temperate, endemic and cosmopolitan species.

The Australian Museum (*Kowari 3*, Commonwealth of Australia, 1992, pages 113 and 114) attempted a preliminary habitat mapping that distinguished eight habitat types. From Figures 4 and 6 below it is possible to estimate the aerial extent of the geomorphological categories for both reefs (see Table 3), however, these have not been ground-truthed nor correlated with habitats types to allow the setting of limits of acceptable change.

Notable here also is the threat posed by the Crown of Thorns Starfish (COTS), first recorded at this site by AIMS in 1981 (Hutchings, 1992). Hutchings (1992) reported on COTS densities observed in surveys of 1987, noting that the densities were highly variable. More information on this threat is provided in Section 3.8.

Quantitative description	Typical range of variability and limits of acceptable change (LACs)	Reference*
Aerial extent of habitats: See comment above regarding geomorphological categories for both reefs, as given in Table 4.	Knowledge gap. LAC: insufficient information.	7
Other notable species or groups thereof: see Ecosystem services 2-5 below.		3

*see Section 5

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Geographical location	Located between the Coral and Tasman Seas, Elizabeth and Middleton Reefs lie in a zone of influence from both the tropical north and the temperate southern waters.	2
Oceanic currents	During summer months the East Australian Current brings warmer, tropical water southward along the Australian east coast, flowing across Elizabeth and Middleton Reefs. During winter the influence of this current is lessened and the West Wind Current (Antarctic Circumpolar Current) brings cooler water from the south into the region.	7
Climate	The effect of climate on water temperature, light and freshwater availability influences the extent and type of biota able to survive at Elizabeth and Middleton reefs. (See water temperature below.)	12
Winds	The reefs experience a range of strong winds from various directions; this impact is reflected in their structure.	3
Geomorphology	Both Elizabeth and Middleton reefs are platform reefs on top of volcanic rises. They are geomorphically complex with variable topography and each with a lagoon surrounded by exposed reef. This geomorphic complexity provides variable depth and substrate for biota (see Figures 3-6 and Table 4).	8
Substrate	The hard and persistent substrate of the atolls provides a stable platform within shallow water to allow for the colonisation and survival of coral and algal species.	8
Available habitat	There are three broad habitat types at Elizabeth and Middleton reefs (see Qualitative description and Figures 3-6): 1. Outer reef, which is exposed to strong currents, waves and tidal action; 2. Reef crest, which is exposed at low tide; and 3. Shallow lagoon, which provides a more sheltered environment. Although the diversity of habitat at Elizabeth and Middleton Reefs is comparatively low, the combination of exposed and protected reef provides a variety of habitats for different species.	8
Habitat connectivity	The habitat zones within both Elizabeth and Middleton reefs are interconnected, allowing for movement of aquatic biota between the zones to meet a variety of needs. The outer reefs, reef crests and shallow lagoon allow different habitat needs to be met within the Nature Reserve.	7
Water quality	Water quality parameters such as water temperature, turbidity and nutrient concentrations influence the biota at Elizabeth and Middleton Reefs.	7
Water temperature	Elizabeth and Middleton Reefs experience annual sea surface temperatures ranging from <19 °C to >25 °C. These probably represent the upper tolerance for temperate species and the lower tolerance for tropical species, but allow for long-term persistence of both. (Coral bleaching is covered in Section 3.8.)	2

*see Section 5

Critical ecosystem components and processes

For this ecosystem service, the critical parameters are diversity of habitats/geomorphology followed by water quality. These are discussed in Sections 3.5 and 3.6.

Figure 3: Elizabeth Reef - aerial view
(Source: Millenium Global Coral Reef Mapping Project, NASA Johnson Space Center via Oceandots.com)

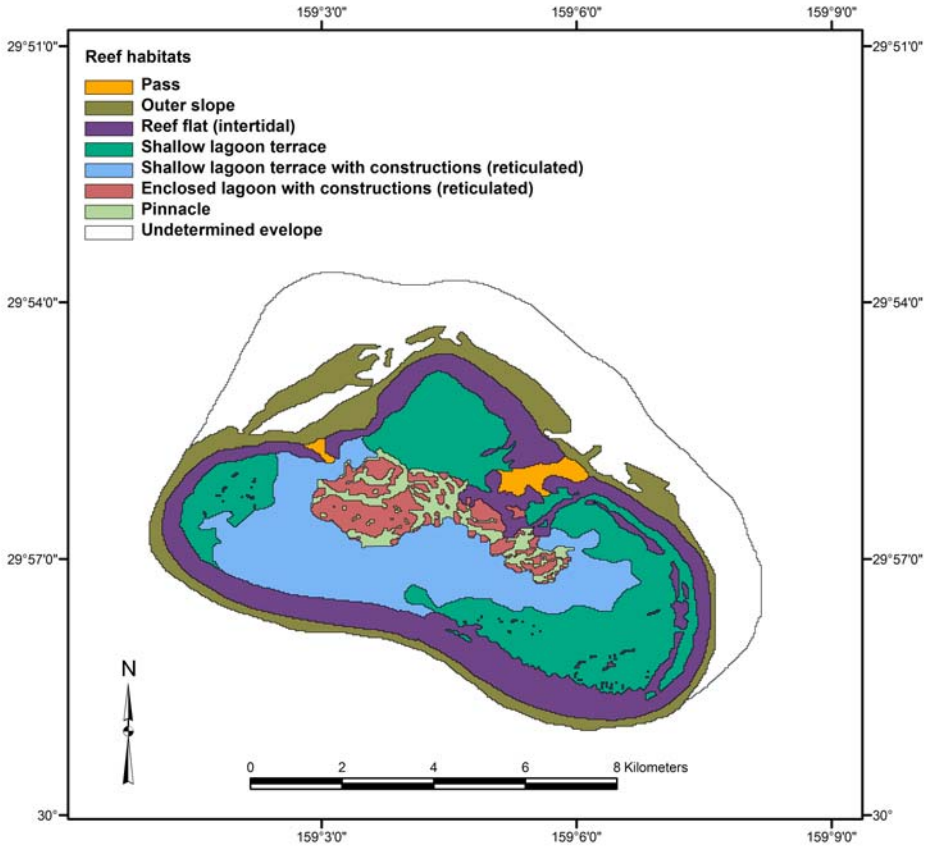


Figure 4: Elizabeth Reef - schematic representation of its geomorphologic categories
Source: Products from Millennium Global Coral Reef Mapping Project, Institute for Marine Remote Sensing at University of South Florida (Imars/USF), USA, and Institut de Recherche pour le Developpement (IRD) at Noumea, New Caledonia. Landsat images NASA/USGS. Processing: S.Andrefouet (IRD)/C. Kranenburg (IMARS/USF).

Figure 5: Middleton Reef - aerial view
(Source: Earth Sciences and Image Analysis Laboratory, NASA Johnson Space Center via Oceandots.com)

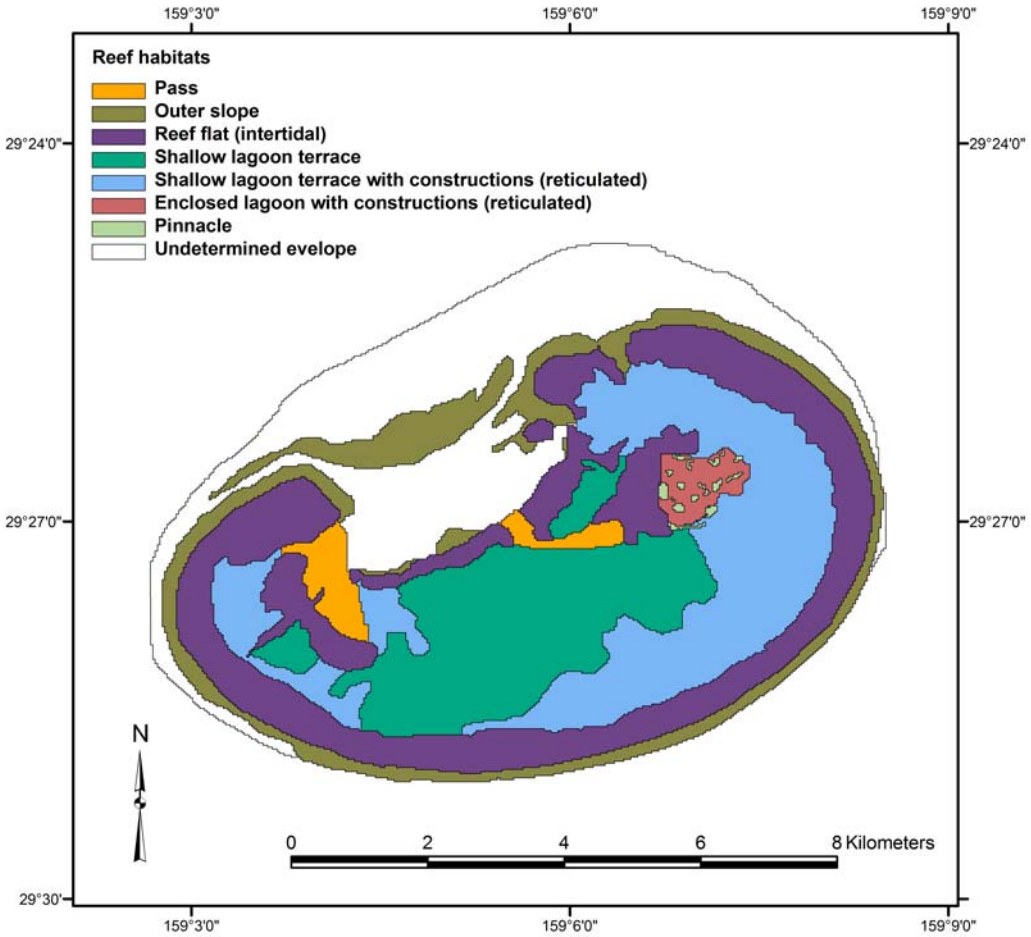
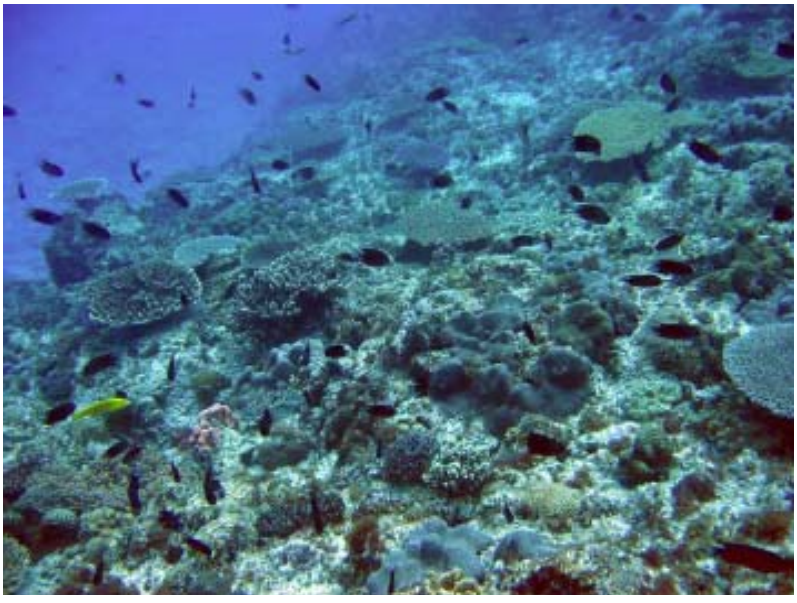


Figure 6: Middleton Reef - schematic representation of its geomorphologic categories
Source: Products from Millennium Global Coral Reef Mapping Project, Institute for Marine Remote Sensing at University of South Florida (Imars/USF), USA, and Institut de Recherche pour le Developpement (IRD) at Noumea, New Caledonia. Landsat images NASA/USGS. Processing: S. Andrefouet (IRD)/C. Kranenburg (IMARS/USF).

Table 4: Estimated areas of geomorphological categories – areas are based on Figures 4 and 6, respectively

Reef	Estimated area (square kilometers)
Elizabeth Reef	
Reef flat (intertidal)	13.72
Pass	0.87
Shallow lagoon terrace	15.41
Shallow lagoon terrace with constructions (reticulated)	12.28
Pinnacle	2.31
Enclosed lagoon with constructions (reticulated)	3.13
Outer slope	8.95
Undetermined envelop	19.66
Middleton Reef	
Reef flat (intertidal)	13.27
Pass	1.31
Shallow lagoon terrace	8.91
Shallow lagoon terrace with constructions (reticulated)	11.07
Pinnacle	0.18
Enclosed lagoon with constructions (reticulated)	0.75
Outer slope	6.13
Undetermined envelop	12.76



Coral and fish communities – Figure A6 from the AIMS survey report, December 2003

Ecosystem service 2: Supports threatened species - Green Turtles		
Qualitative description		
Green Turtles (*Chelonia mydas*) have been recorded in the water surrounding the reefs. The Green Turtle is listed on the 2004 IUCN Red List of Threatened Species and is protected nationally under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.		
Quantitative description	**Typical range of variability and limits of acceptable change (LACs)**	**Reference***
The species seems not to breed or nest here; using the site as feeding habitat only. No population estimates available, and no estimates of primary habitats, such as sea grass and algal beds.	Interim LACs: Population: Knowledge gap Primary habitats: Knowledge gap	-
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) There is insufficient breeding habitat for these turtles and as such the habitat provided is limited to foraging on the abundant macro algae and in the limited seagrass beds.		2, 12

*see Section 5

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Available habitat	As there is no suitable nesting habitat, it is likely that the Green Turtles are using the lagoon and reef habitats for foraging.	8
Geomorphology	The shallow environment provided by the platform reefs allows for benthic feeding on algae and possibly seagrass in the reefs (See Figures 3-6).	7
Food sources / productivity	Green Turtles are herbivores feeding on seagrass and algae. As there is only a small cover of seagrass at these reefs, it is possible that they are foraging in the extensive turf algae.	7
Water quality	Water quality would be indirectly important in maintaining primary production and food sources.	7
Photosynthetically Active Radiation (PAR)	Light levels would need to be sufficient to maintain primary production of food sources for Green Turtles at the reefs.	7

Water temperature	Most marine turtles have an optimum water temperature of 25–30°C and as such it is likely that Green Turtles would only utilise Elizabeth and Middleton Reefs during the warmer months.	7
Climate	The effect of climate on water temperature, light and therefore, food availability (see above), influences the timing and number of turtles present at the site.	12

*see Section 5

Critical ecosystem components and processes

The critical parameter for this ecosystem service is the availability of feeding habitat coupled with the geomorphology. This parameter is followed by water quality, which helps ensure suitable food sources are available. These are discussed further in Sections 3.5 and 3.6.

Ecosystem service 3(a): Supports regionally high species diversity - fishes (see also Black Cod below)

Qualitative description

The Ramsar Information Sheet (Appendix A) states:

"It can be assumed that the productive shallow waters of the Reefs provide a significant nursery area for fishes that have open-water adult stages (Ramsar Convention 2002). The Rosy Job Fish *Aprion virescens*, which is commercially harvested on shallow sea mounts in the Tasman Sea, may also depend upon the reef system, however this has not yet been investigated (ANPWS 1992, p. 110). Migratory Bigeye Tuna *Thunnus obesus* also aggregate near the reefs in this region."

And,
"The Reefs also provide the southernmost habitat for the Queensland Giant Groper *Epinephelus lanceolatus* (Environment Australia 2002a), which in Queensland receives a medium level of legislative protection."

Quantitative description	Typical range of variability and limits of acceptable change (LACs)	Reference*
314 species of fish, from 174 genera and 75 families have been described from the reefs to date. A further 7 undescribed species have been recorded which may be endemics; for example, a new morwong species, *Cheilodactylus (Goniistius) francisi*, is recognised from south-west Pacific Islands including Elizabeth and Middleton Reefs area. The AIMS survey of December 2003 recorded 181 fish species for Elizabeth Reef; 61 of these were new records for this reef although 16 of these had been recorded previously from Middleton Reef by the Australian Museum surveys. The AIMS survey in December 2003 compared abundance (numbers per hectare) of large reef fish and damselfishes across sampling sites but found nothing conclusive about habitat preferences – see figure 13 from that report reproduced below, as Figure 7.	The large variation in species composition between surveys (most likely due to different survey methods) makes it very difficult to set LACs from existing data. Given that the ecosystem service is 'species diversity' the development of LACs should consider issues such as the number of and abundance of individual species. An interim LAC is recommended as no loss of species, until such time as more survey data are gathered.	2
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) Lagoon, outer reefs slopes and reef crests.		2

*see Section 5

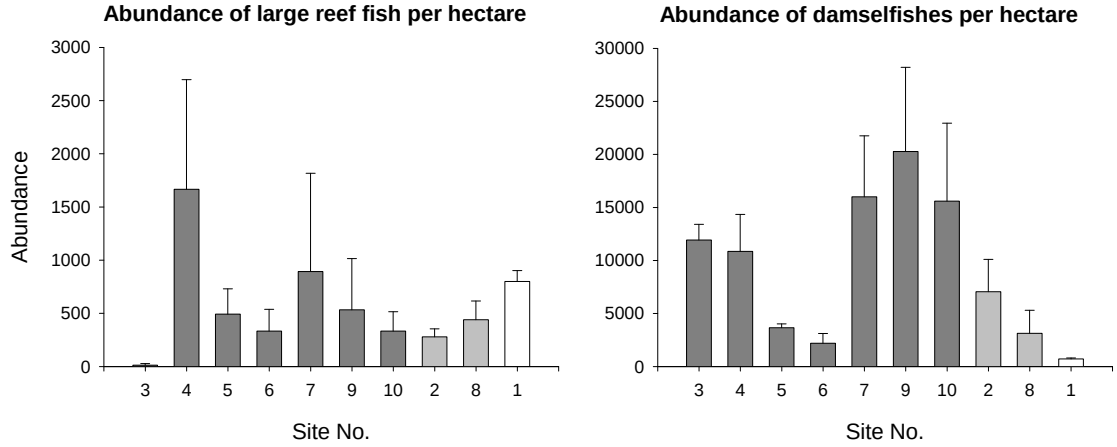


Figure 7: Fish abundances from transect surveys at all sites at Elizabeth Reef. Dark grey bars represent reef slope sites, light grey bars indicate channel sites and the lagoon site is shown in white (Figure 13 from report on AIMS survey in December 2003).

Primary Ecosystem Components and Processes	How they support the ecosystem service	Reference(s)*
Available habitat	Although the diversity of habitat at Elizabeth and Middleton Reefs is comparatively low, the combination of exposed and protected reef provides a variety of habitats for different species.	2
Geomorphology	The geomorphically complex topography of Elizabeth and Middleton Reefs provides a wide range of niche habitats for marine flora and fauna (See Figures 3-6). AIMS (2004) found the highest diversity of biota in areas of greatest structural complexity.	2, 8
Oceanic currents	During summer months the East Australian Current brings warmer, tropical water southward along the Australian east coast, flowing across Elizabeth and Middleton Reefs. During winter the influence of this current is lessened and the West Wind Current (Antarctic Circumpolar Current) brings cooler water from the south into the region. It is possible that both of these currents transport larvae of fish and coral species to Elizabeth and Middleton Reefs: the larvae of tropical species are brought from north through the East Australian Current, while the temperate species larvae are brought from south through the Tasman front.	2
Water temperature	Elizabeth and Middleton Reefs experience annual sea surface temperatures ranging from <19 °C to >25 °C. These probably represent the upper tolerance for temperate species and the lower tolerance for tropical species, but allow for long-term persistence of both.	2

*see Section 5

Critical ecosystem components and processes:

For this ecosystem service, the diversity of (shallow water) habitats coupled with the substrate are the critical parameters. Sections 3.5 and 3.6 expand on this further.

Ecosystem service 3(b): Supports regionally high species diversity – coral communities		
Qualitative description		
The subtropical location of the reefs has resulted in coral communities that contain a unique assemblage of tropical species at or near the southern limits of their distribution, and subtropical species that are rare or absent from tropical reefs.		
Quantitative description	**Typical range of variability and limits of acceptable change (LACs)**	**Reference***
Hutchins (1992), based on survey data from 1981 from Veron and Done, reported 122 coral species, although noted that this was low by comparison with locations such as the Great Barrier Reef presumably because of the relatively simple and limited reefal habitat. In the AIMS 2003 report identified 111 coral species for Elizabeth Reef alone. Through surveys at 10 locations around Elizabeth Reef, the AIMS 2003 survey found per cent cover of hard and soft corals similar to that reported by the earlier Hutchins (1992). The AIMS survey findings for 2003 are provided in Tables 5 and 6.	While the AIMS 2004 survey found similar per cent cover for hard and soft coral to earlier surveys, there remains uncertainty about variability within these communities. Future survey should also consider algae, as did the AIMS survey. Interim LACs are as follows: 1. No loss of species; and 2. Per cent cover of hard and soft corals that falls more than 20% below the estimates of AIMS (2004) – see Table 6 below - for three consecutive years (annual surveys) will be reason for concern. This is assumes repeated surveys at the same 10 sites used by AIMS, and it applies only to Elizabeth Reef for now. Longer term data is needed at both sites.	2
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) The full extent of habitats used is not yet known as systematic and comprehensive surveys across both reefs have not yet undertaken. Hutchins (1992) summarises the distribution of coral communities found on the outer reef slope, lagoons, reef flats, pinnacles and gutters.		

*see Section 5

Table 5: Hard coral species recorded at six or more of the ten survey sites Elizabeth Reef (AIMS, 2003).

**Acanthastrea echinata*	**Leptoria phrygia*
Acropora cuneata	**Montastrea curta*
Acropora glauca	*Pavona varians*
Acropora latistella	**Platygyra daedalea*
**Coscinaraea columna*	*Pocillopora damicornis*
**Cyphastrea serailia*	*Porites lichen*
**Favia favus*	**Porites massive spp*
Favia pallida	*Stylophora pistillata*
Favia rotumana	*Turbinaria mesentaria*
**Favia speciosa*	* Recorded at all sites
Favites abdita	
Favites russelli	
Goniastrea australensis	
Goniastrea favulus	

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Available habitat	Although the diversity of habitat at Elizabeth and Middleton Reefs is comparatively low, the combination of exposed and protected reefs and lagoons provide a variety of habitats for these many different species.	24
Geomorphology	The geomorphologically complex topography of Elizabeth and Middleton Reefs provides a wide range of niche habitats for coral communities (See Figures 3-6).	24
Substrate	Coral larvae require stable substrates in relatively shallow water in order to settle and grow. Elizabeth and Middleton Reefs provide morphologically complex reef habitats in reef front, crest, slope and lagoon zones that provide conditions suitable for a wide range of coral species.	24
Oceanic currents	During summer months the East Australian Current brings warmer, tropical water southward along the Australian east coast, flowing across Elizabeth and Middleton Reefs. During winter the influence of this current is lessened and the West Wind Current (Antarctic Circumpolar Current) brings cooler water from the south into the region. It is possible that both of these currents transport larvae of fish and coral species to Elizabeth and Middleton Reefs.	24
Water Quality	Coral require clear water with good light penetration for the survival and growth of the symbiotic algae within their structures as well as for the growth of phytoplankton that are used as a food source.	24

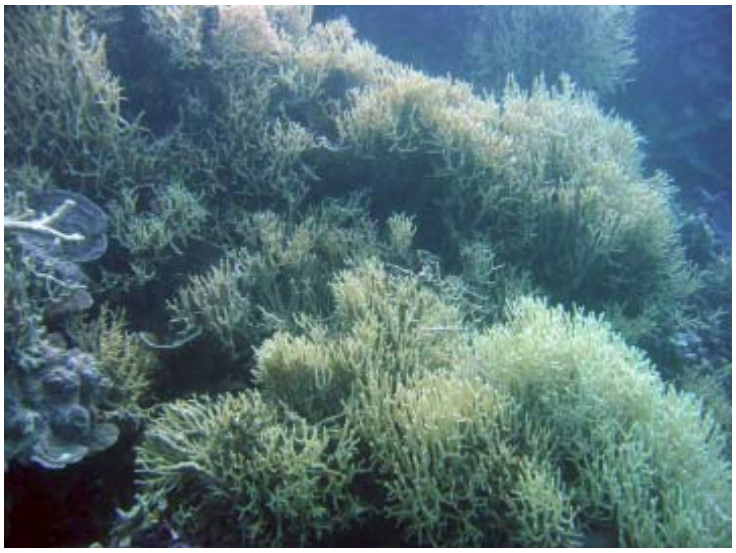
Water temperature	Sea surface temperature is one of the environmental factors responsible for the distribution of coral. Elizabeth and Middleton Reefs experience annual sea surface temperatures ranging from <19 °C to >25 °C. These probably also represent the upper tolerance for temperate species and the lower tolerance for tropical species, but allow for long-term persistence of both. To date there appears to have been limited coral bleaching – see Sections 3.6 and 3.8.	24
Climate	The effect of climate on water temperature, light and therefore, food availability (see above), influences the availability and suitability of habitats.	12

*see Section 5

Critical ecosystem components and processes
For this ecosystem service, the diversity of habitats coupled with the geomorphology and substrate form is the critical parameter; this being followed by water quality and water temperature. Sections 3.5 and 3.6 expand on this further.

Table 6: Per cent cover of major benthic groups at Elizabeth Reef for 10 survey sites (AIMS, 2003). SE = Standard Error. See the AIMS report for a full description of the methods used.

Site No.	Hard Coral	SE	Soft Coral	SE	Coraline Algae	SE	Macro Algae	SE	Turf Algae	SE	All Algae	SE	Sand	SE
1	29.2	3.4	0.0	0.0	0.0	0.0	0.2	0.2	56.2	4.4	56.3	4.3	13.8	6.8
2	10.3	4.3	2.0	1.3	0.0	0.0	33.8	3.9	37.7	3.8	71.5	6.1	15.5	0.8
3	26.8	2.9	4.3	1.9	15.3	3.9	7.3	0.4	45.2	8.1	67.8	4.6	0.3	0.2
4	35.2	2.0	0.3	0.3	19.8	1.6	2.7	1.2	33.7	0.7	56.2	2.0	0.0	0.0
5	28.3	1.6	0.3	0.2	25.8	0.7	10.0	3.5	32.8	4.3	68.7	1.6	0.2	0.2
6	35.2	5.4	1.0	0.3	15.2	2.2	10.7	2.3	36.7	5.0	62.5	5.0	0.3	0.3
7	28.3	2.1	2.0	0.9	3.4	1.7	29.3	1.1	35.1	4.3	67.7	1.9	0.2	0.2
8	11.3	0.4	1.7	1.4	1.8	0.9	15.0	3.0	55.2	2.4	72.0	5.4	12.8	4.2
9	31.7	3.2	5.7	1.3	2.5	0.5	5.2	0.3	53.2	3.8	60.8	4.1	0.0	0.0
10	23.3	1.0	6.9	1.3	4.6	1.9	18.6	1.6	44.7	2.6	67.9	1.5	0.7	0.3
Reef mean	25.4		2.4		8.8		13.3		43.0		65.1		4.4	0.0



Coral community in the lagoon – large stands of *Seriatopora hystrix* were common at depths of 6-9m. Figure A7 from the AIMS survey report, December 2003

Sea star on *Leptoria* coral colony. Figure A5 from the AIMS survey report, December 2003

Ecosystem service 3(c): Supports regionally high species diversity - molluscs		
Qualitative description		
Surveys have shown the presence of 240 species of molluscs, with 3% of them endemic and many numerically dominant. The Ramsar Information Sheet states (Appendix A): "Three mollusc species are endemic to the site (Anabathridae *Amphithalamus* sp. nov.; Retusidae *Decorifer elisa*; Mytilidae *Musculus nubilis*) and seven are endemic to the group of islands in this part of the Tasman Sea. Most of these endemic species are abundant on both reefs, but many of the species with much wider geographic distributions are rare at the site." Loch and Rudman (1992) note that the mollusc fauna of Elizabeth and Middleton Reefs is "...impoverished compared with the southern Great Barrier Reef but has a much larger tropical element than the NSW fauna at similar latitude." They also observed that despite the availability of what seemed like suitable soft-bottom habitats in both lagoons, several families (such as Olividae and Cassidae) were absent or recorded rarely. Likewise, some of the reef-dwelling families that were expected to be present were not. Loch and Rudman (1992) also recorded two giant clam species (*Tridacna derasa* and *T.maxima*).		
Quantitative description	**Typical range of variability and limits of acceptable change (LACs)**	**Reference***
240 species of mollusc, with three species endemic to the site and seven endemic to this group of islands. Two giant clam species (*Tridacna derasa* and *T.maxima*) recorded by Loch and Rudman (1992), although the 2003 AIMS survey reported only one sighting of *T.derasa* on the lagoon floor of Elizabeth Reef.	Typical ranges of variability are a knowledge gap. Interim LAC: No loss of endemic species.	24
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) Loch and Rudman (1992) consider several species and their habitat preferences. These range from species favouring hard substrate either outside or inside the reef through to those routinely found on coarse or softer substrates in the lagoons. For the giant clam species; *Tridacna derasa* was scattered in both lagoons whereas *T.maxima* were commonly found in reef-flat lagoonal areas.		24

*see Section 5

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Available habitat	Although the diversity of habitat at Elizabeth and Middleton Reefs is comparatively low, the combination of exposed and protected reefs and lagoons provide a variety of habitats for these many different species.	24
Geomorphology	The geomorphically complex topography of Elizabeth and Middleton Reefs provides a wide range of niche habitats for marine flora and fauna (See Figures 3-6). AIMS (2004) found the highest diversity of biota in areas of greatest structural complexity.	24
Oceanic currents	During summer months the East Australian Current brings warmer, tropical water southward along the Australian east coast, flowing across Elizabeth and Middleton Reefs. During winter the influence of this current is lessened and the West Wind Current (Antarctic Circumpolar Current) brings cooler water from the south into the region. It is possible that both of these currents transport larvae of fish and coral species to Elizabeth and Middleton Reefs.	24
Food sources / productivity	The highly productive ecosystem of Elizabeth and Middleton Reefs provides sufficient food for filter feeders to supply large and diverse populations.	24
Water temperature	Elizabeth and Middleton Reefs experience annual sea surface temperatures ranging from <19 °C to >25 °C. These probably also represent the upper tolerance for temperate species and the lower tolerance for tropical species, but allow for long-term persistence of both.	24
Climate	The effect of climate on water temperature, light and therefore, food availability (see above), influences the availability and suitability of habitats.	12

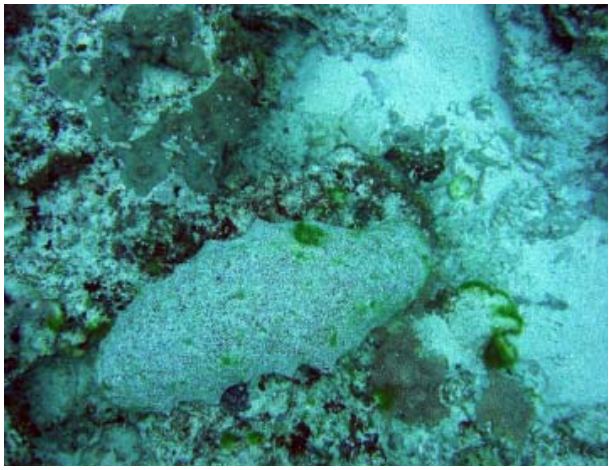
*see Section 5

Critical ecosystem components and processes

For this ecosystem service, the diversity of habitats coupled with their geomorphology is the critical parameter; this is followed by food sources. Sections 3.5 and 3.6 expand on this further.

Ecosystem service 3(d): Supports high species diversity - bêche-de-mer		
Qualitative description		
Elizabeth and Middleton Reefs have a high abundance and diversity of bêche-de-mer with species recorded there.		
Quantitative description	**Typical range of variability and limits of acceptable change (LACs)**	**Reference***
AIMS (2004) surveyed Elizabeth Reef for bêche-de-mer (holothurians) in the lagoon and reef perimeter at a depth of 6-12m. The results of that survey for four species are given in Table 7 below.	Natural variability of these populations is not known and the total population estimates have not been made to date. Given this it is not possible to indicate definitive LACs until further, and longer-term, surveys are conducted. Interim LACs are as follows: 1. No loss of species; and 2. One chosen species (eg.*H.whitmaei (nobilis)*) chosen as the prime LAC indicator: population density that falls more than 10% below the estimates of AIMS (2004) – see Table 7 below - for three consecutive years (annual surveys) will be reason for concern. This is subject to having reliable and long-term data to support such an approach.	2
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 2 above) Lagoon, reefs slopes, sandy habitats.		

*see Section 5



Holothuria whitmaei (Black Teatfish) – Figure A1 from the AIMS survey report, December 2003

Table 7: Density information for four holothurians surveyed at Elizabeth Reef by the 2003 AIMS survey (AIMS 2004). Data are given in individual/ha, with standard deviations in brackets.

Site	Area sampled (ha)	Habitat/ substrate	*H.whitmaei (nobilis)*	*H.atra*	*H.impatiens*	*H.edulis*
Lagoon swim 1	1	Lagoon sand	38 (20.8)	398 (143.5)	153 (61.9)	7 (8.9)
1	0.075	Upper reef slope, sand/ consolidated	0	0	0	200.0
2	0.075	Upper reef slope, sandy, channel	93.3	240.0	80.0	0
3	0.075	Upper reef slope, sandy, channel	306.7	13.3	0	0

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Diversity of habitats	The diversity of habitats at Elizabeth and Middleton Reefs provides for a wide range of species of sea cucumbers (especially sandy lagoon areas and reef slopes).	2
Food sources / productivity	As feeders on detritus, sea cucumbers require high productivity environments that supply organic detritus.	2
Geomorphology	Sea cucumbers are found where significant sand substrate exists, at wide-ranging depths.	2
Substrate	Sea cucumbers are predominantly deposit feeders, ingesting sediment and extracting the nutrients. Some require sandy substrates, while others are reef specialists.	2
Climate	The effect of climate on water temperature, light and therefore, food availability (see above), influences the availability and suitability of habitats.	12

*see Section 5

Critical ecosystem components and processes:
For this ecosystem service, the diversity of (shallow water) habitats coupled with the substrate is the critical parameter; this being followed by food sources. Sections 3.5 and 3.6 expand on this further.

Ecosystem service 4: Supports animal taxa at a vulnerable or critical stage of their lifecycle: Galapagos Sharks
Qualitative description
The presence of Galapagos Sharks (*Carcharinus galapagensis*) has been recorded at Elizabeth and Middleton Reefs on numerous occasions, dating back to the 1920's. However, results of a survey in December 2003 indicate that these sharks may be using the reefs as nursery habitat. They are also found in the waters around Lord Howe Island. The Galapagos Shark is currently considered "Near Threatened" by the World Conservation Union (IUCN).

Galapagos Shark (*Carcharhinus galapagensis*) - Figure A8 from the AIMS survey report, December 2003

Quantitative description	Typical range of variability and limits of acceptable change (LACs)	Reference*
21 juveniles recorded in the lagoon of Elizabeth Reef in December 2003. The resilience of this species is very low, with a minimum population doubling time of more than 14 years.	Population estimates have not been made to date and the natural variability of this population is not known. **Interim LACs:** Knowledge gap. In relation to habitat, that preferred as a nursery area is the sheltered, shallow lagoon at Elizabeth Reef. See Ecosystem service 1 above.	2, 22
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) A common but habitat-limited tropical shark found close inshore as well as offshore near, or on, insular or continental shelves. Prefers clear water with coral		2

and rocky bottoms. Although a coastal pelagic species, it is capable of crossing considerable distances of open ocean between islands (at least 50 km). Sheltered, shallow lagoon habitat at Elizabeth Reef provides nursery conditions for this species. Outer reef provides ideal habitat for adults.	

*see Section 5

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Geographical location	The Galapagos Shark is circumtropical in distribution, with a preference for waters around oceanic islands. Elizabeth and Middleton Reefs represent the extreme southern range of the species.	2
Available habitat	Galapagos Sharks occur in reef-associated waters, ranging from 0-180m deep. The sheltered, shallow lagoon habitat at Elizabeth Reef provides nursery conditions for this species, which are known to shelter in protected waters as juveniles to avoid predation and cannibalism. The outer reef provides ideal habitat for adults which prefer clear tropical waters with strong currents over coral or rocky bottom habitats.	2
Geomorphology	The geomorphologically complex topography of Elizabeth and Middleton Reefs provides a wide range of niche habitats for this species (see Figures 3-6).	2
Food sources / productivity	Galapagos Sharks feed predominantly on bottom dwelling fish, squid and octopus. Elizabeth and Middleton Reefs, with their relative abundance of finfish would provide sufficient food for small populations.	2
Oceanic currents	During summer months the East Australian Current brings warmer, tropical water southward along the Australian east coast, flowing across Elizabeth and Middleton Reefs. During winter the influence of this current is lessened and the West Wind Current (Antarctic Circumpolar Current) brings cooler water from the south into the region. It is possible that both of these currents are transporting larvae of fish and coral species to Elizabeth and Middleton Reefs.	2
Water temperature	The distribution of this shark is limited to tropical waters (36°N-41°S), suggesting that water temperature is an important factor.	2

*see Section 5

Critical ecosystem components and processes:
For this ecosystem service, the diversity of habitats coupled with the geomorphology is the critical parameter. Sections 3.5 and 3.6 expand on this further.

Ecosystem service 5: Supports the last known large population of Black Cod (*Epinephelus daemelii)*

Qualitative description

The Black cod, also known as Black rockcod or Black-saddled rockcod, are a large, reef-dwelling, carnivorous grouper species. They are found in warm temperate and subtropical parts of the south-western Pacific (25°S-43°S and 136°E-177°W). Large black cod are slow moving, territorial and curious, which makes them very susceptible to line and spear-fishing, and their populations have been greatly reduced over the last two centuries.

The Australian range for this species extends from southern Queensland to Kangaroo Island off South Australia; and they are also reported from the Bass Strait.

Elizabeth and Middleton Reefs (together with Lord Howe Island) represent the only principal habitat for significant populations of Black Cod (*Epinephelus daemelii*) in the region.

The Black Cod (*Epinephelus daemelii*) is a protected species in NSW State and Commonwealth waters. It is listed as a Vulnerable Species in NSW under the *NSW Fisheries Management Act 1994* and the Commonwealth EPBC Act 1999.

Continued protection in NSW waters and Commonwealth waters will assist the survival of the Black Cod. The implementation of Marine Protected Areas or no take fishing zones in known habitats may be necessary to provide further protection. The main threat to this species appears to be that of illegal fishing activities. Additionally, the Black Cod is likely to be taken in small numbers as a by-catch of commercial and recreational fishing activities in rocky shore and island habitats along the southern Queensland, NSW and northern Victorian coastlines.

Quantitative description	Typical range of variability and limits of acceptable change (LACs)	Reference*
'Rough' estimate of 4 cod / ha for Elizabeth Reef. In the 2003 survey the length of Black Cod observed (n=18) was 55-150 cm. The mean size of Black Cod observed in 2003 was significantly greater than in 1987 (Australian Museum, 1992) – see Figure 8 below.	The resilience of this species is very low. The minimum population doubling time is more than 14 years. Length-frequency data are useful indicators of stock condition. However, given the small sample size it is necessary to set conservative interim LACs based on relative abundance and size structure. Interim LAC: No decline based on current 'rough' estimate of 4 cod / ha until further surveys are done.	2
Primary habitat zone(s) used for each life history stage: (See Ecosystem service 1 above) The reef slope and lagoon habitats of both Elizabeth and Middleton reefs provide the shallow 'cave' habitats required by this species.		2

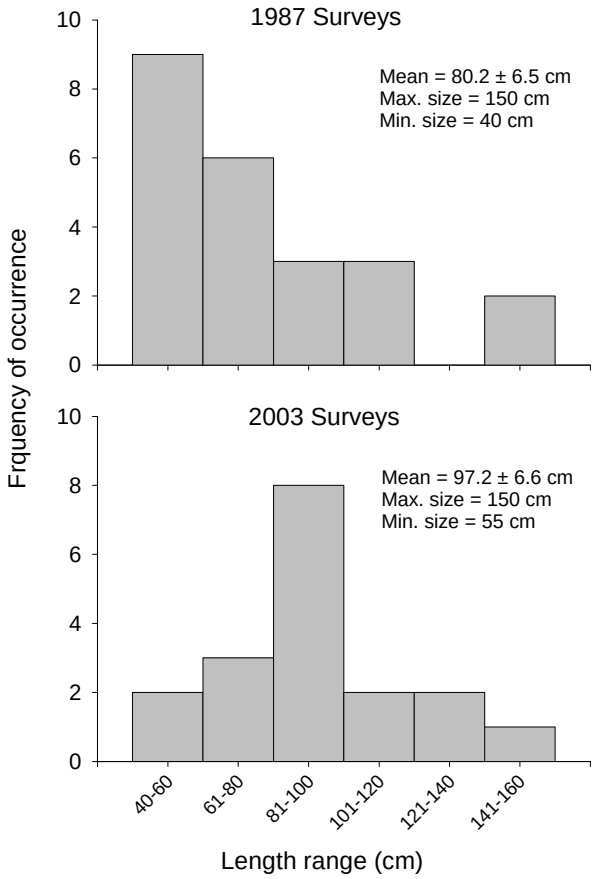


Figure 8: Lengths of Black Cod visually estimated from Elizabeth and Middleton Reefs in 1987, and Elizabeth Reef in 2003. Mean (with standard error), maximum and minimum lengths are included. (Figure 14 from report on AIMS survey in December 2003).

Black Cod (*Epinephelus daemelii*) - Figure A2 from the AIMS survey report, December 2003

Primary ecosystem components and processes	How they support the ecosystem service	Reference*
Food sources / productivity	Black Cod are opportunistic carnivores and the small fish and crustacean populations of the Elizabeth and Middleton Reefs provide suitable food sources to sustain the Black Cod populations.	2
Available habitat	The reef slope and lagoon habitats of both Elizabeth and Middleton reefs provide the shallow "cave" habitat suitable for the Black Cod. These fish are slow moving and slow growing and often occupy the same cave for life.	2
Geomorphology	The complex geomorphology provides the cave habitat for these territorial fish.	2

*see Section 5

Critical ecosystem components and processes:
For this ecosystem service, the availability of habitats is the critical parameter. Sections 3.5 and 3.6 expand on this further.

3.5 Link the selected ecosystem services with the critical ecological components and processes that support them and select those components to be further specified (Step 5 – in part, see Section 3.4 also)

Also part of Step 5 (see Section 3.4 above also) is to cross-reference the primary ecological components and processes with the ecosystem services and use this to select the most critical of these to be further specified (see selection criteria below). The key below indicates the primary ecological components and processes and those selected as the most critical of these.

Table 8: Linking the selected ecosystem services with the critical ecological components and processes

Ecosystem services	Primary ecosystem components and processes										
	Available habitats	Habitat connectivity	Food sources, productivity	Geographic location	Oceanic currents	Climate (including winds)	Geomorphology	Water quality	Water temperature	PAR	Substrate
1. Representative of unique ecosystem in the bioregion	■	▒		▒	▒	▒	■	■	▒		▒
2. Green Turtles	■		■			▒	■	■	▒	▒	
3(a). Fishes	■				▒		▒		▒		
3 (b). Coral communities	■				▒	▒	■	■	■		■
3(c). Molluscs	■	▒	■		▒	▒	■		▒		
3(d) Bêche-de-mer	■		■			▒	■				■
4. Galápagos Sharks	■		▒	▒	▒		■	▒			
5. Black Cod	■		■	▒			■	▒			■

Selecting the critical components and processes (DSE Framework, 2005):	Key
Critical ecosystem components and processes should be selected based on the following criteria: 1. for which baseline data is available to specify the component or process; 2. for which change is reasonably likely to occur over short or medium time scales (<100 years); 3. which will cause significant negative consequences if change occurs; or, 4. those which are practical and meaningful to monitor. Note: 1. above was not applied here as it would disqualify the majority of the components and processes, and, in relation to 4, this project has added the word "meaningful" for obvious reasons.	Black shaded cells = critical ecological components and processes – specified further in Section 3.6 Grey shaded cells = primary ecological components and processes White cells = not a primary ecological component and process for this ecosystem service

.

Critical ecological components and processes to be specified:
From the table above further clarifications are needed in relation to the following ecosystem components and processes identified as being critical parts of the ecological character (shaded back):

1. Available habitats types, geomorphology and substrate are all closely linked and have been considered in the foregoing section, and through Ecosystem Service 1 in particular.

2. Food sources and productivity are related directly to the overall Elizabeth and Middleton Reefs ecosystem (see Ecosystem Services 1-5 in Section 3.4) and the biota that is found there.

3. Water quality and water temperature are critical ecosystem components. At present there are no major concerns about water quality or temperature at the site.

Section 3.6 examines these critical ecological components and processes in more detail.

3.6 Specify the selected critical components and processes that support the selected ecosystem services (Step 6)

Based on the preceding section, the critical components and processes are now described in detail, wherever possible providing limits of acceptable change (see **Important note** in Section 2, page 2).

Table 9: Critical components and processes that support the selected ecosystem services

Critical component or process (see preceding section)	Quantitative description	Limits of acceptable change (LACs)
1. Available habitat types, geomorphology and substrate	As advised under Ecosystem service 1 in Section 3.4, the aerial extent of eight geomorphological categories has been estimated. However, this has not been ground truthed nor correlated with habitat types as yet.	See comment at left. LAC cannot be set at present.
2. Food sources and productivity	While dietary habits are known for many of the notable species or species groups considered in Section 3.4, it is not possible to quantify this in a meaningful way for this exercise.	It is not possible to set LACs for the various food sources referred to at left as there is little or no know data at present.

3. Water quality	**Temperature:** The survey report by AIMS (2004) concludes that "the current state of the coral community would suggest that there has not been severe mortality from bleaching in the lagoon in recent years". Sea surface temperature data provided in that report (as reproduced below in Figure 9) would seem to support this contention. **Nutrients:** The Australian Museum (1987) observed that there is no information on seawater nutrients, either dissolved or particulate, for this site, and it would seem that situation has not altered. **Turbidity:** The Australian Museum (1987) noted that visibility was between 15 and 20 m during December, although down to 2-4 m in the lagoons. This became much less as sampling was undertaken with the suspension of the very fine sediments. They noted that strong winds caused a similar effect.	Given the lack of data on water quality parameters no LACs can be indicated at this time.

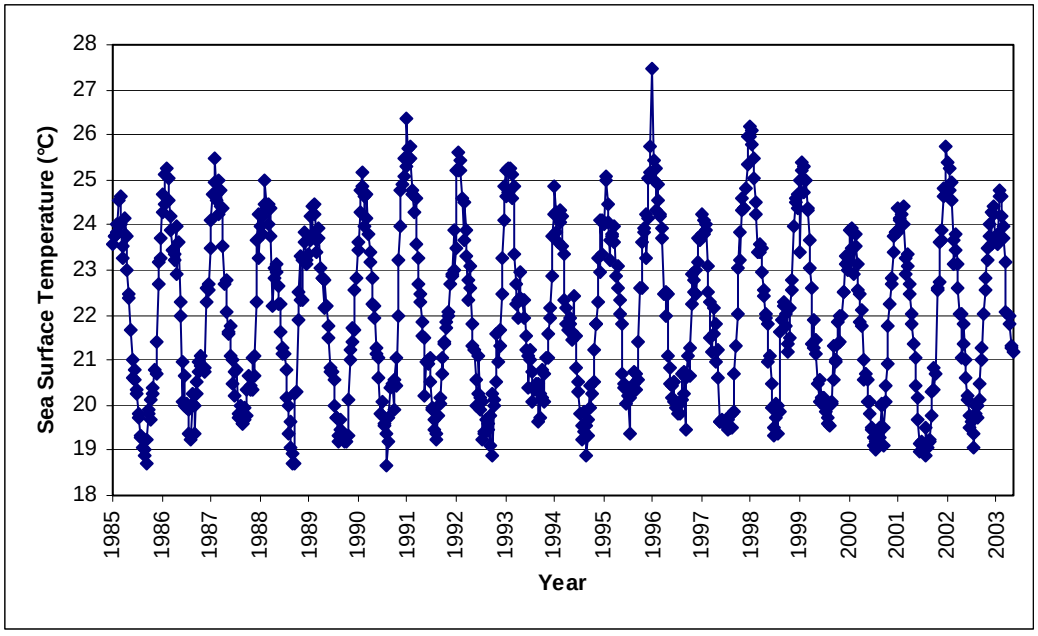


Figure 9: Average sea surface temperature for the waters around Elizabeth and Middleton Reefs (graph provided by DEH). (Figure 3 from report on AIMS survey in December 2003).

3.7 Ecological character management benchmarks (Step 7), key knowledge gaps and recommended monitoring

Based on the information presented in Sections 3.4 and 3.5, the following are the ecological character management benchmarks for this Ramsar site, based on the currently available knowledge (see 'Important note' in Section 2, page 3).

Table 10: Ecological character management benchmarks, key knowledge gaps and recommended monitoring

Ecosystem services	Quantitative description	Typical range of variability and limits of acceptable change (LACs)	Key knowledge gaps and recommended monitoring
1: Representative of a unique ecosystem in the bioregion	Areal extent of habitats: Outer reef slopes: Knowledge gap Reef crests: Knowledge gap Lagoons: Knowledge gap Reef Benthos at Elizabeth Reef (AIMS, 2004). See summary tables below. Other notable species or groups thereof: see Ecosystem services 2-5 below.	**Interim LACs:** **Areal extent of habitats:** Knowledge gap **Reef benthos:** see comment in Section 3.4	**Key knowledge gaps:** The areal extent of the broad habitats and the more detailed breakdown of these, including the reef benthos communities. Build on available estimates of percent coral cover from earlier surveys to establish typical natural variability of these habitat types. **Monitoring:** The areal extents of the broad habitats and the reef benthos communities. It should be possible to do this in part by using remote sensing, with complementary ground-truthing. Bi-annual assessments should be adequate.
2: Supports threatened species – Green Turtles	The species seems not to breed or nest here; using the site as feeding habitat only. No population estimates available, and no estimates of primary habitats, such as sea grass and algal beds.	**Interim LACs:** **Population:** Knowledge gap **Primary habitats:** Knowledge gap	**Key knowledge gaps:** Size and natural fluctuations in this foraging population. Extent of primary feeding habitats. **Monitoring:** Over a minimum 5 year time frame, regular surveys

			and focused assessments at key times to help address the knowledge gaps and provide for more robust LACs. It would be worth exploring the use of aerial or underwater visual census methods.
3(a): Supports high species diversity - fishes	314 species of fish, from 174 genera and 75 families have been described from the reefs to date. A further 7 undescribed species have been recorded which may be endemics; for example, a new morwong species, *Cheilodactylus (Goniistius) francisi*, is recognised from south-west Pacific Islands including Elizabeth and Middleton Reefs area. The AIMS survey of December 2003 recorded 181 fish species for Elizabeth Reef; 61 of these were new records for this reef although 16 of these had been recorded previously from Middleton Reef by the Australian Museum surveys. The AIMS survey in December 2003 compared abundance (numbers per hectare) of large reef fish and damselfishes across sampling sites but found nothing conclusive about habitat preferences – see figure 13 from that report reproduced, as Figure 7.	The large variation in species composition between surveys (most likely due to different survey methods) makes it very difficult to set LACs from existing data. Given that the ecosystem service is 'species diversity' the development of LACs should consider issues such as the number of and abundance of individual species. **Interim LAC** is recommended as no loss of species, until such time as more survey data are gathered.	**Key knowledge gaps:** Habitat needs and population dynamics of species. **Monitoring:** Over a minimum 5 year time frame, regular surveys (at least yearly) and intensive assessments at key times to help address the key knowledge gaps and provide for more robust LACs. Data comparison with a control site such as Lord Howe Island.
3(a): Supports high species diversity – coral communities	Hutchins (1992), based on survey data from 1981 from Veron and Done, reported 122 coral species, although noted that this was low by comparison with locations such as the Great Barrier Reef presumably because of the relatively simple and limited reefal habitat. In the AIMS 2003 report identified	While the AIMS 2004 survey found similar per cent cover for hard and soft coral to earlier surveys, there remains uncertainty about variability within these communities. Future survey should also consider algae, as did the AIMS survey. **Interim LACs** are as follows:	**Key knowledge gaps:** Habitat needs and population dynamics of the coral and algal species. **Monitoring:** Over a minimum 5 year time frame, regular surveys (at least yearly) and intensive

	111 coral species for Elizabeth Reef alone. Through surveys at 10 locations around Elizabeth Reef, the AIMS 2003 survey found per cent cover of hard and soft corals similar to that reported by the earlier Hutchins (1992). The AIMS survey findings for 2003 are provided in Tables 5 and 6.	1. No loss of species; and 2. Per cent cover of hard and soft corals that falls more than 20% below the estimates of AIMS (2004) – see Table 6 below - for three consecutive years (annual surveys) will be reason for concern. This is assumes repeated surveys at the same 10 sites used by AIMS, and it applies only to Elizabeth Reef for now. Longer term data is needed at both sites.	assessments at key times to help address the key knowledge gaps and provide for more robust LACs. Repeat of surveys at the ten sites used by AIMS in 2003 is needed to apply the interim LAC. Data comparison with a control site such as Lord Howe Island.
3(c): Supports high species diversity – molluscs	240 species of mollusc, with three species endemic to the site and seven endemic to this group of islands. Two giant clam species (*Tridacna derasa* and *T.maxima*) recorded by Loch and Rudman (1992), although the 2003 AIMS survey reported only one sighting of *T.derasa* on the lagoon floor of Elizabeth Reef.	**Interim LACs:** No loss of endemic species.	**Key knowledge gaps:** Habitat needs and population dynamics of species. **Monitoring:** Over a minimum 5 year time frame, regular surveys and intensive assessments at key times to help address the key knowledge gaps and provide for more robust LACs.
3(d): Supports high species diversity - bêche-de-mer	AIMS (2004) surveyed Elizabeth Reef for bêche-de-mer (holothurians) in the lagoon and reef perimeter at a depth of 6-12m. The results of that survey for four species are given in Table 7.	Natural variability of these populations is not known and the total population estimates have not been made to date. Given this it is not possible to indicate definitive LACs until further, and longer-term, surveys are conducted. **Interim LACs** are as follows: 1. No loss of species; and 2. One chosen species (eg.*H.whitmaei (nobilis)*) chosen as the prime LAC indicator: population density that falls more than 10% below the estimates of AIMS (2004) – see Table 7 - for three consecutive years (annual surveys) will be reason for concern. This is subject to having reliable and long-term data to	**Key knowledge gaps:** Habitat needs and population dynamics of species. **Monitoring:** Over a minimum 5 year time frame, regular surveys and intensive assessments at key times to help address the key knowledge gaps and provide for more robust LACs.

		support such an approach.	
4: Supports animal taxa at a vulnerable or critical stage of their life cycle - Galapagos Sharks	21 juveniles recorded in the lagoon of Elizabeth Reef in December 2003. No other population data available. The resilience of this species is very low, with a minimum population doubling time of more than 14 years.	Population estimates have not been made to date and the natural variability of this population is not known. **Interim LACs:** Knowledge gap. In relation to habitat, that preferred as a nursery area is the sheltered, shallow lagoon at Elizabeth Reef. See Ecosystem service 1 above.	**Key knowledge gaps:** Size and typical range of variability within this population. **Monitoring:** Over a minimum 5 year time frame, regular surveys (at least yearly) and intensive assessments at key times to help address the key knowledge gaps. Develop surveys using a non-destructive technique such as baited video or underwater visual census.
5: Supports the last large population of Black Cod	'Rough' estimate of 4 cod / ha for Elizabeth Reef. In the 2003 survey the length of Black Cod observed (n=18) was 55-150 cm. The mean size of Black Cod observed in 2003 was significantly greater than in 1987 (Australian Museum, 1992) – see Figure 8.	**Interim LACs:** The resilience of this species is very low. The minimum population doubling time is more than 14 years. Length-frequency data are useful indicators of stock condition. However, given the small sample size it is necessary to set conservative interim LACs based on relative abundance and size structure. **Interim LAC:** No decline based on current 'rough' estimate of 4 cod / ha until further surveys are done.	**Key knowledge gaps:** Typical range of variability within this population. **Monitoring:** Over a minimum 5 year time frame, regular surveys (at least yearly) and intensive assessments at key times to help address the key knowledge gaps. Surveys based on using non-destructive technique such as baited video or underwater visual census. Ideally, it should be possible to monitor sharks and cod at the same time using same techniques.
Key component or process			
1: Available habitat types, geomorphology and substrate	As advised under Ecosystem service 1 in Section 3.4, the aerial extent of eight geomorphological categories has been estimated. However, this has not been ground truthed nor correlated with habitat	See comment at left. LAC cannot be set at present.	**Key knowledge gaps:** See ecosystem service 1 above.

	types as yet.		
2: Food sources and productivity	While dietary habits are known for many of the notable species or groups considered in Section 3.4, it is not possible to quantify this in a meaningful way for this exercise.	It is not possible to set LACs for the various food sources referred to at left as there is little or no know data at present.	**Key knowledge gaps:** Future surveys undertaken in relation to each notable taxa or group will clarify dietary needs and allow for better understanding of the food webs within this ecosystem.
3: Water quality	**Temperature:** The survey report done by AIMS (2004) concludes that "the current state of the coral community would suggest that there has not been severe mortality from bleaching in the lagoon in recent years". Sea surface temperature data provided in that report (as reproduced in Section 3.6) would seem to support this contention. **Nutrients:** The Australian Museum (1987) observed that there is no information on either seawater nutrients, either dissolved or particulate, for this site, and it would seem that situation has not altered. **Turbidity:** The Australian Museum (1987) noted that visibility was between 15 and 20 m during December, although down to 2-4 m in the lagoons. This became much less as sampling was undertaken with the suspension of the very fine sediments. They noted that strong winds caused a similar effect.	Given the lack of data on water quality parameters no LAC can be indicated at this time.	**Key knowledge gaps:** Establish the water quality tolerances of key biota, starting with the species and groups considered 'Ramsar significant' (ie those addressed in this report). **Monitoring:** Continue to monitor see surface temperature. Ideally – 1 year of continuous data logging on turbidity or light meters at a number of key habitat zones (Outer reef slopes, reef crests and lagoons). Week of intensive measuring (conducted annually) of dissolved oxygen profiles and nutrients (TN, NH_4, NO_x, TP, PO_4, SiO_4) at a number of sites in the lagoon.

3.8 Threats, risks and monitoring

The foregoing section set out the (interim) ecological character management benchmarks for the Elizabeth and Middleton Reefs Ramsar site, and recommended monitoring approaches to gain insights into the condition of the ecosystem over time. Related to this is the issue of threat mitigation and risk management; these being factors that can alter ecological character if not addressed.

For this site the following are recognised as the primary threats. While some are more regional in scope, they have been included here for the sake of completeness.

Crown of Thorns Starfish (*Acanthaster planci*) - Figure A12 from the AIMS survey report, December 2003

Table 11: Threats, risks and monitoring

Threats	Qualitative description	Risk to ecosystem services as specified in the Table in Section 3.4	Key knowledge gaps and recommended monitoring
Crown of thorns star-fish	The Crown of Thorns Starfish (COTS) was first recorded at this site by AIMS in 1981 (Hutchings, 1992). Hutchings provided data on the densities observed in surveys of 1987 although noting great variability. A more recent survey in January 2002 by Kelly (as reported in AIMS, 2004) found COTS at densities up to 0.9/m^2 at Middleton Reef, yet at seven sites on the perimeter of Elizabeth reef he found no evidence of feeding	The serious impact COTS can have on coral communities is well documented from other sites, such as the Great Barrier Reef. Threat is to Ecosystem service 1 in particular.	**Key knowledge gaps:** The distribution and abundance of this species across the two reefs and the current status of that population (stable, declining, increasing). **Monitoring:** Ongoing monitoring to remain aware of the possible spread and impact of the COTS on this ecosystem. This would include: routine monitoring and estimation of COTS densities; comparison of densities with historical estimates; correlation with estimated coral cover; and

	scars from COTS.		assessment of size frequency distributions (temporal patterns in recruitment and an early warning of potential outbreaks).
Illegal fishing for Black Cod and other species	This has been an issue for this site in the past as Black Cod are a prized species. Many commercial long-liners and pleasure vessels anchor here for protection and have been known to fish illegally. Anecdotal evidence suggests this issue extends also to other species.	This being a largest known population of the species vigilance is required to avoid illegal take. Threat is to Ecosystem service 5.	**Key knowledge gaps:** Abundance and size structure. **Monitoring:** Is undertaken as part of ongoing management arrangements.
Illegal collection of fish for the aquarium trade	The reefs have many species considered attractive to the aquarium trade.	Small scale collecting may not have a serious impact on ecological character, but would be a concern nonetheless. Threat is to Ecosystem service 3(a)	**Monitoring:** Is undertaken as part of ongoing management arrangements.
Thermal anomalies and coral bleaching	The current view (see preceding section) is that sea surface temperature anomalies have not yet occurred to such an extent to cause significant coral bleaching at this site.	Higher than normal sea surface temperatures have the potential to cause coral bleaching and possibly impact on some other marine biota. Threats are to Ecosystem services 2, 3 and indirectly to 4 and 5. See also Section 3.6, critical component 3 – water temperature.	**Key knowledge gap:** Impact on endemic flora and fauna and significant ecological communities. **Monitoring:** While this issue is beyond the scope of the site managers, ongoing monitoring of sea surface temperatures may help gain a better understanding of climate change phenomenon regionally and globally.
Anchor damage	Service and enforcement vessels as well as other visitors, authorised (scientific) or illegal (fishing – see above), may cause damage to coral areas with indiscrete use of anchors.	Coral damage. Threats are to Ecosystem service.	**Monitoring:** Monitoring of vessel numbers using and not using moorings and the impact the latter is having on the coral communities in those locations.
Ballast water and other pollution	There is the potential to impact on the ecology of the reefs through the release of ballast waters, and other pollutants by service and enforcement vessels as well as other visitors, authorised	Ballast water could introduce marine pest species, and other pollutants (eg. discarded fishing nets) could cause mortalities among the marine biota.	**Monitoring:** Is undertaken as part of ongoing management arrangements.

	(scientific) or illegal (fishing – see above). Other vessels passing nearby could deposit disused nets or other rubbish.	Threats are to Ecosystem services 1-5.	
Pollution from shipwrecks	Elizabeth and Middleton Reefs are well known for the many shipwrecks found there. However most pollution occurs at the time of the wreck. Over time the wrecks may form habitats for some species.	Gradual breakdown of wreck structures over time may not impact significantly on the habitat. Nevertheless, there may be potential for some local scale impacts on coral communities and water quality.	**Monitoring:** Is undertaken as part of ongoing management arrangements.
Shipping accidents	Modern shipping routes pass relatively close to the reefs and pose a potential risk of direct grounding and/or pollution from oil spills.	A number of recent wrecks on the reefs are evidence that the reefs are in an area for potential shipping accidents.	**Monitoring:** Is undertaken as part of ongoing management arrangements.

4. Areas for further investigation

This report has identified a significant number of knowledge gaps, as presented in Sections 3.6 – 3.8 in particular. While it can be said that the Elizabeth and Middleton Reefs Ramsar site has been subjected to some surveys and investigations over the years, the lack of long-term data sets was a major obstacle to this project providing strongly supported limits of acceptable change (LAC) in order to benchmark the ecological character of the system. Instead, interim LACs were developed until such time as these data sets can be gathered.

It is also apparent from the investigation done by this project that there may be additional biological and ecological assets at the Elizabeth and Middleton Reefs Ramsar site that could warrant recognition through the Ramsar Information Sheet for the site (Appendix A) and a subsequent updating of this description of ecological character.

Among these is consideration of the significance of the site for a number of EPBC-listed species that in the draft second management plan for the site are identified as 'known or likely to occur in the reserve'. Those not considered in detail in the foregoing sections are listed below. For many of these species it seems likely that they only occasionally occur in, or possibly pass through, the Elizabeth and Middleton Reefs area, and as such the reefs would not form critically important habitat for them. For others, it may be that future surveys will confirm their presence and show that the Ramsar site is an important habitat.

Cetaceans
Balaenoptera musculus Blue Whale
Eubalaena australis Southern Right Whale
Balaenoptera borealis Sei Whale
Balaenoptera physalus Fin Whale
Megaptera novaeangliae Humpback Whale
Lagenorhynchus obscurus Dusky Dolphin

Reptiles
Dermochelys coriacea Leathery Turtle
Family Hydrophiidae sea-snakes
Family Laticaudidae sea-snakes
Family Cheloniidae marine turtles

Birds
Diomedea exulans Wandering Albatross
Diomedea antipodensis Antipodean Albatross
Thalassarche impavida Campbell Albatross
Diomedea gibsoni Gibson's Albatross
Thalassarche cauta Shy Albatross
Fregetta grallaria grallaria White-bellied Storm-Petrel
Pterodroma neglecta neglecta Kermadec Petrel
Anous stolidus Common noddy
Pterodroma macroptera Great-winged petrel
Pterodroma externa White-necked petrel
Puffinus carneipes Fleshy-footed shearwater
Puffinus pacificus Wedge-tailed shearwater
Puffinus griseus Sooty shearwater
Sula dactylatra Masked booby
Sterna bergii Sooty tern
Arenaria interpres Ruddy turnstone

Fish
Carcharodon carcharias Great White Shark
Family Syngnathidae seahorses, seadragons and pipefish

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Appendix A:

Information Sheet on Ramsar Wetlands

Categories approved by Recommendation 4.7 of the Conference of the Contracting Parties.

1. Date this sheet was completed/updated:
October 2002.

2. Country: Australia

3. Name of wetland: Elizabeth and Middleton Reefs Marine National Nature Reserve

4. Geographical coordinates:
Elizabeth Reef - Latitude: 29° 56' S ; Longitude: 159° 05' E
Middleton Reef - Latitude: 29° 27' S ; Longitude: 159° 07' E

5. Altitude: Wetland areas within the site are situated at, and several metres below, mean sea level. Sand cays within the site have an elevation (variable) of only one or two metres.

6. Area: 88,000 ha
The site boundary corresponds to the boundary of Elizabeth and Middleton Reefs Marine National Nature Reserve.

The area of reef wetland within the Reserve is estimated to be 8,800 ha, of which approximately 5,100 ha is located at Elizabeth Reef and 3,700 ha is located at Middleton Reef. For both reefs, the estimated area of wetland includes some water more than 6.0 metres deep at low tide.

7. Overview:
Elizabeth and Middleton Reefs are the southernmost coral atolls in the world. Their coral structures occur atop isolated, oceanic sea mounts and are influenced both by tropical and temperate ocean currents. The Reefs support a diverse marine fauna including uncommon and undescribed fishes, several endemic species of mollusc, and provide the only habitat for these species in a vast area of ocean.

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8. Wetland Type:

marine-coastal:	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
inland:	**L**	**M**	**N**	**O**	**P**	**Q**	**R**	**Sp**	**Ss**	**Tp**	**Ts**
	U	**Va**	**Vt**	**W**	**Xf**	**Xp**	**Y**	**Zg**	**Zk**		
man-made:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**		

Please now rank these wetland types by listing from the most to the least dominant: C, E.

9. Ramsar Criteria

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**

Please specify the most significant criterion applicable to the site 4.

10. Map of site included? Please tick *yes* ☑ -or- *no.*☐

11. Name and address of the compiler of this form:

Roger Jaensch, Warren Lee Long & Aaron Jenkins,
Wetlands International – Oceania, GPO Box 787, Canberra ACT 2601, Australia.
Contact details (RJ): tel. = +61-7-3406-6047; fax. = +61-7-3896-9624; email = roger.jaensch@epa.qld.gov.au

12. Justification of the criteria selected under point 9, on previous page.

Criterion 1.

There has been no formal inventory of wetlands throughout the Tasman Sea and a biogeographic regionalisation for Australia's oceanic territory has not been finalised. However, Elizabeth and Middleton Reefs may be considered as both rare and representative examples of coral reef wetland in this oceanic region as they are among the few, and largest, present. Furthermore, these reefs are distinctive in occurring atop oceanic sea mounts; they are the southern-most open-ocean platform reefs in the world (Environment Australia 2002a). They represent an environment not present elsewhere in Australian waters, and are a unique coral reef community (ANPWS 1992, pp. xvii, 111).

Criterion 2.

Green Turtle *Chelonia mydas* occurs in waters around the Reefs (ANPWS 1992). There is insufficient sand habitat for nesting by this species at the site and no assessment of its population within the site has been conducted. Nevertheless, Green Turtle is listed as vulnerable under Australian Commonwealth legislation (*Environment Protection and Biodiversity Conservation Act 1999*), is classified as endangered on the IUCN Red List, and is protected under the *Convention on the International Trade of Endangered Species of Wild Animals* (CITES) to which Australia is a signatory.

Criterion 3.

There has been no formal inventory of wetland biodiversity throughout the Tasman Sea. However, in view of the rarity of reef habitat in this oceanic region and the moderately large number of marine animal species and diversity of faunal groups recorded at the site (ANPWS 1992), the Reefs represent a 'hotspot' of biological diversity in the region (Ramsar Convention 2002). To date, 314 fishes belonging to 174 genera and 75 families have provisionally been recorded at the Reefs, compared to only half or less of this number of species at other Tasman Sea islands (ANPWS 1992, p. 90). Furthermore, seven undescribed and thus potentially endemic fishes have been recorded at the Reefs (ANPWS 1992, pp. 92-3). The limited scientific investigations to date have yielded approximately 122 species of corals, 122 species of crustacean, 240 species of mollusc and 74 species of echinoderm (ANPWS 1992), and further surveys would be expected to yield much higher numbers of species. Of the mollusc species collected, 3% are endemic and many of these are numerically dominant at the site (ANPWS 1992).

Criterion 4.

Populations of Black Cod *Epinephelus daemelii* on the Elizabeth-Middleton Reefs are important to survival and protection of this species; in the past, spear-fishing has posed a large threat to populations here and on the east coast of Australia. Furthermore, the coral reefs of the site, together with those of Lord Howe Island, provide the only habitat within an extensive area of ocean for a diverse community of sedentary reef-inhabiting animals. In addition, at least 12 species of migratory waterbirds use the Reefs as resting places. These are mostly terns such as Sooty Tern *Sterna fuscata* and boobies such as Masked Booby *Sula dactylatra*, and some shorebirds (Ruddy Turnstone *Arenaria interpres*) (ANPWS 1992, p. 93). A small breeding colony of 30 pairs of Common Noddy *Anous stolidus* has been documented on a shipwreck on Middleton Reef.

The Reefs potentially provide rare shelter for other species during severe storms.

Criterion 8.

It can be assumed that the productive shallow waters of the Reefs provide a significant nursery area for fishes that have open-water adult stages (Ramsar Convention 2002). The Rosy Job Fish *Aprion virescens*, which is commercially harvested on shallow sea mounts in the Tasman Sea, may also depend upon the reef system, however this has not yet been investigated (ANPWS 1992, p. 110). Migratory Bigeye Tuna *Thunnus obesus* also aggregate near the reefs in this region.

13. General location:
Elizabeth and Middleton Reefs Marine National Nature Reserve is located in the northern Tasman Sea, 630 km east of Coffs Harbour, New South Wales, and 690 km east-south-east of Brisbane (population more than 1.0 million), Queensland. The Reserve is within the Coral Sea Islands Territory, and is administered by the Commonwealth of Australia.

14. Physical features:
The Reefs are 50 km apart, separated by deep ocean, and are situated atop separate volcanic sea mounts that rise steeply from the Lord Howe Rise. Though more than 20 volcanic peaks are known in the Tasman Sea, only Lord Howe Island and Elizabeth and Middleton Reefs are presently above sea level. It is thought that volcanic activity occurred between the Eocene and Miocene, and that reefs have existed on the two peaks for some time (Environment Australia 2002b).

Elizabeth Reef is an open-ocean platform coral reef roughly oval in shape, approximately 8.2 km by 5.5 km. Its lagoon is considerably infilled by reticulated reefs that form a mesh reef complex with the sandy bottom. Water depths of 20-30 metres are common in this area, while the western end of the lagoon is generally shallower (2-3 metres). Along the southern inner margin of the reef, a reticulated reef flat has developed consisting of a fragile non-living pavement derived from coralline algae, with live, active sides. This grades into the generally smooth pavement of the outer reef flat. In places, the outer reef flat is dotted with large boulders which are thought to have been thrown up from the reef slope where there is an extensive high-energy surf zone with well developed and extensive surge channels, gutters, sink holes and groove-spur development. The reef slopes show little leeward/windward differentiation, suggesting that winds do not prevail from any particular direction. The reef slope is being eroded by wave action, suggesting a gradual reduction in the size of the reef (Environment Australia 2002b).

Middleton Reef is an open-ocean platform coral reef roughly kidney-shaped, approximately 8.9 km by 6.3 km. Its lagoon is structurally complex with areas of relatively deep water in the centre and at the eastern end of the main lagoon. Isolated patch reefs with a high percentage of fragile, living corals occur at the western end of the lagoon. The lagoon floor consists of very fine silt, indicating that minimal tidal flushing occurs. Towards the south of the lagoon, patch reefs become increasingly reticulated, finally fusing to form a pavement-like inner reefal margin of coralline algae. This margin forms the boundary of the outer reef flat which is bisected by a moat in which occurs a porous, fragile 'pie crust' of live coral. Sand patches occur towards the eastern end of the moat. The seaward margin of the reef flat is formed by a hard algal ridge. Both algal ridge and reef flat are exposed at low tide. At the only entrance to the lagoon, on the northern side of the reef, a back reef environment has developed and is characterised by large patch reefs dominated by *Acropora* and *Seriatopora* coral species (Environment Australia 2002b).

In summer, the Reefs receive warm tropical water from the East Australian Current, which apparently sustains the reef growth. Although the Reefs remain continually in the path of the Tropical Convergence, in winter cooler water from the Southern Ocean reaches the Reefs via the dominant West Wind Drift. Therefore, coral growth and erosion are probably seasonal and delicately balanced.

The Reefs are completely inundated at high tide, except for the presence of sand cays which occur on both Elizabeth and Middleton Reefs. Tides are semi-diurnal, modified by local wind and currents; monthly tidal maxima range from 1.8 to 2.6 m and minima range from 0.0 to 0.2 m (ANPWS 1992). Surface seawater temperatures vary seasonally from 20°C to 25°C (ANPWS 1992).

There are no rainfall data for the site but data at Lord Howe Island (150 km to the south), despite the presence of mountain peaks, may broadly indicate conditions at Elizabeth and Middleton Reefs. Monthly averages at Lord Howe range from 108 mm in February to 184 mm in July. Air temperatures range from maxima of 25°C in summer to minima of 14°C in winter. The Reefs lie at latitudes just within the southern-most zone of influence of destructive tropical cyclones.

15. Hydrological values:
As isolated oceanic wetlands with no permanent dry land, the Reefs have no hydrological value with regards to this information category.

16. Ecological features:
Elizabeth and Middleton reefs have a restricted number of habitats, for instance there is a complete lack of leeward or outer reef slopes protected from the wind. However, the reefs can be divided into three major habitats:

- **Outer exposed reef** slope which is deeply dissected by spurs and grooves, and which, below 30m, drops off rapidly into deeper water;
- **Reef crest** which is exposed at low tide;
- **Shallow protected lagoon** with well developed patch reefs that coalesce to form a reticulated reefal structure around the margins of the lagoon.

Apart from small sand cays present at both Reefs, the reef areas within the site are entirely submerged at high tide and do not support terrestrial plant communities. Coral communities, sandy lagoons and algal meadows (encrusting or turf algae) form the dominant structural components and ecological features of the site, and these are described within Item 14. Seagrass, *Halophila ovalis*, has a small patchy distribution on the sheltered sandy lagoons at both Reefs. The Reefs also support an extremely rich and diverse algal flora (see Item 17).

17. Noteworthy flora:
No terrestrial plants occur at present (see item 16), though there is evidence that the sandy cay was vegetated with grass in the recent past (Environment Australia 2002b). A preliminary survey revealed that the Reefs have a rich and diverse algal flora; to date 18 taxa have been identified, and the remoteness of the site suggests a high potential for genetic uniqueness. The only seagrass recorded is *Halophila ovalis* (ANPWS 1992, p. 97).

18. Noteworthy fauna:

Threatened species.
The globally endangered Green Turtle *Chelonia mydas* occurs in waters around the Reefs (ANPWS 1992). See Item 12, Criterion 2.

Other noteworthy fauna.
The Reefs support possibly the only remaining large population of Black (Saddle) Cod *Epinephelus daemelii*, which is protected in Commonwealth and New South Wales waters (ANPWS 1992). This fish is a large, slow-growing, sedentary, reef-dwelling serranid that occurs in seas of the south-western Pacific and north-eastern Australia. World-wide, most members of its genus are in demand for human consumption. The Reefs also provide the southernmost habitat for the Queensland Giant Groper *Epinephelus lanceolatus* (Environment Australia 2002a), which in Queensland receives a medium level of legislative protection.

Three mollusc species are endemic to the site (Anabathridae *Amphithalamus* sp. nov.; Retusidae *Decorifer elisa*; Mytilidae *Musculus nubilis*) and seven are endemic to the group of islands in this part of the Tasman Sea. Most of these endemics are abundant on both reefs, but many of the species with much wider geographic distributions are rare at the site.

19. Social and cultural values:
Many ships have been wrecked on the Reefs, dating back to the earliest years of European settlement in Australia in the late 18th Century, making the area of considerable marine archaeological significance. Remains of several wrecks are a conspicuous feature of the site. Shipwrecks located within the Reserves are protected under the *Historic Shipwrecks Act 1976* if they are more than 75 years old.
The wreck *Fuku Maru* on Middleton Reef supports a small breeding colony of sea terns; due to lack of suitable dry land, the colony otherwise would not occur at the site.

20. Land tenure/ownership:
a) Site
The site is a National Nature Reserve owned by the Commonwealth Government of Australia.

b) Surrounding area
Oceanic waters surrounding the Reserve are within the Economic Exclusion Zone of Australia.

21. Current land use:

a) Site

Nature conservation and scientific research; also limited recreational diving and fishing; no resident human population is present on or near the site.

b) Surroundings/catchment

Surrounding areas support commercial, demersal long-line fisheries based on Blue-eye Trevella *Hyperglyphe antarctica* and Rosy Job Fish *Aprion virescens*.

22. Factors (past, present or potential) adversely affecting the site's ecological character, including changes in land use and development projects:

a) Site

b) Around the site

No exotic species have been observed at the Reefs, and occasional visitation by humans is believed to be largely benign. However, the Crown-of-thorns Starfish *Acanthaster planci* has been quite common and widespread on the reefs and may be responsible for recent reduction in live coral cover, as it has on the Great Barrier Reef (ANPWS 1992). Under present management plans, a number of potentially detrimental activities are not permitted (see Item 23). However, oil spills associated with shipwrecks, anchoring and diving do represent potential threats to the Reefs.

23. Conservation measures taken:

Elizabeth and Middleton Reefs Marine National Nature Reserve was proclaimed in December 1987 and is subject to provisions of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. It is a Category 1a Nature Reserve under IUCN classification, as it is managed primarily for scientific research and environmental monitoring. The second Management Plan for the Reserve came into effect in March 1994 and applies for ten years (Environment Australia 2002b). The main objectives of the Reserve are to protect the natural communities and species and to maintain and protect natural processes in an undisturbed state. Activities such as scientific research, dive charter tours and other commercial activities are allowed but are managed through the use of permits. Staff from Environment Australia undertake on average one management patrol per year to the Reserve, generally using Royal Australian Navy patrol boats or Customs vessels for transport and support. Commercial fishing and operations for the recovery of minerals are not permitted whilst the current Plan is in effect.

24. Conservation measures proposed but not yet implemented:

Environment Australia is currently developing a formal monitoring program for the Reserve for some species and habitat parameters. A new Management Plan is also to be completed for the Reserve by March 2004 – a draft plan will be released for public comment in late 2002.

25. Current scientific research and facilities:

The Reefs have been visited by a number of scientific expeditions, notably that of the Australian Museum in December 1987 (ANPWS 1992). Due to the remote location and lack of permanent dry land, research opportunities are limited and no permanent field station exists at the Reefs. However, staff from Environment Australia undertake observations of key features during management patrols to the Reserve and are developing a formal monitoring program for some habitat parameters and species, including Black Cod.

26. Current conservation education:

Due to the remote location and limited land area, the Reefs are not suitable for visitor education programs or static educational displays. Detailed information on the Reefs, including the Management Plan, photographs, and a brochure are available on the Internet (Environment Australia 2002a).

27. Current recreation and tourism:

Due to the remote location and limited land area, the Reefs are not convenient or popular destinations for recreation or tourism. Recreational and commercial dive and/or fishing charter tours and cruise ships have visited the Reefs in the past. However, no permits for commercial activities in the Reserve have been requested of, nor issued by, Environment Australia in recent times.

28. Jurisdiction:
The Reserve is within the Coral Sea Islands Territory and falls under the jurisdiction of the Commonwealth Government of Australia. Functional jurisdiction lies with the Director of National Parks, Department of Environment and Heritage, Canberra.

29. Management authority:
The Reserve is managed by the Marine Protected Areas Section, Marine and Water Division, Environment Australia, GPO Box 787, Canberra ACT 2601, Australia.

30. Bibliographical references:
ANPWS (ed. P. Hutchings) (1992) *Reef Biology: A survey of Elizabeth and Middleton Reefs, South Pacific, by The Australian Museum*. Kowari 3 (series), Australian National Parks & Wildlife Service, Canberra. 230 pp.

Environment Australia (2002a) *Elizabeth and Middleton Reefs Marine National Nature Reserve*. [Online], http://www.ea.gov.au/coasts/mpa/elizabeth/index.html, 20 June 2002.

Environment Australia (2002b) *Elizabeth and Middleton Reefs Marine National Nature Reserve Plan of Management*. [Online], http://www.ea.gov.au/coasts/mpa/elizabeth/plan.html, 4 June 2002.

Ramsar Convention (2002) Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance of the Convention on Wetlands. [Online], http://www.ramsar.org/key_guide_list_e.htm, 4 June 2002.