Australian Museum

Description of Key Species Groups in the East Marine Region

Final Report – September 2007

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Acronyms

Acronym	Definition
ABIF	Australian Biodiversity Information Facility
ABRS	Australian Biological Resources Study
ACAP	Agreement for the Conservation of Albatrosses and Petrels
AM	Australian Museum
BRD	Bycatch Reduction Device
CAAB	Codes for Australian Aquatic Biota
CAMBA	Chinese and Australian Migratory Bird Agreement
CITES	Convention for International Trade in Endangered Species
CMS	Convention for the Conservation of Migratory Species of Wild Animals (Bonn Convention)
DEW	Department of the Environment and Water Resources
DFFF	Deepwater Fin Fish Fishery
DPI	Department of Primary Industries
DPI&F	Department of Primary Industries and Fisheries
DPIW	Department of Primary Industries and Water
EAC	East Australian Current
ECDTS	East Coast Deepwater Trawl Sector
ECTF	East Coast Trawl Fishery
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EMR	East Marine Region
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FTF	Finfish Trawl Fishery
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature and Natural Resources
JAMBA	Japanese and Australian Migratory Bird Agreement
MPA	Marine Protected Area
NSW	New South Wales
OPT	Offshore Prawn Trawl
OTF	Otter Trawl Fishery
OTLF	Ocean Trap and Line Fishery
OZCAM	Online Zoological Collections of Australian Museums
Qld	Queensland
QM	Queensland Museum
RRFFF	Rocky Reef Fin Fish Fishery
SESSF	Southern and Eastern Scalefish and Shark Fishery

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Crustacea: Copyright and photography as indicated on the image or figure caption in text.

Demersal Fish: First row (from left to right): Blue-eye trevalla (*Hyperoglyphe antarctica*); Gemfish (*Rexea solandri*); Second row (from left to right): Ocean perch (*Helicolenus barathri*) ; Eastern school whiting (*Sillago flindersi*); Third row (from left to right): Mirror dory (*Zenopsis nebulosus*); Orange roughy (*Hoplostethus atlanticus*)—Photography and © K. Graham.

Echinodermata: First row (from left to right): Blue starfish (*Linckia laevigata*); Black teatfish (*Holothuria whitmaei*); Robust feather star (*Himerometra robustipinna*)—Photography and © A. Hoggett; Second row (from left to right): Brittlestar (O*phiarthrum elegans*); Crown-of-thorns starfish (*Acanthaster planci*)—Photography and © J. Keesing; Longspine sea urchin (*Centrostephanus rodgersii*)—Photography and © M. Byrne unless otherwise stated.

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Sponges: From left to right: *Clathria craspedia*; *Thrachycladus laevispirula*; *Cliona montiformis*—Photography and © J. Hooper.

Syngnathids: First row (from left to right): Pot-bellied seahorse (*Hippocampus abdominalis*); Weedy seadragon (*Phyllopteryx taeniolatus*)—Photography and © S. Schulz; Sad seahorse (*Hippocampus tristis*); Second row (from left to right): Duncker's pipehorse (*Solegnathus dunckeri*); Spiny pipehorse (*Solegnathus spinosissimus*)—Photography and © K. Graham unless otherwise stated.

Trawl Bycatch: First row (from left to right): Toothed whiptail (*Lepidorhynhcus denticulatus*); Longspine flathead (*Platycephalus longispinis*); Common bellowfish (*Macroramphosus scolopax*); Second row (from left to right): Roundsnout gurnard (*Lepidotrigla mulhalli*); Bycatch (on deck); Threespine cardinalfish (*Apogonops anomalus*); Third row (from left to right): Antlered crab (*Dagnaudus petterdi*); Swimmer crab (*Ovalipes molleri*)—Photography H. McLennan, © Australian Museum; Mantis shrimp (*Lysiosquilla colemani*); Fourth row (from left to right): An ancillid olive (*Ancillista velesiana*); Deepwater dumpling squid (*Austrorossia australis*); Southern white-spot octopus (*Octopus* cf. *bunurong*)—Photography and © K. Graham unless otherwise stated.

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1 Introduction

Author: Stephen J. Keable

This report has been prepared by the Australian Museum in response to a request for tender by the Department of the Environment and Water Resources (DEW) to gather, review and summarise the best available information for the East Marine Region (EMR). It is intended that this information will be used by the Department to support the development of a Regional Profile as the first stage in the development of a Marine Bioregional Plan for the EMR. As part of this process the principal objective of this report is to broadly describe the Key Species Groups of the region.

Additional reports prepared by others, also in response to DEW's request for tender, outline the following aspects of the EMR:

- ecological characteristics
- commercial, recreational and charter fishing activities
- all other marine resource use activities
- indigenous interests.

The information provided here for Key Species Groups is primarily for use in the development of the Regional Profile for the EMR; however, the DEW request for tender indicates that it may also be used to support later stages of the planning process, such as the identification of a Marine Protected Area (MPA) network for the region. In gathering this data information gaps and uncertainties have been summarised, as required by DEW, to aid in identification of the areas in which further investigation is required for subsequent stages of drafting the East Marine Bioregional Plan.

The scope and aims of this report, as outlined further by the DEW request for tender, are to:

- review the current state of knowledge and literature for the key functional groups of marine species for the EMR, including information on their conservation status, threats, movements/migrations, abundance, habitat and distribution
- describe the significance of the species group to the EMR
- identify functional links between species group and habitat, ecosystem functions and ecological processes
- review literature on major impacts/threats to each species group—including impacts of human use and environmental change

- identify any projects in the Region that may assist in later stages of developing the East Marine Bioregional Plan.

The key functional species groups have been selected by DEW through application of one or more of the following criteria, as previously used in developing a description of the Key Species Groups of the Northern Planning Area (National Oceans Office 2004):

- commercial importance (target and significant bycatch species): species within the group have an existing or emerging economic value

- recreational importance: species within the group possess a quality that has a known or possible recreational value to a community group

- conservation importance: species within the group are listed, or are being considered for listing, under state, federal or international legislation

- ecological importance: species within the group contribute to essential ecological processes (e.g. provide essential breeding and/or feeding habitat for species recognised under other criteria)

- cultural importance: species within the group have a known or possible value to a community group based on their historical, aesthetic or educational qualities.

The species groups initially chosen by DEW are (in alphabetical arrangement, here as for the rest of the report, for easy reference): corals, crustaceans, demersal fish (inshore, shelf and slope), marine snakes, marine turtles, plankton (phyto- and zooplankton), seabirds, seals and dugong, sharks and rays, sponges, syngnathids and trawl bycatch species. Additionally, echinoderms (Phylum Echinodermata) and molluscs (Phylum Mollusca) have been justified for inclusion by the Australian Museum on the basis of their commercial and ecological importance in the region.

The EMR is defined by DEW as comprising an area of 2.4 million square kilometres, extending from the northern reaches of the Coral Sea, off the east coast of Queensland to the Tasman Sea off Bermagui in southern New South Wales (NSW). The Region is administered by the Commonwealth: it begins three nautical miles from the coastline and continues to the outer limit of the Australian Exclusive Economic Zone (EEZ)—200 nautical miles from the coastline. It excludes the Great Barrier Reef Marine Park, which is managed separately by the Great Barrier Reef Marine Park Authority, and waters within three nautical miles of the coast for which the states have primary responsibility. The Region also includes waters surrounding Norfolk and Lord Howe Islands. It is divided into 14 Provincial Bioregions defined by ecological characteristics (Figure 1.1).

In order to address the requirements outlined in the DEW request for tender, for the key functional groups of marine species in the EMR, a team led by the Australian Museum has been assembled composed of individuals with expert knowledge of one or more of the groups (Table 1.1). The personnel in this team also have a wide network of contacts which has been drawn upon to provide additional input. The time frame and resources available in developing this report, however, have varied significantly from previous descriptions of key species groups in other planning areas (National Oceans Office 2004) where a steering committee was able to coordinate expert input over a longer period. The report presented here has been compiled largely through a process of collaboration and consultation between the project coordinators, project officer and key personnel with expert knowledge of the key species groups (Table 1.1). In some cases the key personnel provided this information directly for inclusion in the report. In other cases the project officer obtained advice from the key personnel regarding the appropriate sources of relevant information. In some cases this involved searches of literature databases using keywords or contacting additional individuals or institutions. The project officer then provided a draft, of the information obtained, to the key personnel with expertise in the relevant species group, to check for accuracy and quality assurance.

Additionally, point data from specimen collections in the Australian Museum and Queensland Museum databases, and those available via Online Zoological Collections of Australian Museums (OZCAM, see http://www.ozcam.gov.au/about.php) and the Australian Biodiversity Information Facility (ABIF, see http://www.abif.org/) were utilised. Information was obtained from these databases for the key species groups of corals, crustaceans, echinoderms, fish, molluscs and sponges to further examine knowledge gaps within the EMR. The method used for this aspect of the report involved interrogation of these databases using a latitudinal and longitudinal bounding box covering the EMR. A Geographic Information System (GIS) database consisting of this data and relevant shape files describing the EMR was then used to eliminate records outside the study area. Inequalities in sampling, biological inventory and available collection data identified through this process can be used to set priorities for research and determine locations for targeted surveys to fill these gaps.

The information gathered from the above process is presented in the following chapters. These chapters have been designed to stand alone so that information on a single species group can be accessed individually, if required, as in previous Key Species Group reports (National Oceans Office 2004).

Table 1.1 Key Personnel

Key Personnel	Role in Project	Institution
Dr Stephen Keable	Coordinator. Provide expert knowledge and comment for **crustaceans**	Australian Museum
Dr John Hooper	Coordinator of Queensland Museum staff input. Provide expert knowledge and comment for **sponges**	Queensland Museum
Dr Vicky Tzioumis	Project Officer responsible for drafting final report	Australian Museum
Mr Ken Graham	Provide expert knowledge and comment for **bycatch**, **demersal fish**, and **sharks and rays**	NSW Department of Primary Industries/Australian Museum
Dr Carden Wallace & Dr Paul Muir	Provide expert knowledge and comment for **corals**	Museum of Tropical Queensland
Dr Jim Lowry	Provide expert knowledge and comment for **non-decapod crustaceans**	Australian Museum
Mr Peter Davie	Provide expert knowledge and comment for **decapod crustaceans**	Queensland Museum
Professor Maria Byrne	Provide expert knowledge and comment for **echinoderms**	The University of Sydney
Mr Mark McGrouther	Provide expert knowledge and comment for **fish**	Australian Museum
Dr Jeff Leis	Provide expert knowledge and comment for **fish**	Australian Museum
Mr Jefferey Johnson	Provide expert knowledge and comment for **fish**	Queensland Museum
Professor Helene Marsh	Provide expert knowledge and comment for **dugong**	James Cook University
Professor Iain Suthers	Provide expert knowledge and comment for **plankton**	University of New South Wales
Ms Helen Stoddart	Project Officer responsible for drafting chapter for **plankton**	Australian Museum
Mr Ian Loch	Provide expert knowledge and comment for **molluscs**	Australian Museum
Dr Walter Boles	Provide expert knowledge and comment for **seabirds**	Australian Museum
Dr Peter Shaughnessy	Provide expert knowledge and comment for **seals**	South Australian Museum
Dr Col Limpus	Provide expert knowledge and comment for **marine turtles**	Environmental Protection Agency
Dr Hal Cogger	Provide expert knowledge and comment for **marine snakes**	Australian Museum
Dr Pat Hutchings	Provide expert knowledge and comment regarding conservation status of i**nvertebrates**	Australian Museum

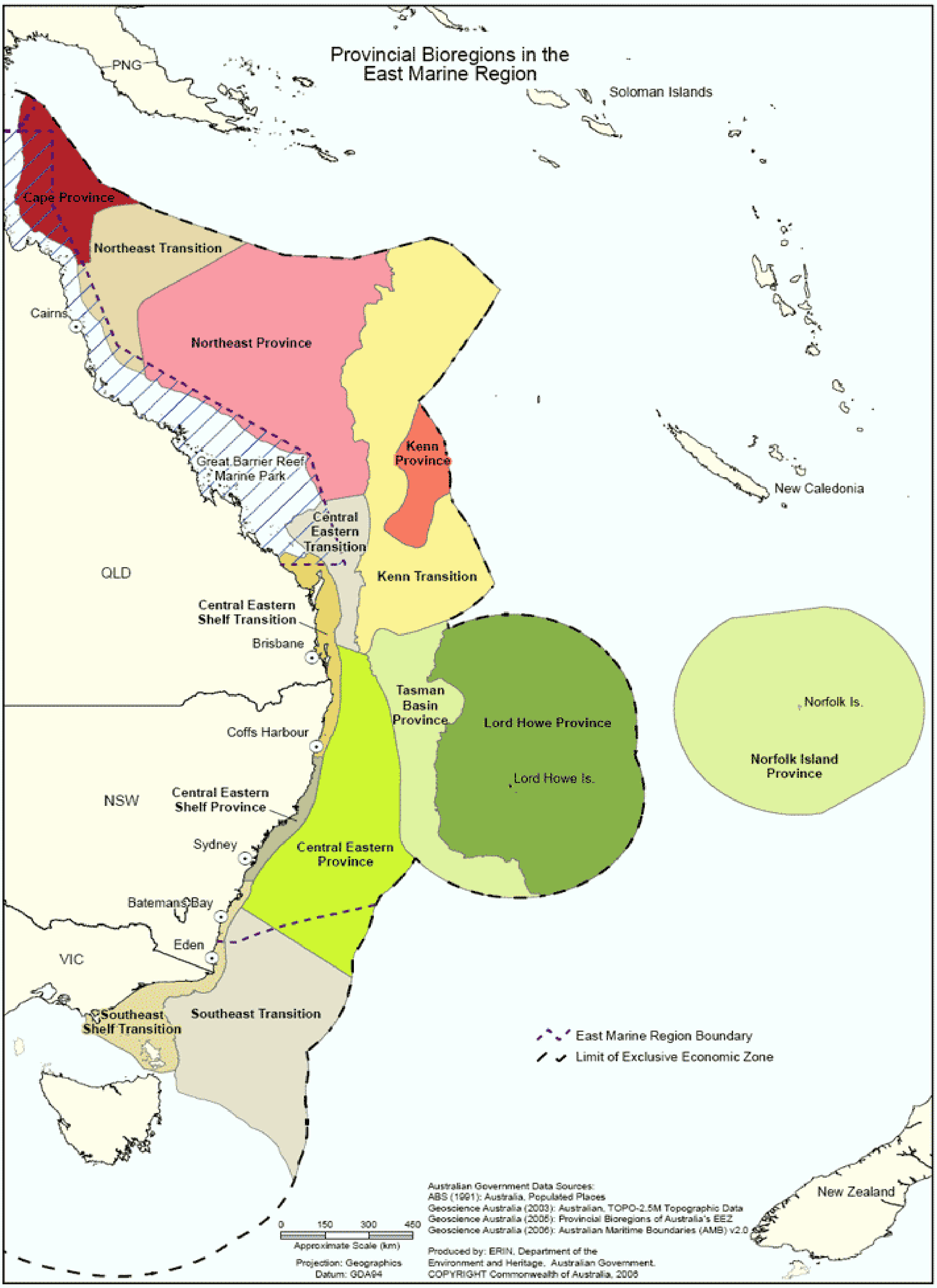

Figure 1.1 Location of the East Marine Region and associated Provincial Bioregions

Source: http://www.environment.gov.au/coasts/mbp/east/bioregions.html

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National Oceans Office 2004, *A description of Key Species Groups in the Northern Planning Area*, Australian Government, Hobart, 320 pp.

2 Corals (Scleractinia)

Authors: Carden Wallace & Paul Muir




Description

Corals belong to the phylum Cnidaria, an ancient group with a simple radially symmetrical body with a single body opening that serves as both mouth and anus. The body is composed of two cell layers separated by a jelly-like layer (mesoglea) with no true internal organs and containing specialized stinging cells known as nematocysts. There are three classes in this phylum, covering the jellyfish (Class Scyphozoa), hydrozoans (Class Hydrozoa) and corals and sea anemones (Class Anthozoa). During their adult life, Anthozoans exist in polyp form: a cup-shaped body is anchored at its base and opens via a mouth surrounded by a ring of tentacles. The term 'corals' is generally used to describe those groups of the Anthozoa that are sessile and secrete a skeleton. The hard corals secrete a skeleton of calcium carbonate (in aragonite form) and belong to the order Scleractinia. These are the subject of this report.

Corals may be colonial or solitary and consist of a single polyp or a colony of polyps formed from the division of a single 'founder' polyp. Corals are generally divided into two broad groups: the zooxanthellate ('reef-building' or 'hermatypic') corals, which contain symbiotic microalgae (zooxanthellae) that enhance growth and allow the coral to secrete large amounts of calcium carbonate; and the azooxanthellate ('ahermatypic') corals, which are generally smaller and often solitary. Zooxanthellate corals are generally found in shallower (<50 m) waters while the azooxanthellate corals are found at most depths, particularly those below 50 m.

In the East Marine Region (EMR), corals are present in a variety of marine habitats. The northern, tropical shallow water areas have the greatest diversity and abundance of zooxanthellate corals (around 400 species), with the shallow water corals being restricted to the atolls and islands of the Coral Sea. Outside of the tropics opportunities for reef building are limited by water temperature and reduced winter day length and available calcium carbonate for skeleton formation (Kleypas et al. 1999): zooxanthellate coral diversity gradually decreases with latitude to 31°S, after which no further reefs exist and only a small number of species occur. The southern limit of reef development is seen at Lord Howe Island, however, many zooxanthellate coral species are present in non-reef environments in coastal areas such as Moreton Bay (Qld) and the Solitary Islands (NSW) and a few species exist right down to the southern limit of the EMR. Azooxanthellate corals are present in deeper waters throughout the EMR continental shelf, slope and off-slope regions, to well below the limit of light penetration.

Conservation Status

All scleractinian corals are listed in Schedule 2 of the Convention for International Trade in Endangered Species (CITES). This means that all member countries of CITES have agreed that international trade in corals will have to be regulated to ensure it is not harmful to the survival of wild populations. Corals are also protected by Commonwealth and State legislation such as the Great Barrier Reef Marine Park Act, and the Queensland and New South Wales Environmental authorities.

Habitat and Distribution

Zooxanthellate corals are mostly found between latitudes 31° north and south of the equator within temperature and calcium carbonate saturation limits suitable for modern reef development (Opdyke & Wilkinson 1993; Kleypas et al. 1999). They are generally limited in their depth distribution by light and thus are usually found in depths of less than 30–50 m and in water which is quite clear. In the EMR, areas suitable for zooxanthellate coral growth include the reefs and atolls of the Coral Sea and, to a lesser extent, the coastline of the subtropics and temperate zones, including offshore islands such as Lord Howe and the Solitary Islands (Harriott & Banks 1995). Coral abundance, usually measured in percent cover, reaches over 90% on some reef slopes at around 5 to 15 m depth, and decreases below this. Species of zooxanthellate corals from the EMR held in collections of the Australian (AM) and Queensland (QM) Museums are listed in Table 2.1. Some common, shallow water species are shown in Figure 2.1.

Azooxanthellate corals are found in deeper waters across the entire EMR, from the continental slope to around 2,000 m. The number of solitary and colonial azooxanthellate species occurring within the region is not known as yet, but is thought to be greater than 200. This is an area of active taxonomic study which will lead to clarification of this number in coming years. Abundance in terms of number of individuals is again patchy but may reach up to about 50 per square metre, as seen in benthic grab samples, although overall biomass may be quite low due to the small size of the individuals. Corals are distributed by a planula larval phase, which offers great potential for dispersal, and both the azooxanthellate and zooxanthellate coral species of the EMR are generally Indo-Pacific in distribution, although there are some Pacific Ocean and western Pacific Ocean endemics (Cairns 2004; Veron 1986, 2000; Wallace 1999). Species of azooxanthellate corals from the EMR held in collections of the AM and QM are listed in Table 2.2. Examples of some deep water species are shown in Figure 2.2.

The distribution of zooxanthellate and azooxanthellate specimen samples held in AM and QM collections is shown in Figure 2.3 and discussed in chapter 16 (summary of information gaps).

Life history and reproductive ecology

Corals are generally highly fecund hermaphrodites that release large quantities of eggs and sperm into the water column which are fertilised externally to form a planktonic ‘planula’ larva. There are, however, many variations to this pattern with some species having separate sexes and/or internal fertilisation within the body cavity. The planula larvae are generally less than one millimetre in length and simple, ciliated, sack-shaped organisms which may feed on other plankton or use internal reserves. They are the dispersal phase and may live in the water column for up to several weeks, travelling hundreds of kilometres in the process. If a suitable settlement site is found, the planula settles, anchoring to the substrate and developing tentacles around the mouth. In colonial corals this ‘founder’ polyp divides repeatedly to form a colony of interconnected ‘clone’ polyps. Spawning is highly seasonal in most zooxanthellate corals, usually restricted to once per year (Babcock et al. 1986; Harrison & Wallace 1990). A variety of reproductive strategies is seen in azooxanthellate corals, with extended seasons and staggered gonad development being common. Asexual reproduction, by regeneration of accidentally broken fragments, is also possible in many colonial coral species.

Significance of Corals in the East Marine Region

The zooxanthellate corals are a critical group in the reefs of the EMR since they are ‘reef-building’—i.e. they produce much of the calcium carbonate which makes up the reefs. While calcium carbonate is laid down by a variety of reef organisms, it is likely that without corals these reefs would cease to exist. With a greatly reduced calcium carbonate production the reefs would be susceptible to erosion from physical (i.e. waves) and biological processes (e.g. boring molluscs) and in the longer term would be unable to keep pace with rising sea levels. Corals also form much of the ‘habitat’ on reefs, providing shelter and food for a wide range of invertebrates and fishes. Outside of reef areas, corals are less significant but still provide shelter and food for a wide range of invertebrates and fishes.

Commercially, corals and the reefs that they make up are of great significance to Australia in the areas of tourism, fishing and potentially, medicine. The Great Barrier Reef (GBR) is listed as one of Australia’s principal tourist destinations producing significant income for Australia. While the reefs of the EMR are less extensive, they provide an important resource for diving, tourism and fisheries. Corals may also have some direct commercial value; several unique chemical compounds have been isolated from corals which have potential application in the development of new medical drugs and in industrial processes.

Azooxanthellate corals are potentially important as bioregion indicators because many of them exist in great numbers and most occur within species-specific depth ranges. The overall suitability of deep sea corals for characterisation of regions and for corroborating patterns from other benthic invertebrates will be possible to test in coming years, as the species composition and relative abundance become better studied through deep sea research initiatives such as the cruises of the RV *Southern Surveyor*. The deep sea coral fauna of Australia has recently been revised from available material (Cairns 2004) and this effort is continuing with new material as it comes to hand.

Impacts/Threats

Corals and coral reefs are very sensitive to climate change and many human impacts and are often located in coastal areas adjacent to large population centres. It has been estimated that around 20% of the world’s coral reefs have been effectively destroyed in recent years (Wilkinson 2004). In Australia, and globally, there is general consensus among reef scientists that the main threat to corals is from coral bleaching caused by climate change. Widespread coral bleaching associated with extremely high seawater temperatures is an apparently new phenomenon (in recorded history) which has been seen across the world in the last 15 years and has already led to the loss of many reef areas (Wilkinson 2004). Bleaching is the term given to the phenomenon which sees the affected corals turn white in colour due to the loss of symbiotic microalgae from their tissues. The bleached corals can recover but frequently die within a few weeks. Bleaching events have occurred in the EMR, for example in the Coral Sea in 1998, 2002 and 2004 (Oxley et al. 2003, 2004a,b) but to date these events have been quite minor compared to bleaching events seen in other parts of the world. For example, in 1998 some areas of the Indian Ocean experienced extremely high seawater temperatures for several weeks which resulted in widespread bleaching and loss of up to 95% of corals in many areas. Many of these severely affected areas have still only partly recovered. The general scientific consensus is that these high temperature events will become more common in most reef areas, including those of Australia, over the next few decades possibly leading to the loss of many of our reefs (Hoegh-Guldberg 1999).

Another cause for concern is the change in ocean carbonate chemistry due to greatly elevated levels of atmospheric carbon dioxide (CO_2) resulting from human activities (Guinotte et al. 2003; Hoegh-Guldberg 2005). Carbonate chemistry is critical for corals as they rely upon converting carbonates dissolved in seawater into a skeleton by a process known as calcification. As atmospheric CO_2 increases, seawater acidity increases and calcification becomes more difficult (Kleypas et al. 1999; Kleypas et al. 2006). Research with corals in experimental aquaria indicates that corals cease calcification at an atmospheric concentration of around 500 ppm (Langdon et al. 2000; Fine & Tchernov 2007). The concentration of CO_2 in the atmosphere was stable for at least 400 000 years until around 1800, after which it has increased approximately 35% with a present concentration of 375 ppm and the rate of increase accelerating (Hoegh-Guldberg 2005).

Additionally, corals are considered to be at risk locally from various human activities including coastal development and runoff leading to poor water quality, impact of anchor damage, and unsustainable fishing and harvesting practices (Wilkinson 1999). These are not likely to impact greatly on offshore coral locations but deep sea dredging and trawling would be a threat to deep sea corals as well as to most other benthic invertebrates. Various natural impacts such as cyclonic weather impact on shallow sites, and shallow-water corals are vulnerable to episodic population explosions of coral-feeding organisms (sea stars, molluscs) and coral diseases. Corals are also quite sensitive to water quality and in coastal areas increases in sediments and nutrients from coastal development and agriculture have been documented as causing severe declines in reefs (e.g. Wilkinson 2004). In the southern coastal provinces of the EMR, adjacent to high levels of coastal development and agriculture, reduced water quality is likely to adversely affect corals in some areas.

Information Gaps

There is limited information available for corals in many of the offshore regions, primarily because of their remoteness and the depth of the seafloor. The subtropical coastal regions are also poorly represented in the museum collections, possibly because coral researchers tend to work on the tropical reef areas and overlook the so called 'marginal areas' of the temperate regions where coral species diversity is low. A particular concern is the effect of high temperature bleaching on the reefs of the Coral Sea—since few researchers visit these reefs there is little likelihood of detecting severe bleaching events and consequent losses in diversity.

Key References and Current Research

Current research

Current research of corals in the offshore regions is severely limited by the cost of access (outlined in the previous section). However, researchers from the Museum of Tropical Queensland are funded by a commercial live-aboard dive vessel, the MV *Undersea Explorer*, to conduct field trips to Osprey Reef in the Coral Sea. During these field trips researchers document the coral and sea anemone diversity as well as conduct their own research programs. Active research is currently underway on the deep sea corals of Australian waters, including material from cruises of the RV *Southern Surveyor*, and this will allow deep sea corals to be fully included in future reviews.

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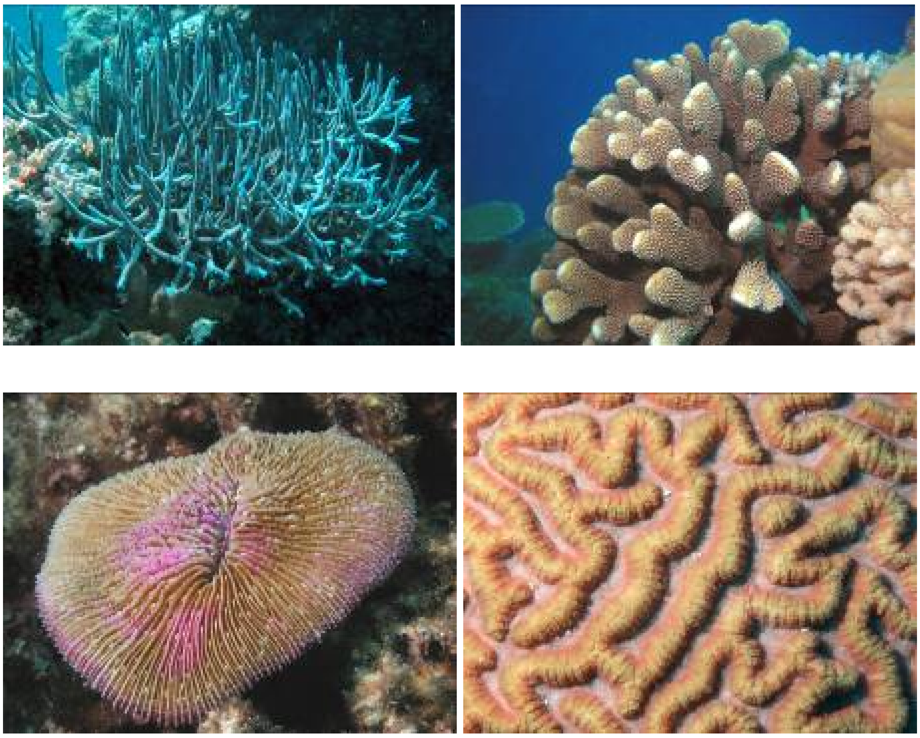


Figure 2.1 Examples of zooxanthellate coral groups of the EMR, as listed in table 2.1 (a) a staghorn coral, *Acropora valenciennesi* (b) an 'antler' coral *Pocillopora eydouxi* (c) a 'mushroom' coral *Fungia valida* (d) a 'brain' coral, *Symphyllia recta*. The first two corals come from families which provide some of the major colonisers of shallow waters, but they are also subject to damage from heat stress due to elevated sea surface temperatures, and from cyclonic weather. Photography and © P. Muir.

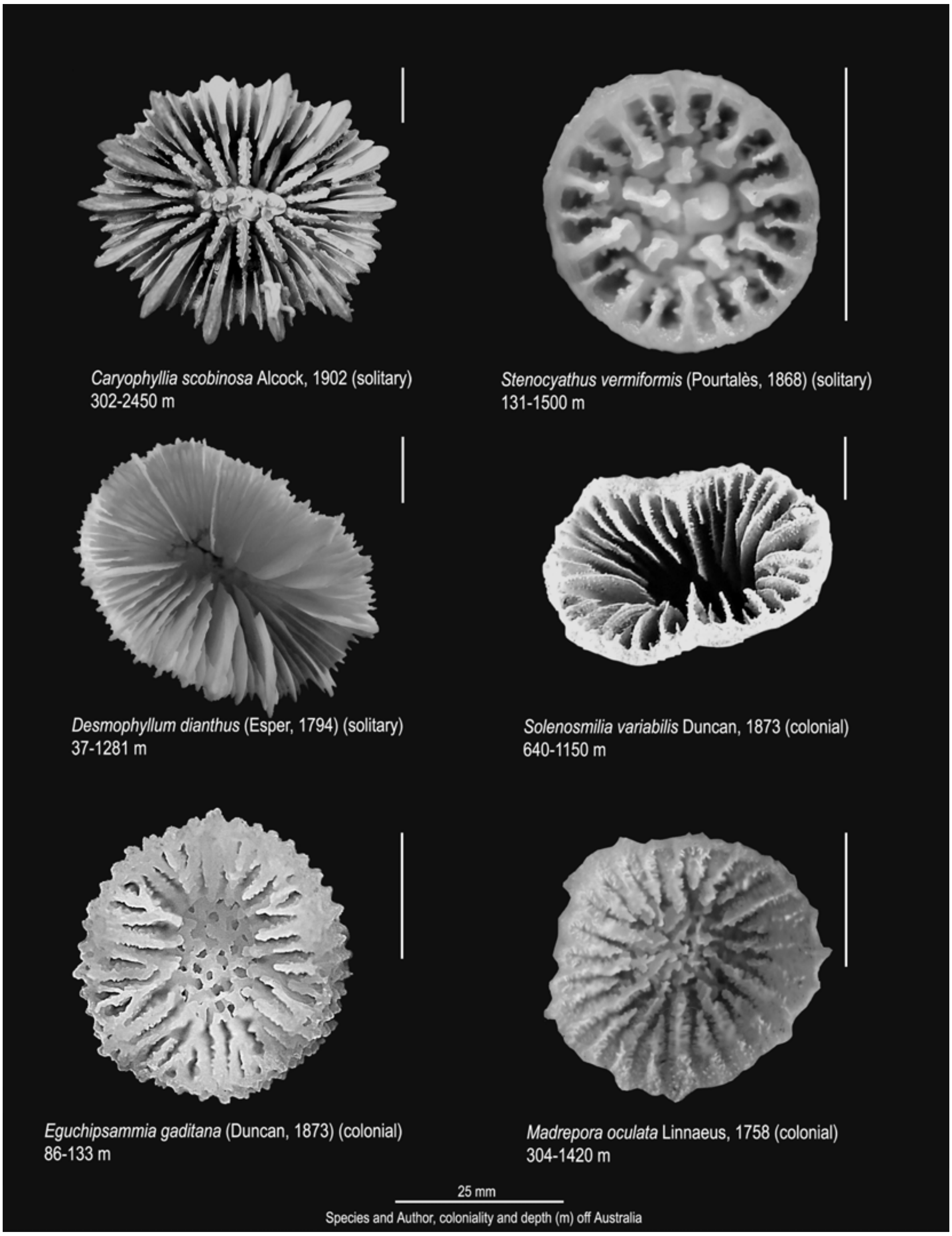


Figure 2.2 Examples of azooxanthellate corals of the EMR. The first three species are solitary, that is, they occur as a single polyp: their coverage of the seafloor would depend on their occurring in great numbers (which sometimes is the case). The remaining images are single polyps from colonial corals: a single colony of these may occupy an area of seafloor. The known depth range is given for each species, and from this it can be seen that different depth zones are occupied by different species, although most of them overlap from about 300 to 1500 m. When further studies are carried out (e.g. from the voyages of the RV *Southern Surveyor*) it is likely that some of these species or combinations of species may provide indicators for particular habitats within the provinces of the EMR. Images and data courtesy M. Kitahara.

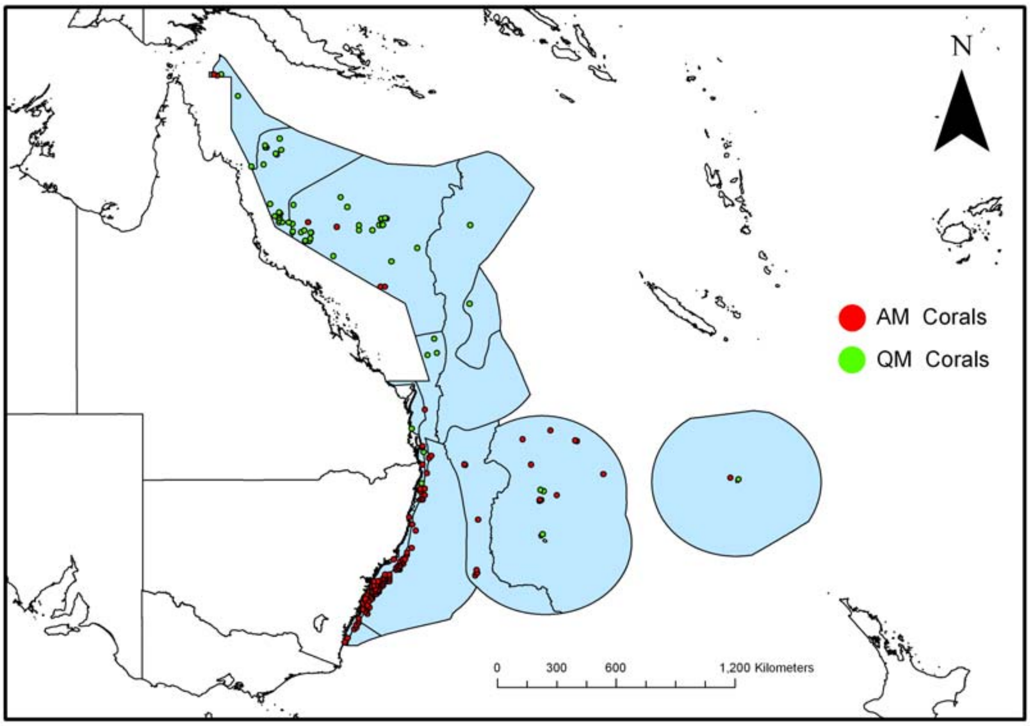


Figure 2.3 Coral records from the East Marine Region based on Queensland (QM) and Australian (AM) Museum datasets.

Table 2.1 Zooxanthellate or 'reef-building' coral families and species from the EMR, for which specimens are held in collections of the QM or AM. These species represent a subsample of all the reef-building corals likely to occur at 40 m depth or above, on the atolls and fringing reefs within the EMR. Family and common names are given for each grouping of corals.

Spiny Brain Corals (Mussidae)
Acanthastrea bowerbanki
Acanthastrea hillae
Acanthastrea lordhowensis
Scolmyia sp.
Scolymia vitiensis
Symphyllia radians
Staghorn Corals (Acroporidae)
Acropora aculeus
Acropora acuminata
Acropora anthocercis
Acropora aspera
Acropora austera
Isopora brueggemanni
Acropora bushyensis
Acropora carduus
Acropora cerealis
Acropora cf secale
Acropora chesterfieldensis
Acropora clathrata
Isopora cuneata
Acropora cytherea
Acropora abrotanoides
Acropora digitifera
Acropora divaricata
Acropora donei
Acropora elseyi
Acropora florida
Acropora muricata
Acropora gemmifera
Acropora glauca
Acropora globiceps
Acropora grandis
Acropora granulosa
Acropora horrida
Acropora humilis
Acropora hyacinthus
Acropora latistella
Acropora listeri
Acropora longicyathus
Acropora loripes
Acropora lovelli
Acropora lutkeni
Acropora microclados
Acropora millepora
Acropora monticulosa
Acropora nana
Acropora nasuta
Isopora palifera
Acropora palmerae
Acropora paniculata
Acropora polystoma
Acropora pulchra
Acropora robusta
Acropora samoensis
Acropora sarmentosa
Acropora secale
Acropora selago
Acropora solitaryensis
Acropora speciosa
Acropora striata
Acropora subglabra
Acropora subulata
Acropora tenuis
Acropora tortuosa
Acropora valenciennesi
Acropora valida
Acropora vaughani
Acropora verweyi
Acropora yongei
Astreopora cucullata
Astreopora gracilis
Astreopora listeri
Astreopora moretonensis
Astreopora myriophthalma
Astreopora ocellata
Montipora aequituberculata
Montipora angulata
Montipora australiensis
Montipora caliculata
Montipora crassituberculata
Montipora danae
Montipora efflorescens
Montipora floweri
Montipora foliosa
Montipora foveolata
Montipora grisea
Montipora hispida
Montipora hoffmeisteri
Montipora incrassata
Montipora informis
Montipora mollis
Montipora nodosa
Montipora peltiformis
Montipora spongodes
Montipora spumosa
Montipora tuberculosa
Montipora turgescens
Montipora turtlensis
Montipora undata
Montipora venosa
Montipora verrucosa
Siderastreidae
Coscinaraea columna
Coscinaraea wellsi
Caryophylliidae
Euphyllia sp.
Brain Corals (Faviidae)
Cyphastrea serailia
Favia stelligera
Favites sp.
Goniastrea australensis
Goniastrea pectinata
Montastrea curta
Platygyra lamellina
Plesiastrea versipora
Leptastrea purpurea
Mushroom Corals (Fungiidae)
Fungia fungites
Fungia scutaria
Galaxy Corals (Oculiniidae)
Galaxea astreata
Gardineroseris planulata
Oculina virgosa
Oulophyllia crispa
Merulinidae
Hydnophora exesa
Hydnophora sp.
Agaricidae
Leptoseris hawaiiensis
Corrugated Corals (Agariciidae)
Pavona explanulata
Pavona maldivensis
Pavona varians
Lace Corals (Pocilloporidae)
Pocillopora damicornis
Pocillopora meandrina
Golf Ball Corals (Poritidae)
Alveopora allingi
Alveopora catalai
Alveopora fenestrata
Alveopora marionensis
Alveopora spongiosa
Alveopora verrilliana
Goniopora djiboutiensis
Goniopora minor
Goniopora norfolkensis
Goniopora somaliensis
Goniopora tenuidens
Porites annae
Porites australiensis
Porites cylindrica
Porites densa
Porites lichen
Porites lobata
Porites lutea
Porites mayeri
Porites nigrescens
Porites rus
Porites solida
Porites vaughani
Turban Corals (Dendrophylliidae)
Turbinaria frondens
Turbinaria patula
Turbinaria radicalis

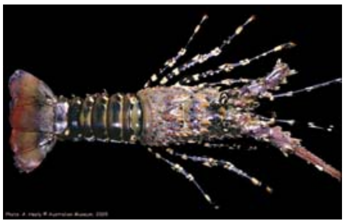
Table 2.2 Azooxanthellate (non reef-building) coral species from the EMR, for which specimens are held in collections of the QM or AM.

Anthemiphyllia dentata	*Deltocyathus rotulus*	*Notophyllia etheridgi*
Anthemiphyllia macrolobata	*Deltocyathus sp*	*Notophyllia hecki*
Anthemiphyllia pacifica	*Deltocyathus stella*	*Notophyllia recta*
Anthemiphyllia spinifera	*Dendrophyllia alcocki*	*Paraconotrochus zeidleri*
Asterosmilia sp	*Dendrophyllia sp.*	*Peponocyathus australiensis*
Aulocyathus recidivus	*Dendrophyllia sp.*	*Placotrochides cylindrica*
Balanophyllia bairdiana	*Desmophyllum cristagalli*	*Placotrochides minuta*
Balanophyllia crassitheca	*Desmophyllum dianthus*	*Placotrochides scaphula*
Balanophyllia dentata	*Dunocyathus parasiticus*	*Plerogyra sinuosa*
Balanophyllia desmophyllioides	*Dunocyathus wallaceae*	*Rhizotrochus flabelliformis*
Balanophyllia gigas	*Eguchipsammia fistula*	*Rhombopsammia niphada*
Bathyactis palifera	*Eguchipsammia gaditana*	*Solenosmilia variabilis*
Bouneotrochus stellulatus	*Enallopsammia pusilla*	*Sphenotrochus cuneolus*
Caryophyllia ambrosia	*Enallopsammia rostrata*	*Stenocyathus vermiformis*
Caryophyllia communis	*Flabellum australe*	*Stephanocyathus coronatus*
Caryophyllia cornu	*Flabellum hoffmeisteri*	*Stephanocyathus coronatus*
Caryophyllia crosnieri	*Flabellum japonicum*	*Stephanocyathus imperialis*
Caryophyllia cyathus	*Flabellum lamellulosum*	*Stephanocyathus platypus*
Caryophyllia diomedeae	*Flabellum lowekeysi*	*Stephanocyathus regius*
Caryophyllia hawaiiensis	*Flabellum pavoninum*	*Stephanocyathus regius*
Caryophyllia lamellifera	*Flabellum sexcostatum*	*Stephanocyathus spiniger*
Caryophyllia planilamellata	*Flabellum transversale*	*Stephanocyathus weberianus*
Caryophyllia ralphae	*Foveolocyathus alternans*	*Stephanocyathus weberianus*
Caryophyllia rugosa	*Fungiacyathus granulosus*	*Stephanophyllia complicata*
Caryophyllia scobinosa	*Fungiacyathus margaretae*	*Stolarskicyathus pocilliformis*
Ceratotrochus pleurocyathus	*Fungiacyathus paliferus*	*Tethocyathus virgatus*
Confluphyllia juncta	*Fungiacyathus sandoi*	*Thalamophyllia tenuescens*
Conocyathus formosus	*Fungiacyathus stephanus*	*Thecopsammia elongata*
Conocyathus zelandiae	*Fungiacyathus variegatus*	*Thrypticotrochus petterdi*
Conotrochus funicolumna	*Idiotrochus alatus*	*Trematotrochus hedleyi*
Crispatotrochus gregarius	*Javania insignis*	*Trematotrochus petterdi*
Crispatotrochus inornatus	*Javania lamprotichum*	*Trochocyathus maculatus*
Crispatotrochus woodsi	*Javania pachytheca*	*Trochocyathus rhombocolumna*
Cyathoceras cornu	*Labyrinthocyathus limulatus*	*Trochocyathus sp.*
Cyathotrochus pileus	*Leptopsammia queenslandiae*	*Trochocyathus wellsi*
Deltocyathus cameratus	*Lissotrochus curvatus*	*Truncatoflabellum vigintifarium*
Deltocyathus magnificus	*Monomyces rubrum*	*Tubastrea micrantha*
Deltocyathus ornatus	*Madrepora oculata*	*Tubastrea sp.*

3 Crustacea

Authors: Peter J.F. Davie and James K. Lowry

Contributors: Stephen J. Keable


Description

Crustaceans are a morphologically diverse group of invertebrates that occur in a broad range of marine habitats in the East Marine Region (EMR). They are found in both pelagic and benthic environments and from shallow waters to extreme depths. Elsewhere they occur across a range of estuarine, freshwater and terrestrial habitats.

Characteristics shared by crustaceans include a hardened outer covering, a segmented body, many body segments with paired legs, and two pairs of antennae on each of the first two head segments. They are classified in six classes: Branchiopoda, Remipedia, Cephalocarida, Maxillopoda, Ostracoda, and Malacostraca (Martin & Davis 2001). The morphology of these classes is highly variable within and between the groups. An interactive information retrieval system describing them is available at www.crustacea.net. A summary of the classification of these groups, and the higher subgroups contained in them discussed in this report, is given in Table 3.1.

The Branchiopoda and the Remipedia are mainly found in freshwater or live in salt water environments without a surface connection to the sea; they do not occur in the EMR. The cephalocarideans are marine; one species is known from New Zealand but none have been reported from Australia.

The maxillopodans are a large disparate group occurring widely within and outside the EMR. There is no single publication that provides an overview of this fauna from the EMR. Within this group cirripedians (barnacles) are best known from the intertidal zone and shallow depths, however, deepwater species occur in the EMR (Jones et al. 1990). Copepods may be one of the most diverse and abundant groups but they have not been comprehensively studied. They are mainly represented by the pelagic Calanoida and the benthic Harpacticoida. There are also many parasitic species, usually on fish.

Ostracods are also common in the EMR, mainly in the subclass Podocopa and Myodocopa. One study along the length of the region reports that abundance and diversity of this group is high, and increases with depth, and that more than 60 undescribed species occur (Lowry & Smith 2003).

Malacostracans dominate museum crustacean collections from the EMR. This class includes the Decapoda, one of the most diverse of the crustacean orders, containing the familiar edible and commercially important species, including the shrimps, prawns, lobsters, bugs and crabs. Because of their commercial and recreational importance this report focuses on these crustaceans (Table 3.2). However, information is provided for other crustacean groups on the basis of their ecological importance. Decapods are recognised by having a carapace (development of the outer covering which hides segmentation between the head and other body segments), and attachment and modification of the limbs to leave the last five pairs of the middle body segment for locomotion. The other large group within the malacostracans is the Peracarida. Peracaridan groups represented in the EMR are the orders Amphipoda, Cumacea, Isopoda and Tanaidacea. An interactive information retrieval system for these crustaceans is available at www.crustacea.net.

Over 2,250 decapod species have been recorded from Australia, and new distribution records and species continue to be found. This diversity is relatively high, for example 15% of the known crab species are represented. Queensland is an area of particularly high diversity, with 50% of the Australian species of Decapoda and closely related crustaceans occurring there. This diversity reflects the variety of habitats found in tropical regions. Typically, endemism is low with 62 species (6%) of these species being restricted to Queensland, however, the estuarine/intertidal fauna is unique in having about 25 endemic species of crabs (Davie 1985). While the precise number of species from the EMR is not known it can be expected to be significant.

Decapods exhibit a range of reproductive strategies but dispersal is predominantly via a planktonic larval phase, typically with a number of stages. The closest affinities of the Australian decapod fauna are with that of the Indo-Malaysian Archipelago directly to the north, and then more broadly with the rest of the Indo-west Pacific region. A marked overlap zone on both the eastern and western Australian coasts indicates a transition toward the south to a temperate fauna including a significant proportion of endemics. In the EMR the East Australian Current (EAC) also carries tropical larvae well south with tropical reef communities established at Elizabeth and Middleton Reefs and Lord Howe Island. The diversity in these areas is markedly less than the tropics but richer than typical temperate assemblages. The southern area of the EMR is dominated by temperate species that typically do not extend much farther north than the Central Eastern Transition. Eastwards into the tropical Coral Sea, at the northern end of the Kenn Transition, the Herald and Willis Groups are the remotest shallow reef systems. While the fauna is fully tropical, there is an apparent loss in diversity compared to the Great Barrier Reef (Davie & Short 2001), probably due to difficulty in larval recruitment caused by the small size of the resident population, remoteness of the area and regular severe weather events.

Information on the non-decapodan malacostracans, such as amphipods, cumaceans and isopods, is mostly from shallow water coastal areas and those of the EMR are not well known. Work in progress (see Key References and Current Research) indicates there is a distinct separation between tropical reef amphipod faunas and southern temperate faunas with little overlap at the species level. One study of the scavenging guild throughout the EMR region indicates that isopods and amphipods are abundant and diverse, with distributions restricted by depth and by latitude. The isopods are more speciose in tropical environments while the amphipods become more varied and abundant in deeper water, and in more temperate environments (Lowry & Smith 2003). However, the distribution patterns found in this study of scavenging species are unlikely to apply more generally to amphipods and isopods in the region.

Conservation Status

No Crustaceans in the EMR are listed under International, Commonwealth or state legislation as being vulnerable or endangered. A recent paper indicates that the amphipod, *Metaprotella haswelliana* no longer occurs along the New South Wales (NSW) coast adjacent to the EMR (Takeuchi & Lowry 2007). There are indications from other areas that peracaridan crustaceans are particularly susceptible to change, and amphipods have poor tolerance to hydrocarbon and heavy metal pollution (Thomas 1993). There is currently no direct evidence to suggest that any marine decapod species is threatened, however, data to confirm this are lacking in many cases; the conservation of the commercially harvested species is dependent on management plans attached to the relevant fisheries. There is also no evidence that non-decapod crustaceans are threatened by fisheries in the area. Some of these fisheries, however, utilise methods such as trawling which significantly modify the structure of the seafloor and the communities that live there (see Impacts and Threats).

Habitat and Distribution

Malacostracans are a conspicuous and ecologically important component of most benthic communities in the EMR from coral reefs to rocky reefs and soft sediments. Amphipods, in particular, often dominate the smaller macro-invertebrate fauna on the seafloor. Isopods and amphipods dominate the scavenging component of all soft bottom communities within the area (Lowry & Smith 2003). A variety of juvenile and adult crustaceans are also pelagic.

The high diversity of decapod crustaceans in Queensland is a consequence of the great variety of habitats within the region. As a generality, reef environments support the widest range of species followed by seagrass, mangrove and soft-sediment habitats. While the communities of these latter habitats are less diverse than reef systems, they remain highly varied. For example, the estuarine systems of the Wet Tropics region (e.g. Trinity Inlet, Murray River) have some of the most diverse communities of decapod crustaceans in Australia (Davie 1994). There has been insufficient research to give details on any cross-shelf and latitudinal trends in crustacean abundance or diversity within the EMR; however, there appears to be a steady decrease in species diversity from north to south for decapods. Deepwater shelf and slope habitats within the EMR are relatively poorly studied at least north of southern Queensland, and the potentially highly diverse fauna of the seamounts off the central east coast is unknown. Figure 3.1 shows the combined sampling sites from Australian Museum and Queensland Museum collections where data and specimens have been collected for Crustacea. This indicates that the Queensland provincial bioregions and those east of NSW, and not immediately adjacent to the coast, are poorly sampled apart from clusters off Brisbane, the southern GBR and Townsville/Cairns.

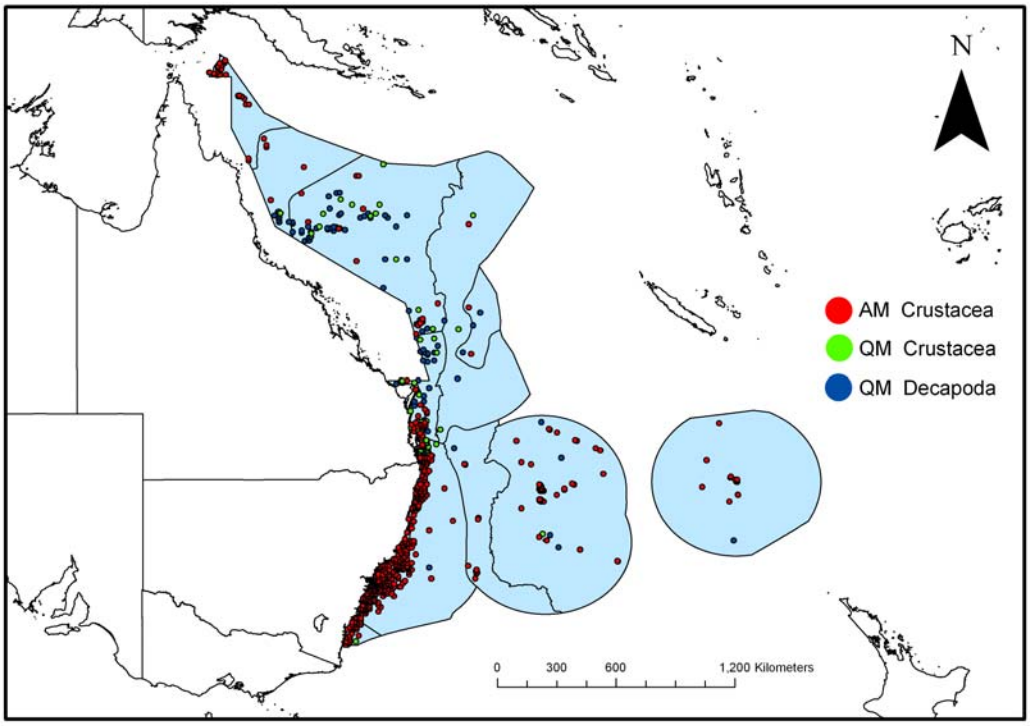


Figure 3.1 Crustacean records from the East Marine Region based on Australian (AM) and Queensland (QM) Museum datasets.

Life history and reproductive ecology

The dominant reproductive strategy within the crustaceans is considered to be the nauplius larva, however, within the malacostracans all members of the peracaridan group lack larval stages; instead the young develop within a brood pouch and are released as juveniles. This may account in part for their more restricted distributions. Peracaridans may also have elaborate sexual dimorphism. In some instances the males are modified for holding the female and mate guarding, or for reproductive swimming.

Decapod crustaceans have a wide range of reproductive strategies but most follow a basic pattern. The female stores sperm transferred to her by the male until her eggs are ready for fertilisation and external deposition. Fertilised eggs are typically attached as a mass to specially modified structures and cared for while they mature. The first stage larvae are released from the eggs into the water column. For many species this process is cued by lunar or tidal cycles. Depending on the species there may be relatively few large eggs or several million tiny eggs. Larvae of marine species are free living in the plankton and typically moult through a series of stages to reach maturity. This is a period when they are often a major food source for other organisms. The larval stage is also the main dispersal phase for most species, and in the case of lobsters and bugs specialised larval forms may persist as a free-swimming phase for up to 12 months. Dispersal may also be actively undertaken by adults of some species. Longevity of decapod crustaceans is not well known but can vary depending on the species from one or two years to 10 years or more. Colder water temperate species may grow more slowly and live longer than tropical species.

Prawns/Shrimps

Prawns are a large and varied group of crustaceans of enormous commercial value to Australia. The commercial species belong almost exclusively to the family Penaeidae. Eighteen species are fished in the EMR. Kailola et al. (1993) describe their diagnostic features, distribution, life history, stock structure and resource status. Some of the remaining 29 species found in the EMR may have some value, but are insufficiently common to be targeted. The full species list with a synopsis of their geographical distribution and biological data is presented in Appendix D.

The general distribution of prawns is known internationally (Dall et al. 1990) and throughout Australia (Grey et al. 1983; Davie 2002). Knowledge of abundance and habitat for most non-commercial and incidental catch species is, however, poor (Kailola et al. 1993).

Deepwater penaeoid prawns are trawled in waters of the EMR, at depths exceeding 200 m, and have been particularly targeted off NSW. These species include the red prawn (*Aristaeomorpha foliacea*) the giant scarlet prawn (*Aristeopsis edwardsiana*), the pink striped prawn (*Aristeus virilis*) and the royal red prawn (*Haliporoides sibogae*; Figure 3.1). A few larger species of the other major group of shrimps, the Caridea, are also sometimes caught but are of minor importance, at least in the EMR, *viz.* the pandalid shrimp (*Plesionika martia*) and the white shrimp (*Heterocarpus sibogae*).

Within the EMR two species are of particular commercial interest: the eastern king prawn (*Penaeus plebejus*) which is targeted in fisheries off both Queensland and NSW; and the royal red prawn (*Haliporoides sibogae*), which is the most significant deepwater prawn fished, this occurs mainly in the south of the EMR off NSW. Other commercial prawn species (Table 3.2), while perhaps sometimes occurring in the EMR, are considered to be mostly inshore in habit and lifecycle, and are not dealt with further here.

Eastern king prawns are restricted to the Australian east coast between Mackay, Queensland, and north-eastern Tasmania. The population is considered a single stock which inhabits estuaries as juveniles and migrates to offshore waters at approximately 12 months of age. Individuals mature after approximately 12 to 18 months and can live for up to three years (Kailola et al. 1993; DEH 2006a).

The biology, growth rates, and reproduction of the royal red prawn have been studied in the south-eastern part of their range where the main population is centred (Baelde 1992; Baelde 1994). Females apparently breed several times in their life, whereas males probably breed only once. The number of offspring produced is relatively low compared with other prawns. Two short breeding seasons occur per year (February to April and July to August) and the average age is between two and three years.

Tropical rock lobster

The life cycle of the Tropical Rock Lobster (*Panulirus ornatus*; Figure 3.2) is similar to many other lobsters. After hatching, the larvae, known as phyllosoma, are pelagic and by the final larval phase, known as the puerulus, they are active swimmers and seek suitable benthic habitat on which to settle. The spawning season is between November and April (MacFarlane & Moore 1986; Bell et al. 1987) with a larval life of approximately four to six months (Dennis et al. 1997). The pueruli settle during winter in holes or crevices in limestone substrates partially covered by seagrass or macroalgae. Juveniles develop rapidly and this species is among the fastest growing lobsters (Dennis et al. 1997).

Eastern rock lobster

Eastern rock lobsters (*Jasus verreauxi*) are distributed in coastal and offshore waters of eastern Australia and northern New Zealand. They are targeted in commercial fishing operations east of NSW as the populations off Victoria, Tasmania and Queensland are small. Mature lobsters congregate off the northern NSW coast and spawning occurs there during spring and summer at depths shallower than 50 m. Females can carry hundreds of thousands to millions of eggs (Kensler 1967). Larvae take approximately one year to reach the puerulus stage and then settle on inshore reefs and algae or seagrass beds. Sexual maturity is reached after four to five years at which time aggregations are formed as individuals move offshore into depths from 10 m to the edge of the continental shelf (approximately 200 m). They live for 10 years or more (DEH 2006b).

Bugs

Two species of 'Moreton Bay bugs' are targeted in fisheries operating in the northern EMR (Table 3.2); *Thenus parindicus* (mud bug, previously known in Australia as *T. indicus*) and *T. australiensis* (reef bug, previously known in Australia as *T. orientalis*). Reef bugs are predominantly known from Australia. The mud bug is most common in northern Australia but has a distribution extending to Karachi in the Indian Ocean (Burton & Davie 2007). Relevant information regarding the biology, lifecycle and fisheries of both species has been recently reviewed by Vance et al. (2004) and Jones (2007). On the east coast of Australia these bugs occur in tropical or subtropical areas. Reef bugs are generally found in water depths of 26 to 60 m in areas with sand, sandy mud or rock, while mud bugs usually occur in depths of less than 25 m where muddier substrates occur (Courtney & Williams 2002). Spawning of reef bugs on the east coast of Queensland occurs throughout the year but mostly in spring and early summer. Females produce thousands to tens of thousands of eggs. After hatching the larvae metamorphose before settling as juveniles (Courtney & Williams 2002). Bugs forage at night to feed on small invertebrates, including crustaceans, polychaetes (worms) and molluscs that they locate in the sediment (Johnston & Yellowlees 1998). They remain buried in sediments during the day. Growth is comparatively rapid as individuals reach a size that is legally taken in the fishery at one or two years of age. The life span is up to four years for the mud bug and eight years for the reef bug (Vance et al. 2004; Jones 2007).

In the central EMR, off the northern NSW and southern Queensland coasts, significant catches of Balmain bugs (*Ibacus* species) are taken in commercial fisheries (Table 3.2). Information on the fishery and biology of these species is reviewed by Haddy et al. (2007). Four species occur, *I. chacei* (Figure 3.3), *I. peronii*, *I. brucei*, and *I. alticrenatus*, but *I. chacei* is the principal species caught. All species occupy sandy or muddy substrates and their distributions are summarised in Table 3.3. *Ibacus chacei* and *I. peronii* are apparently sedentary during the day and probably bury themselves in sediments at this time. Information on reproduction is best known for *I. peronii*: females with eggs are found year round off the NSW coast but are most abundant in July to September and then in December; eggs generally hatch in the Spring/Summer period and some females may spawn several times per year; females do not produce viable eggs south of 26 ºS to 27 ºS although mature sized individuals occur south of this range; males are believed to be reproductively active throughout the year; unlike some other crustaceans mating does not require the female to have recently moulted. Contrasting information for other species is shown in Table 3.3. For all four species found in the EMR, data on development can summarised as follows: eggs are brooded by the female for two to four months; there are six to eight larval stages which develop over two to four months into a non-feeding stage which transforms into the juvenile; sexual maturity is reached after four to six moults of the juvenile stage. Growth models suggest individuals of *I. peronii* may live for more than 15 years.

Spanner Crabs

Spanner crabs (*Ranina ranina*; Figure 3.4) are widespread and abundant in offshore sandy areas of the Indo-Pacific region, from intertidal waters to depths of more than 100 m, in both exposed and sheltered conditions. Little is known of their biology, population dynamics and ecology, despite being the target of commercial fishing operations. They are readily recognised by their frog-like appearance, bright red colouration and spanner shaped claws. They bury themselves in sand and are opportunistic predators on many different bottom-dwelling species including small fish. Spanner crabs occur on the east and west coasts of Australia, from Yeppoon in Queensland to Nowra in NSW and from Quinn Rocks north of Perth to the Houtman Abrolhos and Geraldton in Western Australia. Male crabs grow to about 15 cm shell breadth, while females grow to about 11.5 cm. Recent research shows that *R. ranina* grow slowly and are, therefore, susceptible to overexploitation (Kirkwood et al. 2005). Fisheries for this species are, however, considered ecologically sustainable (DEH 2006c; DEH 2007).

Mud crab (Scylla serrata and S. olivacea)

Relevant biological information has been summarised by Smit et al. (2004). Mud crabs favour soft, muddy substrates of warm temperate to tropical waters in the vicinity of coastal mangroves. They are carnivorous scavengers living in large burrows around mangrove roots and in the banks of tidal waterways. Mating takes place after mature females moult. Sperm is retained by the female for between two and six months, while the eggs mature. The eggs are then fertilised, extruded from the body and deposited under the abdomen. Females subsequently migrate offshore to spawn. The eggs hatch into a larval planktonic phase, lasting approximately one month, before currents move them inshore and they moult into a swimming stage. Over a period of one to two years they develop into adults within the coastal environment. Adults mature in northern waters at 18 months (Kailola et al. 1993) and individuals live up to three years. Females spawn as many as three times after mating and may mate several times during their life (Knuckey 1999).

Blue Swimmer Crab (Portunus pelagicus)

Relevant biological information has been summarised by Smit et al. (2004). Blue swimmer crabs (Figure 3.5) are found in estuaries and coastal regions throughout Australia in depths of 0 to 60 m. They favour muddy or sandy environments and seagrass. They are scavengers and predators on benthic fauna, particularly other crustaceans and shellfish. Mating takes place shortly after the female moults. Mature females produce up to four batches of eggs between each moult. In the vicinity of the EMR the crabs generally mate in estuaries and move out to sea when the salinity drops during seasonal rainy periods. They can store sperm for a considerable time and have a series of larval stages which settle out within four to six weeks of hatching. Maturity is reached within 12 months.

Migration

Prawns

A number of prawn species utilise inshore estuaries, mangroves and shallow seagrass beds as nursery areas for juvenile growth, and then move into deeper offshore habitats as they mature. This estuarine/marine migration pattern is typical of commercial species where adults live and spawn at sea, usually in waters less than 50 m deep (Kenyon 2004). Larvae move in the water column with incoming tides back to inshore environments. Eastern king prawns favour seagrass habitat as juveniles and migrate into offshore waters at approximately 12 months of age. Tagging studies indicate there is northward migration of individuals at this time (Kailola et al. 1993; DEH 2006a). For the south-eastern Australian royal red prawn fishery a size-related latitudinal distribution has been documented (Baelde 1992, 1994). Larger prawns are more abundant in the northern part of the fishing area although spawning individuals apparently occur outside the main fishing ground. Juveniles predominate in the south. This distribution pattern is not well understood, however, as prawns are found along the entire eastern seaboard. This is an area that needs further research, particularly as the fishery apparently targets immature individuals.

Tropical Rock Lobster

Near the end of their second year of benthic life many lobsters in Torres Strait undergo an extensive breeding migration through the Great North East Channel into the Gulf of Papua as far east as Yule Island (Moore & MacFarlane 1984). High natural mortality occurs in the vicinity of Yule Island with apparently no return migration to Torres Strait (MacFarlane & Moore 1986).

Large aggregations of Tropical Rock Lobster have been observed on the eastern coast of Queensland, however, there is no evidence to suggest that these join the migration to Yule Island. Instead, tagging studies indicate lobsters from the Queensland east coast move in a south-east direction and that mature rock lobsters travel as single individuals or in small groups (Bell et al. 1987). Breeding females have been found on the eastern reefs of Torres Strait and outside the Great Barrier Reef at depths in excess of 100 m. The presence of much older *Panulirus ornatus* populations on the east coast suggests that there is no catastrophic mortality as occurs in the Gulf of Papua (Atfield 2004).

Eastern Rock Lobster

Adults migrate northwards to spawn off the north coast of NSW, larger individuals are therefore concentrated in this area and commercial catches from this area have a larger average size than those from the southern and central coast (DEH 2006b).

Bugs

Ibacus chacei is the only bug species known to undertake extensive migrations. Tagging studies show individuals can travel over 300 km in approximately 21 months. Migration is in a northwards direction to locations beyond 27 ºS where egg development and spawning occurs. It has been suggested that this migration pattern is an adaptation which allows southward dispersal of larvae via the EAC as it is prevalent at the depths occupied by this species (Haddy et al. 2007).

Spanner Crabs

While not undergoing migrations to separate locations, spanner crabs are known to move in large numbers to form dense mating aggregations on shallow to exposed sand banks and sometimes remote coastal beaches.

Mud Crabs

Gravid females are known to migrate some kilometres offshore to spawn which may place them into the EMR proper for a brief period of their lifecycle.

Significance of Crustacea in the East Marine Region

Ecological significance

Crustaceans are an important and conspicuous component of the marine invertebrate fauna of the EMR. Feeding types include herbivores, detritivores, suspension feeders, predators, parasites and scavengers. They are a major source of food for a wide variety of invertebrates and vertebrates. In particular decapod larvae are a major component of the zooplankton, and thus are essential to the food chain maintaining finfish industries. The importance of the ecological role of Crustacea, particularly in food chains of benthic and pelagic systems, cannot be overestimated.

Commercial significance

Other than finfish, decapod crustaceans are the most significant species group for fisheries. The crustaceans targeted by commercial fisheries operating in the EMR are listed in Table 3.2.

Prawns

The commercial prawn catch in Queensland is valued at over $100 million annually. Prawn fisheries comprise distinct sectors based on prawn species and location (Table 3.2, Appendix D). In particular eastern king prawns (*Penaeus plebejus*) migrate from estuarine nursery areas to deep waters and may be caught inshore and offshore throughout the EMR.

Rock Lobsters

Most rock lobster species found in Queensland waters belong to the genus *Panulirus* or tropical rock lobsters. In the East Coast Tropical Rock Lobster Fishery, almost the entire catch is of the painted rock lobster, *Panulirus ornatus*, which is targeted from inshore and mid-shelf reef systems. This fishery is part of a larger stock that encompasses the Torres Strait and Papua New Guinea; recruits in the EMR are probably supplied via currents from the clockwise gyre in the north-west Coral Sea.

The NSW lobster fishery is a small but valuable fishery. Eastern rock lobster *(Jasus verreauxi)* is the main species harvested. The fishery extends from the Queensland border to the Victorian border and includes all waters to approximately 80 nautical miles from the coast (DEH 2006b).

Bugs

Bugs are valuable species in fisheries operating in the EMR although the majority of the harvest occurs as incidental catch when targeting other higher value species such as prawns (Table 3.2). In particular *Ibacus chacei* is a notable species largely restricted to the EMR and comprising most of the Balmain bug catch, valued at over $2 million. The majority of these bugs are taken from southern Queensland and northern NSW in depths between 20 to 200 m (Haddy et al. 2007). Moreton Bay bugs are mostly taken from Queensland waters, however, significant catches occur in fisheries operating entirely, or principally, outside the EMR (Vance et al. 2004; DEH 2004a; Jones 2007).

Spanner Crabs

The area of the Spanner Crab Fishery encompasses the waters off Queensland from the NSW border to the Northern Territory border but fishing effort is concentrated in coastal waters to 80 m depth between central Queensland and the NSW border.

Mud Crab

The mud crab fishery is primarily tropical and subtropical with most harvesting occurring in tidal areas along the coast, however, it is a significant fishery particularly in Queensland adjacent to the EMR and adults may migrate up to 50 km offshore to spawn (Kailola et al. 1993).

Blue Swimmer Crab

Blue swimmer crabs occur widely throughout the EMR but the commercial fishery is concentrated in coastal southern Queensland from the NSW border to Bundaberg, however, there has been a recent expansion of effort into offshore waters.

Impacts/Threats

There are no recognised threatened marine crustaceans, nor are any considered to represent relict populations within the EMR. Threatening processes may be both anthropogenic and the result of natural processes. Although many impacts/threats can be identified, their extent is largely unknown. Possible impacts may occur from contamination, chemical spills etc., and on a local scale from shipping, mine sites, ports and population centres. Contaminants are likely to accumulate along the food chain. Oil, oil-dispersants and heavy metals are also known to be toxic to crustaceans.

Very little is known about the lifecycles of most non-commercial species and there are significant impediments to be overcome in order to identify or classify crustaceans. This basic lack of knowledge about crustacean biodiversity and ecology limits understanding of impacts and resulting changes.

Habitat Loss

Global climate change is expected to lead to a rise in sea level and sea water temperatures. Such transformations may have long-term impacts on habitat distribution/composition and species distribution, particularly in coastal habitats, such as seagrass, mangroves, salt marshes/flats and coral reefs. Changes in freshwater flows and seasonal flood events will have indefinite impacts on deeper shelf waters, however, dramatic effects on shallow coastal communities, such as reefs, seagrasses and mangroves, can be expected. These expected disruptions to inshore systems will almost certainly impact on the deeper offshore waters.

Habitat loss due to coral bleaching may have a profound effect on the associated fauna. Coral rubble at the base of the living reefs is an important habitat for smaller crustaceans. The rubble is continuously replenished by the natural life cycle of the corals but any loss of living corals, through bleaching or global warming, will alter this extremely rich habitat.

Fishing

Management of the major fisheries target species is crucial and dependent upon continued research and consistent approaches between State and Commonwealth agencies.

The threat to non-target crustaceans by commercial fisheries is primarily through habitat modification and change in community structure caused by continuous bottom trawling over long periods. This, however, is typically confined to particular grounds where nets are not fouled. Hutchings (1990) has reviewed the state of knowledge on the effects of trawling on macrobenthic epifaunal communities, and it is clear that we are hampered in our understanding by a lack of controlled scientific studies. Crustaceans may also be taken as discarded bycatch, particularly of trawl fisheries (see Bycatch chapter).

Information Gaps

Crustaceans are a dominant component of the benthos of the shelf and deep water but there are significant gaps in our knowledge of the basic taxonomy, biodiversity, ecology and community structure of the Crustacea of the EMR (Ponder et al. 2002). An overview of the crustaceans of this region such as that of Poore (2004), which covers a region from Sydney south west to Perth, is lacking. In particular smaller crustaceans such as copepods, ostracods and peracaridans are poorly known. Consequently, baseline data to monitor the impacts of fisheries or climate change is lacking.

The combined crustacean data points from the Queensland and Australian Museum collections are shown in Figure 3.1. The Central Eastern Shelf Transition, the Central Eastern Shelf Province and some inner parts of the Central Eastern Province have been intensively sampled. Many of these records result from the extensive survey work undertaken by NSW fisheries agencies, particularly that of the RV *Kapala*. From Fraser Island north, however, the sampling sites become very sparse. Because most survey work has been conducted by fisheries agencies the sampling gear used is not designed to collect a wide range of invertebrates. The larger mesh sizes and the poor bottom penetration, of the gear used, results in the wide range of crustaceans (and invertebrates in general) being undersampled. Some effective cruises were undertaken during the *Cidaris* expeditions off Townsville in the early 1990s, but this has been an exception. A systematic series of cross-shelf and cross-slope transects along the coast to the east of the Great Barrier Reef, using appropriate methods to sample both pelagic and benthic environments would assist in understanding the ecology of this rich zone.

To the south information regarding the fauna of the seamount chain to the east of southern Queensland and northern NSW is lacking. This includes the Recorder, Moreton, Brisbane, Queensland, Britannia, Stradbroke, Derwent Hunter, Barcoo and Taupo Seamounts. Seamounts are complex yet fragile communities with much higher diversity than surrounding waters and Australia has designated them priority areas for marine biodiversity research. Information from the seamounts of the Tasman Sea and New Caledonia indicates that rare and endemic species are confined to individual seamounts while other species may be distributed more widely. The central east coast seamounts may play an important role as a ‘biological reservoir’ both for endemic species and as part of a biological ‘highway’ connecting the seamounts of the south-western Pacific.

Fisheries management is hampered by lack of knowledge of impacts to the population of many target species—effective management of these genetic stocks can only be achieved through continuing research and monitoring. Knowledge of the impacts of fisheries on non-target crustacean species is also needed.

Key References and Current Research

Current Research

While not specifically concentrating on the EMR there are a number of research initiatives that will provide information for the crustaceans from this region.

*Tropical Rock Lobsters***:** A FRDC-funded CSIRO/QDPI&F research project (2002/2008) 'Biology, larval transport modelling and commercial logbook data analysis to support management of the NE Queensland Rock Lobster *Panulirus ornatus* Fishery' will provide information on the dispersal of larvae of this species within the EMR.

*Deep-sea***:** A new deep-sea exploration program called 'Deep Australia Project 2007-2010' is planned to commence in late 2007 or early 2008. It is to be partly funded by an ARC Linkage grant, the Deep Ocean Quest group and individual institutions. It will involve a purpose-built deep-sea research vessel (MV *Alucia*) operating submersibles and ROVs allowing exploration to 3,000 m depth, which has not been previously possible in Australia

The results of the NORFANZ cruise in 2003 will significantly expand our knowledge of deep water and temperate crustaceans and this may be relevant to the southern provinces of the EMR. (http://www.environment.gov.au/coasts/discovery/voyages/norfanz/index.html).

Amphipod and isopod pericaridan crustaceans

Identification keys to Australian marine amphipods and isopods are being developed through Australian Biological Resources Study (ABRS) grants.

A book, 'The Amphipoda of the Great Barrier Reef' (edited by J.K. Lowry and A.A. Myers) will be published in 2008 in the journal *Zootaxa.* This will include 47 papers and information for approximately 230 species, significantly expanding the knowledge of tropical amphipods, particularly those that inhabit inter-reefal areas adjacent to the EMR.

A study currently underway (Circum-Australian Amphipod Project), funded by Department of the Environment and Water Resources, on selected groups of amphipods will provide new biogeographic and taxonomic information for these crustaceans for the EMR.

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Figure 3.1 Royal Red Prawn (*Haliporoides sibogae*). Photo by P. Davie, © Queensland Museum.

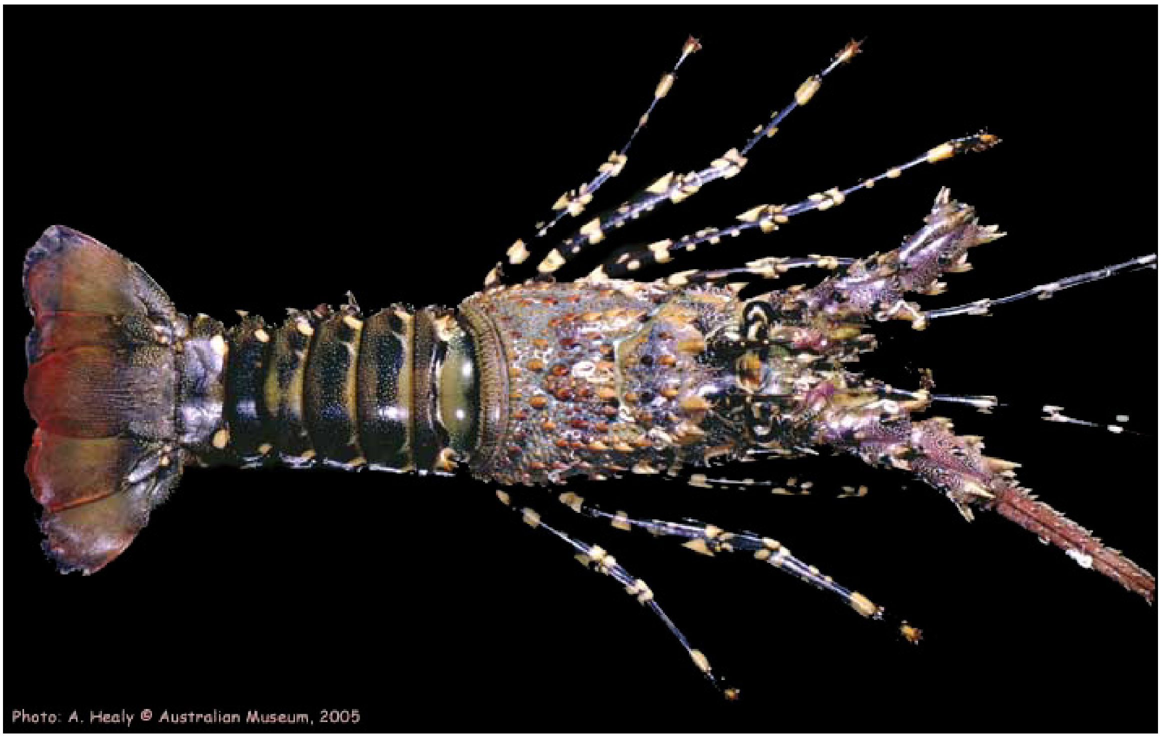

Figure 3.2 Painted rock lobster (*Panulirus ornatus*).

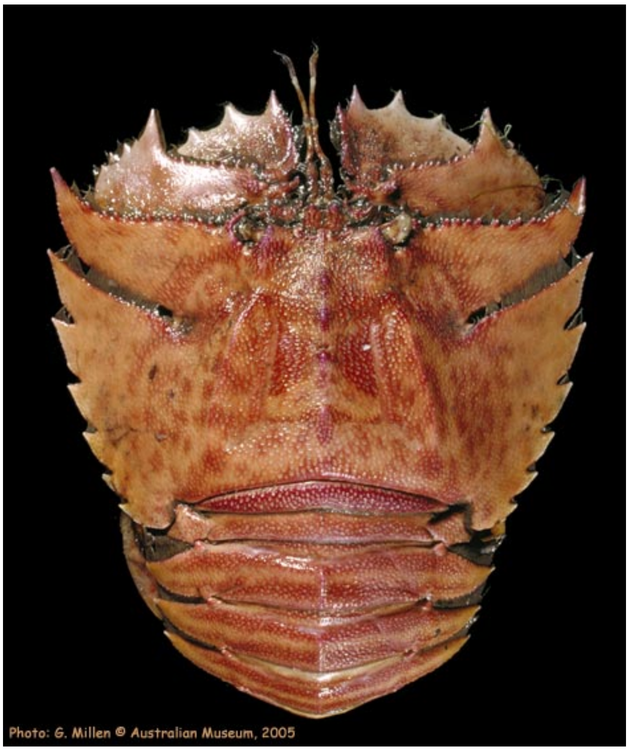

Figure 3.3 Balmain bug (*Ibacus* chacei).

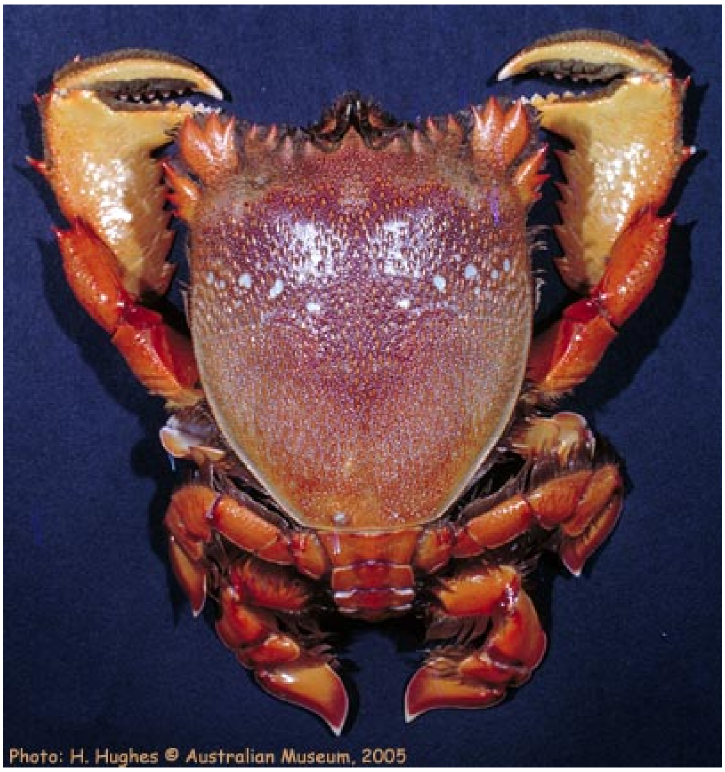

Figure 3.4 Spanner crab (*Ranina ranina*).

Figure 3.5 Blue swimmer crab (*Portunus pelagicus*).

Table 3.1 Summary of the classification of the higher level groups and subgroups of the subphylum Crustacea of the EMR discussed in this report based on Martin& Davis (2001).

Group/ Classification	Class	Subclass	Infraclass	Superorder	Order	Infraorder	Superfamily	Comment
BRANCHIOPODA	■							Mainly freshwater
REMIPEDIA	■							Not marine
CEPHALOCARIDA	■							Known from New Zealand but not the EMR
MAXILLOPODA	■							
Cirripedia			■					Includes barnacles
Copepoda		■						
Calanoida					■			
Harpacticoida					■			
OSTRACODA	■							
Myodocopa		■						
Podocopa		■						
MALACOSTRACA	■							
Decapoda					■			Includes shrimp, prawns, lobsters, bugs and crabs
Caridea						■		Shrimps
Penaeoidea							■	Prawns
Peracarida				■				
Amphipoda					■			
Cumacea					■			
Isopoda					■			
Tanaidacea					■			

Table 3.2 Crustaceans targeted or occurring as significant secondary catch in fisheries able to operate in the EMR.

Those of particular importance to the EMR are highlighted. Source: http://www.environment.gov.au/coasts/fisheries/index.html, http://www.afma.gov.au/fisheries/fisheries_index.htm.

Common & Scientific Name	**Fishery where a target or primary species**	**Fishery where a byproduct or secondary species**	**Comments**
Blue swimmer crab (*Portunus pelagicus*)	Qld Blue Swimmer Crab Pot Fishery.	NSW Ocean Trawl Fishery. Qld East Coast Otter Trawl Fishery. Qld Mud Crab Fishery.	
Three-spot /redspot crab (*Portunus sanguinolentus*)		Qld Blue Swimmer Crab Pot Fishery. Qld East Coast Otter Trawl Fishery.	Minor bycatch.
Mud crab (*Scylla olivacea*)	Qld Mud Crab Fishery.	Qld Blue Swimmer Crab Pot Fishery.	Inshore fishery; adults may migrate offshore into EMR to spawn.
Mud crab (*Scylla serrata*)	Qld Mud Crab Fishery.	Qld Blue Swimmer Crab Pot Fishery.	Inshore fishery; adults may migrate offshore into EMR to spawn.
Spanner crab (*Ranina ranina*)	NSW Ocean Trap and Line Fishery.		Also targeted in the Qld Spanner Crab Fishery with effort concentrated in coastal waters up to 80 m depth between Yeppoon in central Qld and the Qld/NSW border. Bycatch in Qld Blue Swimmer Crab Pot Fishery.
Eastern rock lobster (*Jasus verreauxi*)	NSW Lobster Fishery.		Minimum and maximum size limits have been set for this species in the South-East Qld Developmental Slipper Lobster Fishery, however, it has not been targeted and the Fishery is not established (DEH Assessment 2004c).
Barking crayfish (*Linuparus trigonus*)		Qld East Coast Otter Trawl Fishery.	Minor commercial importance, occasionally targeted when other species are uncommon.
Painted (tropical) rock lobster (*Panulirus longipes*)		NSW Lobster Fishery.	
Tropical rock lobster (*Panulirus longipes bispinosa*)	Qld East Coast Tropical Rock Lobster Fishery.		Taken very infrequently and generally comprises less than 1% of the annual fishery take. Formerly recorded *as Panulirus longipes femoristriga*.

Common & Scientific Name	Fishery where a target or primary species	Fishery where a byproduct or secondary species	Comments
Painted (tropical) rock lobster (*Panulirus ornatus*)	Coral Sea Fishery; Qld East Coast Tropical Rock Lobster Fishery.	NSW Lobster Fishery.	In Qld most fishing activity occurs in World Heritage Areas within GBRMP around three groups of inshore/mid-shelf reefs off Shelburne Bay, however, the recreational fishery extends along the entire Qld east coast out to the AFZ limit.
Tropical rock lobster (*Panulirus penicillatus*)	Qld East Coast Tropical Rock Lobster Fishery.	Coral Sea Fishery.	Taken very infrequently and generally comprises less than 1% of the annual fishery take.
Tropical rock lobster (*Panulirus versicolor*)	Qld East Coast Tropical Rock Lobster Fishery.	Coral Sea Fishery.	Taken very infrequently and generally comprises less than 1% of the annual fishery take.
Slipper lobster (*Scyllarides haani*)	South-East Qld Developmental Slipper Lobster Fishery.		The fishery was originally intended to operate within the GBRMP but this was not permitted. Development of the fishery is awaiting determination of economic viability and interest (DEH Assessment 2004).
Slipper lobster (*Scyllarides squammosus*)	South-East Qld Developmental Slipper Lobster Fishery.		The fishery was originally intended to operate within the GBRMP but this was not permitted. Development of the fishery is awaiting determination of economic viability and interest (DEH Assessment 2004).
Royal red prawn (*Haliporoides sibogae*)	NSW Ocean Trawl Fishery.		
Bay prawn (*Metapenaeus bennettae*)	Qld East Coast Otter Trawl Fishery.		Unlikely to be common within the EMR as typically shallower water inshore species.
Endeavour prawn (*Metapenaeus endeavouri*)	Qld East Coast Otter Trawl Fishery.		Unlikely to be common within the EMR as typically shallower water inshore species.
Endeavour prawn (*Metapenaeus ensis*)	Qld East Coast Otter Trawl Fishery.		Juveniles estuarine, but adults can be in deeper waters to 65 m; main fishery believed to be coastal.
School prawn (*Metapenaeus macleayi*)	NSW Ocean Trawl Fishery.		Uncommon within the EMR as typically shallower water inshore species.
Tiger prawn (*Penaeus esculentus*)	Qld East Coast Otter Trawl Fishery.		Unlikely to be common within the EMR as typically shallower water inshore species.
Western king prawn (*Penaeus latisculatus*)	Qld East Coast Otter Trawl Fishery.		Occurs over a variety of bottoms to 90 m, so may occur within the EMR south of the GBR region.

Common & Scientific Name	Fishery where a target or primary species	Fishery where a byproduct or secondary species	Comments
Red spot prawn (*Penaeus longistylus*)	Qld East Coast Otter Trawl Fishery.		Associated with hard bottom near reefs from 35–55 m. Unlikely to be of significance within the EMR.
Banana prawn (*Penaeus merguiensis*)	Qld East Coast Otter Trawl Fishery.		Unlikely to be common within the EMR as typically shallower water inshore species.
Tiger prawn (*Penaeus monodon*)	Qld East Coast Otter Trawl Fishery.		Juveniles in shallow estuarine waters, but adults in deeper waters to 110 m, therefore will be fished within the EMR but generally uncommon within Australian waters.
Eastern king prawn (*Penaeus plebejus*)	NSW Ocean Trawl Fishery; Qld East Coast Otter Trawl Fishery.		A significant, targeted commercial species within the EMR.
Tiger prawn (*Penaeus semisulcatus*)	Qld East Coast Otter Trawl Fishery.		Juveniles in shallow estuarine waters, but adults in deeper waters to 130 m. Fished within the EMR but relatively uncommon in east Australian waters.
Balmain bug (*Ibacus* spp.)		NSW Ocean Trawl Fishery. Qld East Coast Otter Trawl Fishery. Qld Finfish (Stout Whiting) Trawl Fishery.	*Ibacus chacei* is the main species taken, *I. peronii* is regularly taken in small numbers, and *I. brucei* and *I alticrentatus* are taken less frequently in small numbers.
Moreton Bay bugs – Reef bug, Coral bug (*Thenus* spp.)	Qld East Coast Otter Trawl Fishery.	Qld Finfish (Stout Whiting) Trawl Fishery.	*Thenus parindicus* (Mud Bug, previously known in Australia as *Thenus indicus*) and *Thenus australiensis* (Reef Bug, previously known in Australia as *Thenus orientalis*).
Hermit crabs (Paguridae)		NSW Lobster Fishery.	Minor bycatch of inshore fishery.
Mantis shrimp (Squilloidea spp.)		Qld East Coast Otter Trawl Fishery.	Minor bycatch of inshore fishery.

Table 3.3 Summary of distribution and spawning data for Balmain bugs (*Ibacus* spp.) found in the EMR. Source: Haddy et al. (2007).

Species	Geographic Distribution	Depth Distribution	Number of eggs held by females	Number of spawning events per year
Ibacus alticrenatus	Between north east Qld (20°S, ~ latitude of Mackay) around the southern Australian coastline to North West Cape, WA (22°S). Also around most of New Zealand.	Between 80 and 700 m but usually on the upper-continental slope between 200 and 400 m.	1,700 to 14,800	One
Ibacus brucei	Between central Qld (20°S, ~ latitude of Mackay) and central NSW (35°S) but rarely south of ~ Newcastle (32°S). Also recorded from New Zealand.	Between 80 and 560 m but most abundant on the continental shelf break between 150 and 250 m.	2,000 to 61,300	One
Ibacus chacei	Between northern Qld (17°S, ~ latitude of Cairns) and southern NSW (36°S) but rarely south of Sydney (34°S).	Between 30 and 330 m but most abundant on the mid-continental shelf between 50 and 150 m.	2,100 to 28,800	Multiple
Ibacus peronii	From south east Qld (28°S, ~ latitude of border with NSW) south to south east Tas., including Bass Strait, and north west Tas. to south west WA (29°S, just north of Perth).	Between 4 and 288 m but mainly in inshore waters of less than 80 m.	5,500 to 36,700	Multiple

4 Demersal Teleost Fish

Author: Ken Graham






Description

Demersal teleosts or bony fishes live on or near the seabed and comprise a very diverse group, both morphologically and in the habitats occupied. They are the focus of important fisheries in the Eastern Marine Region (EMR) being exploited from inshore trawl grounds and rocky reef habitats, in depths between 300 and 1000 m along the continental slope, and from deepwater seamounts and ridges in remote areas of Australia’s maritime economic zone. A wide variety of teleosts are caught in the various fisheries with over 100 species reported in NSW commercial landings alone while a greater number of teleosts are discarded as bycatch in some fisheries, particularly the trawl sector. This report focuses on the principal commercial teleosts landed by the main fisheries operating in the EMR and also includes information on those species with significant recreational-fishery harvest.

Commercial trawl, trap and line fisheries off southern Queensland and NSW account for a very high proportion of the demersal fish harvest in the EMR. The NSW Ocean Trawl Fishery (OTF) extends from the Queensland border in the north to the Victorian border in the south. North of Barrenjoey Point (Sydney) the boundaries extend from the coast to the 4000 m depth contour while south of Barrenjoey Point, the NSW jurisdiction extends to three nautical miles seawards of the coast; trawling outside this boundary is managed by the Commonwealth as part of the Southern and Eastern Scalefish and Shark Fishery (SESSF). Jurisdiction for the NSW Ocean Trap and Line Fishery (OTLF) extends from the shore to 80 nautical miles seawards. The Queensland fishery jurisdiction extends seawards from the coast to the 400 m isobath. Its main demersal fisheries south of the Great Barrier Reef are the East Coast Trawl Fishery (ECTF), Finfish Trawl Fishery (FTF), Rocky Reef Fin Fish Fishery (RRFFF) and Deepwater Fin Fish Fishery (DFFF).

In addition to these state-based fisheries, there are two small Commonwealth managed fisheries in offshore areas of the EMR: the Coral Sea Fishery and the East Coast Deepwater Trawl Sector (ECDTS) of the SESSF. The demersal line and trawl operators in the Coral Sea Fishery produced 156 t of teleost catch in 2006 but no further details are publicly available; there was no catch or fishing effort in the ECDTS in 2006 but significant catches (> 1000 t) of deepwater species were made in previous years (see below).

The trawl fisheries off southern Queensland and northern NSW target principally saucer scallops (Queensland), eastern king prawns, cephalopods and whiting with fishing mostly in depths less than 150 m and seldom beyond 200 m. Fish and royal red prawn trawlers operate off central and southern NSW on the shelf and upper slope in depths to 650 m. There is only occasional trawling on the NSW midslope (650–1100 m). In both states, the line and trap fisheries operate mostly on hard-substrate and reef areas in depths to 150 m but there is also some dropline fishing deeper than 200 m. Sectors of the line fisheries that target sharks are discussed in the Sharks and Rays chapter of this report.

NSW demersal fisheries are fully described in recently completed Environmental Impact Statements (EIS) for the OTF (DPI 2004) and OTLF (DPI 2006) while Queensland demersal fisheries are summarised in Annual Status Reports (ASRs 2006). Reported total landings in 2000–2001 by the NSW OTF and OTLF were approximately 4600 t and 1800 t with the demersal teleost components about 1650 t and 910 t respectively. The SESSF harvests about 20 000 t of mainly teleosts from grounds between Sydney and Kangaroo Island in South Australia (Status Report 2006); the proportion of that catch taken in the EMR sector off NSW is not reported separately but is currently less than 3000 t. In Queensland, teleost landings include approximately 1100 t of stout whiting (FTF) and, including the estimated recreational catch, about 700 t of mainly snapper and pearl perch from rocky reef areas (RRFFF). Production from the deepwater line-fishery (DFFF) is small (~25 t per annum) and, since turtle excluder and bycatch reduction devices became mandatory, teleost landings from Queensland prawn-trawl fisheries are restricted to small quantities of goatfishes (Mullidae), threadfin breams (Nemipteridae) and pipefishes (Syngnathidae).

Demersal teleosts identified as primary or key secondary species in the NSW OTF and/or OTLF are listed in Table 4.1; these species contribute to more than 90% of the total catch in each of these fisheries. Included are flathead, bream, snapper, and silver trevally, the most commonly caught of the demersal fishes taken by the recreational sector (Henry & Lyle 2003). The table also identifies the demersal teleosts targeted by Queensland offshore fisheries, and those species in the SESSF managed with individual quotas and total allowable catches.

Table 4.1 Demersal teleosts caught in the EMR that are recognised as primary (P), key secondary (K2), or secondary (S) species in the NSW Ocean Trawl (OTF) and Ocean Trap and Line (OTL) Fisheries, target (T) species in the Queensland offshore fisheries (Qld), and SESSF quota (Q) species.

Family	Species	Common Name	OTF	OTL	Qld	SESSF
Ophidiidae	*Genypterus blacodes*	Pink Ling	S			Q
Trachichthyidae	*Hoplostethus atlanticus*	Orange roughy				Q
Berycidae	*Beryx splendens*	Alfonsino				Q
Berycidae	*Centroberyx affinis*	Redfish	K2			Q
Zeidae	*Zeus faber*	John dory	K2			Q
Zeidae	*Zenopsis nebulosus*	Mirror dory	K2			Q
Sebastidae	*Helicolenus barathri*	Ocean perch	K2			Q
Triglidae	*Chelidonichthys kumu, Pterygotrigla* spp.	Red gurnard, latchets				
Platycephalidae	*Neoplatycephalus richardsoni*	Tiger flathead	P			Q
Platycephalidae	*P. caeruleopunctatus*	E. bluespotted flathead	P			
Serranidae	*Epinephelus ergastularius*	Banded rockcod		P		
Serranidae	*Polyprion* spp.	Hapuku and Bass groper		K2		
Glaucosomidae	*Glaucosoma scapulare*	Pearl perch		K2	T	
Sillaginidae	*Sillago robusta*	Stout whiting	P		T	
Sillaginidae	*Sillago flindersi*	Eastern school whiting	P			Q
Malacanthidae	*Branchiostegus wardi*	Pink tilefish	K2			
Carangidae	*Dentex georgianus*	Silver trevally	P	P		Q
Sciaenidae	*Argyrosomus japonicus*	Mulloway		K2		
Sciaenidae	*Atractoscion aequidens*	Teraglin		K2	T	
Sparidae	*Pagrus auratus*	Snapper		P	T	
Sparidae	*Acanthopagrus australis*	Yellowfin bream		P		
Pentacerotidae	*Paristiopterus labiosus*	Boarfish	K2			
Cheilodactylidae	*Nemadactylus douglasii*	Grey morwong	K2	P		
Cheilodactylidae	*Nemadactylus macropterus*	Jackass morwong		K2		Q
Labridae	*Bodianus unimaculatus*	Blackspot pigfish		K2		
Gempylidae	*Rexea solandri*	Gemfish		K2		Q
Centrolophidae	*Hyperoglyphe antarctica*	Blue-eye trevalla		P		Q
Paralichthyidae	*Pseudorhombus* spp.	Flounders	K2			
Cynoglossidae, Soleidae	*Paraplagusia bilineata, Brachirus nigra*	Tongue sole, Black sole	K2			
Monacanthidae	*Nelusetta ayraudi,* Monacanthidae spp.	Ocean jacket Leather jackets	K2	P		

Conservation Status

No species are listed on any international, Commonwealth or state threatened species list. However, orange roughy (*Hoplostethus atlanticus*) is listed under the Environment Protection and Biodiversity Conservation Act as ‘conservation dependent’.

Habitat and Distribution

There are approximately 4000 species of marine fish in Australian waters (Hoese et al. 2006) and a high proportion of these are found in the EMR. In demersal trawl surveys off NSW, almost 400 species of teleosts were recorded, of which 122 were classed as commercial (Appendix A). This high diversity is reflected in NSW commercial catches with about 80 demersal teleost species reportedly landed for sale by each of the NSW OTF and OTLF fisheries (DPI 2004, 2006). However, more than 90% of the total catch in each sector comprised less than 15 primary and key secondary species (see Table 4.1). Similarly, about 85% of the Queensland rocky-reef (RRFFF) landed catch comprises just two species, snapper and pearl perch (ASR 2). For all the main species, the capture method generally reflects their preferred habitat (Table 4.2).

Demersal trawls can only operate on relatively smooth and firm sandy or muddy substrates whereas trap and line fisheries usually target fish on reefs or areas of foul ground. Catches from inshore trawling grounds are characterised by stout whiting (northern NSW and southern Queensland), school whiting (most of the NSW coast), silver trevally and bluespotted flathead. On the NSW central and outer shelf (100–200 m), the teleost trawl-catch comprises mainly tiger flathead, redfish and john dory, while on upper slope grounds pink ling, ocean perch and mirror dory are the most abundant commercial species. In recent years, juvenile ocean jackets have frequently formed dense schools on central NSW inshore grounds causing disruption to whiting and prawn trawling operations. Although trawlers land significant quantities, most ocean jackets are harvested at larger sizes from traps in deeper reef areas. Key line and trap species such as snapper, grey morwong and pearl perch typically inhabit reef areas in depths less than 100 m and are targeted by both commercial and recreational fishers. The deepwater blue-eye trevalla, barred rockcod and hapuku are species mainly caught by dropline in untrawlable ravine or seamount areas.

Remote seamount and plateau areas in the Australian Fishing Zone such as the Lord Howe Rise and the Taupo and Derwent Hunter Seamounts have been exploited in recent years by trawlers and dropline vessels. In the 1990s, the Lord Howe Rise was explored for orange roughy. More recently, alfonsino (*Beryx splendens*) became the major target species with catches totalling more than 1000 t in the period 2001–2005; catches of other seamount species included 100 t of pelagic armourhead (*Pseudopentaceros richardsoni*) and almost 90 t of blue-eye trevalla (Larcombe & McLoughlin 2007).

Table 4.2 Summary of habitat characteristics and migrations/movements of key demersal fishes in coastal waters of the EMR.

	Depth categories			Habitat			
Species	**Inshore**	**shelf**	**slope**	**reef**	**smooth**	**sea-mount**	**Migrations / movements**
Pink ling			x		x		
Orange roughy			x		x	x	spawning aggregation
Alfonsino			x			x	
Redfish		x	x	x	x		inshore to offshore
Dory - john	x	x			x		
Dory - mirror			x		x		spawning migration
Ocean perch		x	x	x	x		
Flathead - tiger	x	x			x		inshore to spawn
Flathead - eastern bluespotted	x				x		
Barred rockcod		x	x	x	x		
Hapuku and bass groper			x	x	x	x	
Pearl perch	x	x		x			
Whiting - stout	x				x		
Whiting - eastern school	x				x		
Silver trevally	x	x		x	x		
Mulloway	x			x	x		
Teraglin	x	x		x			
Snapper	x	x		x	x		
Morwong - grey		x		x	x		
Morwong - jackass		x	x		x		
Blackspot pigfish		x		x			
Gemfish			x		x		spawning migration
Blue-eye trevalla			x			x	
Ocean jacket	x	x		x	x		inshore to offshore

Life history and reproductive ecology

For the most part, teleosts are relatively fast growing and produce large numbers of pelagic eggs and larvae. The early larval and post-larval life stages of several key species (e.g pink ling, redfish, silver trevally and gemfish) were delineated by Neira et al. (1998) while the environmental impact statements for the OTF and OTLF (DPI 2004, 2006) summarise the available information on growth and reproductive biology of the primary and key secondary teleosts in the fisheries. Key species with documented fishery and biological studies include tiger flathead (Fairbridge 1952), jackass morwong (Smith 1982, 1983; Jordan 2000), redfish (Morison & Rowling 2001), snapper (Ferrell & Sumpton 1997), gemfish (Rowling 1999) and silver trevally (Rowling & Raines 2000); the age, growth and reproduction of several other important commercial teleosts in east coast fisheries such as eastern bluespotted flathead, ocean jackets and pearl perch are currently being studied at the Cronulla Fisheries Research Centre of Excellence.

Migration

Few shallow water demersal teleosts are known to undergo significant migrations although the larvae of many species settle in inshore or estuarine habitats before recruiting to deeper water as they mature. Key species that typically follow this pattern include snapper, ocean jackets and redfish (Chen et al. 1997), while tiger flathead seasonally move inshore to spawn (Graham et al. 1995). On the upper continental slope, mirror dory, gemfish and frostfish (*Lepidopus caudatus*) make winter spawning migrations which originate east of Bass Strait and move northwards to a spawning area off central and northern NSW (Rowling 1994). In midslope depths (~800–1000 m), orange roughy aggregate at specific spawning sites and the discovery of such sites quickly become the focus of intense trawling activities e.g. St Helens Hill, a seamount off north-eastern Tasmania (Larcombe & McLoughlin 2007). A substantial catch of spawning orange roughy taken off Newcastle-Port Stephens in 1988 (Graham & Gorman 1988), followed by the capture of numerous orange roughy eggs in the same area in 1989 (Graham 1990), indicate that there is an orange roughy spawning site off central NSW. It is therefore likely that mature orange roughy from along much of the NSW coast seasonally congregate to this area for spawning.

Significance of Demersal Fish in the East Marine Region

Key demersal teleosts harvested in the EMR do not have any cultural significance but they do, by definition, contribute a major proportion of landed catch in several fisheries and consequently generate significant economic return to the fishing industry and local communities. The management of the various fisheries is the responsibility of the respective Queensland, NSW and Commonwealth fishery agencies and, in recent years, their focus has changed from individual species-based management responses to ones that aim to ensure that fishing activities are managed in an ecologically sustainable way. In NSW, these changes required the development of fishery management strategies and associated environmental impact assessments for each major state-based fishery (e.g. DPI 2004, 2006); similarly, the annual Queensland and Commonwealth fishery status reports canvas environmental issues and fishery impacts on the relevant ecosystems (see ASR1,2,3 2006, Larcombe & McLoughlin 2007).

All demersal teleosts exploited in the EMR are important components of the marine ecosystem and over-exploitation of any one species within a fishery may have flow-on consequences across the ecosystem as a whole. For example, the greatly reduced biomass of adult gemfish, a top predator, and the almost total elimination of the formerly abundant *Centrophorus* dogfishes from the NSW upper slope (Graham et al. 2001; Rowling & Makin 2001) may have significantly impacted the deepwater ecology. However, ecosystem-based fishery management methods are being developed with the aim of ensuring that the marine ecosystem, including its component populations, habitats and processes, is maintained such that it supports viable and sustainable fisheries (Pitcher & Pauly 1998). To this end, a collaborative study is underway between NSW DPI and the University of British Columbia to develop an ecosystem-based model for fisheries operating in the coastal waters of NSW (DPI 2006). The implementation of any such model will probably have wider application across much of the EMR.

Impacts/Threats

The Environmental Impact Statement processes for the NSW OT and OTL fisheries (DPI 2004, 2006) determined the exploitation status for key commercial species. Silver trevally and snapper were found to be growth-overfished, gemfish recruitment-overfished, and blue-eye trevalla fully fished (Table 4.3). Stocks of six SESSF quota-managed fish caught off central and southern NSW (ling, orange roughy, redfish, tiger flathead, silver trevally and gemfish) are listed as overfished while the status of three others (john dory, mirror dory and ocean perch) is uncertain (Larcombe & McLoughlin 2007); NSW has complementary catch restrictions on the overfished species (DPI 2004, 2006). Target species in the Queensland fisheries are continually monitored with annual status reports. In the latest report for the rocky reef fishery (ASR 1), there are concerns about the exploitation rate for snapper while the status of pearl perch and teraglin is classed as uncertain; the trawl fishery for stout whiting is considered sustainable (ASR 2).

The NSW Environmental Impact Statements (DPI 2004, 2006) also assessed the risk to primary and key secondary and secondary species from harvesting, by determining the fishery impact profile and the biological resilience of each species. Barred rockcod and blackspot pigfish, exploited by the OTLF, were the only species with a high risk rating although a further six demersal fish were considered to be at moderately high risk (Table 4.3). A significant risk to key teleosts, particularly in the trawl fisheries, is the problem of discarding commercial species because of size; this can be the proportion of the catch that is below minimum legal length or those fish that are of a smaller size than the market will readily accept. While minimum mesh sizes are in place for trawl codends, gradual changes in gear construction and the species targeted have made such regulations largely ineffective. However, in an effort to address the problem, bycatch action plans have been formulated for Commonwealth managed fisheries (AFFA 2000) and bycatch reduction devices (BRDs) are now mandatory in Queensland and NSW trawl fisheries. In 2001 the Conservation Technology Unit of NSW DPI was set up to examine fishing practices. Projects investigating the selectivity of the various fishing gears have resulted in innovative gear modifications aimed at ensuring that target species are optimally harvested and discarding is minimised (DPI 2007).

Table 4.3 Summary of minimum legal sizes (MLL) and daily recreational-fishery bag limits for NSW and Queensland, fishery exploitation status for NSW and SESS fisheries, and NSW EIS risk assessments for primary and key secondary demersal fishes caught in the EMR.

	New South Wales				Queensland		SESSF	
Species	**MLL (cm)**	**Bag Limit**	**Exploit. Status**	**Risk Level**	**MLL (cm)**	**Bag Limit**	**Catch Limits**	**Exploit. Status**
Ling							AQ	O
Orange roughy							AQ	O
Redfish			GO	MH			AQ	O
John dory			FF	I			AQ	U
Mirror dory			FF	L			AQ	U
Ocean perch			FF	MH			AQ	U
Flathead-tiger	33		FF	L			AQ	O
Flathead-east. bluespotted	33		FF	L				
Flathead-offshore spp.	33	20		I	30			
Barred rockcod		5 +		H				
Hapuku and Bass groper		5 +		MH				
Pearl perch		5		MH	35	5		
Whiting-east. school				I				
Whiting-stout				I				
Silver trevally		20	GO	MH			AQ	O
Mulloway	45	5 *		M	45	10		
Teraglin	38	5		MH	38	5		
Yellowfin bream	25	20	FF	L				
Snapper	30	10	GO	MH	35	5		
Morwong-grey	28	20	FF	MH				
Morwong-jackass	28	20		M			AQ	
Blackspot pigfish				H				
Gemfish		2 +	RO	ML			AQ	O
Blue-eye trevalla		5 +	FF	M				
Leatherjackets				MH				

FF: fully fished, GO: growth overfished, RO: recruitment overfished; L:low, I: intermediate, MH: moderately high, H: high; AQ: annual quota and TAC; O: overfished, U: uncertain. * limit of 2 fish > 70 cm; +5 in total with max. 2 gemfish

Habitat Loss

Although not assessed by scientific study, the overall impact on habitat by static fishing gear such as traps and lines is thought to be minimal (DPI 2006). Trawling, however, can have major impacts on seabed habitat. While most trawling is conducted on relatively smooth areas of seabed and does not greatly alter the seafloor profile, continual trawling on substrates that support sessile organisms (e.g. sponges and gorgonians) can destroy such assemblages in a relatively short period (Sainsbury et al. 1993); the loss of these organisms can reduce habitat diversity and consequently lower species diversity (see DPI 2004 for discussion). Fish trawls fitted with groundropes rigged with large bobbins (or rollers) are designed to avoid gear damage when trawling across seabed areas of relatively hard substrate that often support rich assemblages of sessile organisms. In NSW, the fishing areas and allowable size of bobbin-rigged groundropes are regulated to protect areas of fragile habitat (DPI 2007).

In recent years, specialised trawling techniques have been developed to target deep-sea species such as orange roughy on seamounts and rough terrain. These habitats can be highly productive in fishery terms, but there are growing concerns about the effects of fishing on the biodiversity and ecosystem productivity of such areas. A stark example was a description by Clark & O'Driscoll (2003) of a photographic survey in New Zealand waters that showed a reduction from almost 100% coral cover on unfished seamounts to 2–3% cover on fished seamounts. In areas adjacent to the EMR, large catches of coral were reported from the Tasman Sea fisheries on the Northwest Challenger Plateau and seamounts in the South Tasman Rise (Anderson & Clark 2003). It is likely that similar habitats exist in the remote areas of the EMR.

Fishing

By definition, Key Demersal Teleosts are species targeted by commercial fishers and also harvested by the recreational sector. As such, they are subject to various State and Commonwealth fishery management strategies aimed to ensure their long-term sustainable harvest. Regulations and restrictions used to control harvest include Total Allowable Catch (TAC) allocated to participants in the fishery as annual quotas, minimum legal lengths for some species and minimum allowable mesh size in trawl codends (see Table 4.3; DPI 2007). More recently, Marine Protected Areas, Marine Parks and Recreational Fishing Havens have been established to protect sensitive habitats and enhance the productivity of various fisheries (see NSW DPI, Qld EPA websites).

Information Gaps

The NSW Ocean Trawl Fishery Management Strategy (DPI 2007) identified priority areas of research relevant to the ecological sustainability of the fishery which included:

- improved resource assessments of primary and key secondary species
- research on the impact of trawling on ocean ecosystems, although it is recognised that the broad scope of such research would require significant resources and a long-term approach

- life history data for commercial species.

Recreational fishers are known to harvest significant quantities of demersal teleosts from ocean waters in the EMR (Henry & Lyle 2003) but there is little up-to-date information on the impact of the recreational sector on the stocks of key species such as snapper, pearl perch, grey morwong and bluespotted flathead.

References and Current Research

Current Research

To address the research priorities identified by the NSW OTF Management Strategy (DPI 2007), an improved and more comprehensive resource assessment methodology for key NSW commercial teleosts is being developed at the Cronulla Fisheries Research Centre of Excellence. In addition, the age, growth and reproduction of several important commercial teleosts caught in east coast fisheries, including the eastern bluespotted flathead, school whiting, ocean jacket and pearl perch, are currently being studied. Also underway is a large recreational fishing survey of the Greater Sydney Basin which is collecting catch data from offshore trailer-boat and charter-boat fishers.

Similarly, the Queensland Department of Primary Industries and Fisheries have specific fishery research projects, as well as the continual monitoring of all Queensland fisheries and publication of annual status reports for each of these (see www.dpi.qld.gov.au).

Good management of fisheries relies on accurate stock identification and up-to-date taxonomy of the exploited species. The international Barcode of Life project aims to DNA barcode all fish species (FISH_BOL, see www.fishbol.org) and many Australian taxa have already been included in this study. Recent studies have shown that the populations of some eastern Australian teleosts, previously thought to have wide geographical distributions, comprises a number of relatively small regional stocks or, in some cases, are part of a species complex. For example, undescribed species of *Centroberyx* (redfish) and *Nemadactylus* (morwong) are now known from offshore seamounts in the southern area of the EMR.

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NSW and Qld Government websites:

NSW DPI. www.fisheries.nsw.gov.au/marine_protected_areas

Qld EPA. www.epa.qld.gov.au/parks_forests/marine_parks

5 Echinodermata

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Description

Echinoderms are an easily recognised group of invertebrates that occur in a broad range of marine habitats and are widely distributed in the East Marine Region (EMR). There are five classes and these can be identified due to their distinctive body profiles. Asteroids (sea stars or starfish) are either star-shaped with arms (5 or more) tapering from a central disc, or have a cushion-like pentagonal shape lacking arms. Holothuroids (sea cucumbers), by contrast are elongate, sausage-shaped animals. Ophiuroids (brittle stars, basket stars) have a round central disc and slender flexible arms that are sharply set-off from the body. The ophiuroid body can have a simple (brittle stars or serpent stars) or branched (basket stars) profile. Echinoids (sea urchins, sand dollars, heart urchins) have a rigid body (or test) covered by spines of varying length. The test ranges in shape from globose as in sea urchins to a flat disc as in sand dollars. Crinoids (feather stars) have an array of feather like arms that range in number from five to several hundred.

The monograph of Australian echinoderms by Clark (1946) and the echinoderm volume of the Zoological Catalogue of Australia (Rowe & Gates 1995, also available via the Australian Faunal Directory (http://www.deh.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html) are important references. They provide background information on the taxonomy of the Echinodermata, and details of the Australian species and their distributions. Additionally, a recent key assists with identification of the tropical Australian crinoids (http://geology008.geology.adelaide.edu.a/) and the monographs of New Zealand echinoderms (McKnight 2000, 2006; Clark & McKnight 2001a, b; McKnight et al. in press) will assist in the identification of many species that occur in temperate areas of the EMR.

Conservation Status

No echinoderms in the EMR are specifically listed under state or Australian Government legislation as being vulnerable or endangered. However, there is considerable effort at present to list several species of fished holothuroids under CITES (Lovatelli et al. 2005). Harvesting is a threatening process for the tropical aspidochirotid holothuroids that are fished for the bêche-de-mer fisheries in the region (see Impacts/Threats). The Queensland fishery for the black teatfish *Holothuria whitmaei* has been closed due to conservation concerns for this species.

In the EMR there is only one known narrow range endemic echinoderm, the viviparous (live-bearing) brooding asteroid, *Cryptasterina hystera* which occurs in a small region of coastal Queensland and at One Tree Island, southern GBR (Dartnall et al. 2003; Byrne 2005). There are, however, a plethora of species in the EMR that are endemic to Australia.

Habitat and Distribution

Echinoderms are a conspicuous and diverse component of the invertebrate fauna of the EMR, occupying virtually all habitat types from coral reefs to rocky reefs and soft sediments. They are often the dominant organisms on the seafloor in both shallow and deepwater habitats. Their ecological distribution is tied to a range of habitat factors such as sediment grain size, the presence of rocky reefs and the distribution of specific prey or associated species.

Most echinoderms from tropical Australia have a broad distribution in the Indo-West Pacific with very few endemics (Clark & Rowe 1971). This fauna has been reviewed and surveyed in a number of taxonomic and biogeographic studies (Endean 1957; Clark & Rowe 1971; Clark 1975; Gibbs et al. 1979; Hammond et al. 1985; Rowe 1985; Birtles & Arnold 1988; Byrne et al. 2004a). The echinoderms of the Great Barrier Reef (GBR), adjacent to the EMR, are particularly well studied due to considerable historic and on-going interest in this fauna (Endean 1957; Clark & Rowe 1971; Gibbs et al. 1979; Rowe 1985; Byrne et al. 2004a; Uthicke et al. 2004b). In total 630 species of echinoderms recorded from the GBR are from the following five classes: sea stars (Asteroidea) 137 species; brittlestars (Ophiuroidea) 166 species; sea urchins (Echinoidea) 110 species; sea cucumbers (Holothuroidea) 127 species; and feather stars (Crinoidea) 90 species.

On the east coast of Australia the broad distribution of echinoderms is generally divided into tropical and temperate species with a mixing area in the mid-region (Rowe & Gates 1995; Poore & O'Hara 2007; O'Hara 2007). This transition, from a tropical to temperate echinoderm fauna, is influenced by the East Australian Current (EAC) and the availability of suitable habitat.

Within the EMR, tropical echinoderms occur from the Cape Province to the Central Eastern Transition and out to the Lord Howe Island region, the world's southern limit of coral reef habitat. A recent survey of the fauna of Lord Howe Island Marine Park provides a list of echinoderm species, many of which also occur in the GBR (Aquenal 2006). The distribution of some tropical species may also extend to the middle of the Central Eastern Province where suitable habitat occurs. This distribution of tropical species also includes the deeper waters of the EMR (O’Hara 2007). The southern part of the EMR is dominated by temperate echinoderm species that probably do not extend much farther north than the Central Eastern Transition, depending on availability of habitat.

A combined meta-analysis of records for the Ophiuroidea from 50 to 1,500 metres depth indicates that the EMR is divided into four regions, a large North Queensland Region from Cape York to Fraser Island and three smaller regions: South Queensland, Northern and Southern New South Wales (NSW) (O’Hara 2007). The last three regions exhibit continual change in the composition of the species occurring there. A similar pattern of continual ophiuroid species turnover also occurs as depth increases (O’Hara 2007).

Surveys of temperate echinoderms, many of which occur in the EMR, have also been undertaken (Clark 1966; O’Hara & Poore 2000). Although considerable collection effort has focussed on shallow water echinoderms many specimens remain to be entered into databases. Sampling sites in the EMR from the Australian (AM) and Queensland Museum (QM) echinoderm collections are indicated in Figure 5.1. A good understanding of the deepwater ophiuroid fauna exists (O’Hara & Stöhr 2006; O’Hara 2007) and the *Fauna of Australia Echinodermata* volume (O’Hara & Byrne, in prep.) will provide information on the other deepwater echinoderms.

Cryptic species (new species recognised from within an otherwise, widely distributed, single species) have recently been identified in the EMR with the assistance of ecological, life history and molecular data (Dartnall et al. 2003; O’Loughlin & Rowe 2005; Byrne & Walker 2007). Some of these are likely to be endemic to Australia.

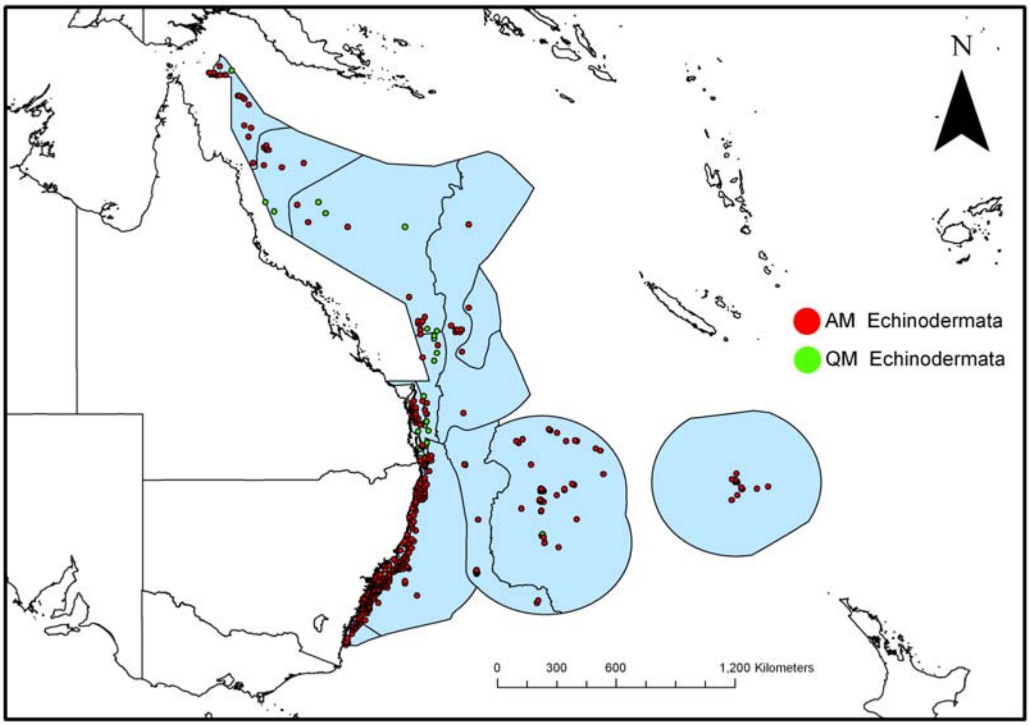

Figure 5.1 Echinoderm records from the East Marine Region based on Australian and Queensland Museum datasets.

Reproduction and life history

Echinoderms exhibit the full range of reproductive strategies found in marine invertebrates, including species with sexual and asexual reproduction, free spawners, brooders and species with long and short-lived larvae (Byrne 2001). Asexual reproduction is common in the echinoderms and is restricted to asteroids, ophiuroids and holothuroids. This involves the animals breaking in half or fragmenting a part of their body. This process is followed by regeneration of each portion to a complete individual.

For the most part, there are no external morphological differences between male and females. Most echinoderms reproduce sexually, with seasonal spawning periods, releasing large numbers of eggs (Byrne 2001). Free spawning echinoderms have dispersive (planktonic) larvae. Echinoderms that lay benthic egg masses do not have a larval stage. Other species brood their young in brood chambers outside or in the body. These species also lack a dispersive stage.

Migration

For the most part echinoderms are not migratory animals. They can, however, move in large groups following sources of food as described for the feeding fronts of sea urchins (Lawrence 2007), or the movement of the crown-of-thorns sea star (*Acanthaster planci*) across coral reef habitat (Moran 1986; Birkeland & Lucas 1990; Brodie et al. 2005). While the adult echinoderms do not cover great distances, their dispersive larvae do. Depending on the species the planktonic larval duration ranges from weeks to months. This is a key aspect of the connectivity between echinoderm populations with genetic structure often influenced by the duration of the larval phase. The spread of the sea urchin *Centrostephanus rodgersii* to Tasmania from NSW appears to be associated with the long planktonic larval duration of this species (Andrew & Byrne 2007).

Significance of Echinoderms in the East Marine Region

Echinoderms are ecologically important in many ecosystems of the EMR. Through their feeding and locomotory activity, and other aspects of their physiology, they play a major role as grazers, predators, bioeroders (organisms which cause erosion of substrates) and bioturbators (organisms which mix sediment by burrowing, feeding, etc.) (Byrne 2001).

The feeding biology of sea stars is varied from specific to general diets. Many sea star species are of commercial and ecological concern, especially those that specialise on molluscs (e.g. *Coscinasterias muricata*) or corals (e.g. *Acanthaster planci*).

The sea cucumbers are diverse and common in the EMR, many are harvested commercially (Table 5.1) (see Impacts/Threats) and *Holothuria scabra* (sandfish) is being used for aquaculture. The commercial species (Table 5.1) belong to the Order Aspidochirotida. These are benthic deposit feeders and are prominent members of the soft-sediment benthos (Uthicke 2001a, b). They contribute to benthic productivity, providing essential ecosystem services, particularly in the nutrient-poor carbonate sediments. Their feeding, respiratory and excretory activities are important in nutrient cycling (Uthicke 2001a, b). Burrowing species play a role in bioturbation and oxygenation of benthic sediments. Removal of these organisms is likely to affect sediment-ecosystem processes and is of particular concern for tropical reef health. This aspect of bêche-de-mer fisheries is rarely considered. The ecological significance of other sea cucumbers in the EMR, such as the suspension feeding Order Dendrochirotida is not known.

The echinoids (e.g. sea urchins, sand dollars) are ubiquitous in the EMR with a few species harvested commercially (Table 5.1) (see Impacts/Threats). The urchin *Tripneustes gratilla* is common in seagrass areas and is currently the focus of aquaculture development. Most sea urchins are grazers removing algae and encrusting organisms from the surface of various substrates. As major benthic herbivores, sea urchins are ecologically keystone species. They are well known for their ability to alter habitat structure through their grazing activity, with the phase shift between algal dominated communities to barrens, areas devoid of macroalgae, depending on urchin density. *Centrostephanus rodgersii* in temperate Australia is an 'ecosystem engineer' forming extensive areas of barrens (Andrew & Byrne 2007). The burrowing activity of echinoids, particularly by *Echinometra* species in the tropics, is important in bioerosion (Bak 1990). Spatangoid heart urchins are a key bioturbator of soft sediment benthic ecosystems (Vopel et al. 2007). Crinoids and most ophiuroids are suspension feeders and can be numerically super-abundant in densities of hundreds per square metre. Some ophiuroids are predators and some are scavengers. The ecological role of these echinoderms is not well studied.

Table 5.1 Taxonomy and common names of commercial echinoderms in the East Marine Region.

Scientific Name	Common Name
Class Holothuroidea **Family Holothuriidae**	
Actinopyga echinites	Deep water redfish
Actinopyga miliaris	Blackfish
Actinopyga sp.*	Surf redfish
Actinopyga sp.**	Burrowing blackfish
Holothuria atra	Lollyfish
Holothuria fuscogilva	White teatfish
Holothuria fuscopunctata	Elephants trunk fish
Holothuria scabra	Sandfish
Holothuria scabra versicolor	Golden sandfish
Holothuria whitmaei	Black teatfish
Thelenota ananas	Prickly redfish
Family Stichopodidae	
Stichopus chloronotus	Greenfish
Stichopus hermanii	Curryfish
Stichopus sp.*	Peanutfish, dragonfish
Class Echinoidea **Family Diadematidae**	
Centrostephanus rodgersii	Black urchin
Family Echinometridae	
Heliocidaris erythrogramma	
Heliocidaris tuberculata	Red urchin

* Taxonomy is being revised (Byrne 2007); ** species has not been determined.

Impacts/Threats

Habitat loss and climate change

Trawling activities by commercial fisheries impact on echinoderms in two ways: through species being caught as bycatch; and through its direct effect on the physical structure of the benthos, resulting in habitat loss (Hutchings 1990). Excessive trawling also causes a considerable increase in suspended matter and this can have a negative impact on benthic communities.

Habitat loss associated with global change, such as that currently occurring through the demise of coral habitat due to bleaching, has a profound effect on associated biota including echinoderms (Hutchings et al. 2007). If this pattern continues it is likely that benthic habitats will be subjected to several stressors (e.g. sea level rise, increased temperature, increased storm frequency and strength) that will result in habitat loss. Storms are a natural hazard for echinoderms. For example, a population of the sea star *Cryptasterina pentagona* near Mission Beach was wiped out in 2005 by the massive sand inundation of its habitat due to the sea conditions created by cyclone Larry (Byrne, unpublished data).

Moreover, impaired skeletogenesis (ability of organisms to lay down calcium carbonate skeletons) caused by ocean acidification, as a result of global warming, is expected to compromise survivorship of both planktonic and benthic life stages of echinoderms. The fragile larval skeletons are particularly vulnerable (Kurihara & Shirayama 2004).

Coastal development is a threat to the persistence of shallow water echinoderms in general. Echinoderms have poor tolerance to low salinity and freshwater run-off into the sea can be lethal (Andrew 1991).

Fishing

Bêche-de-mer fisheries

Approximately 15 species comprise the bêche-de-mer fisheries across northern Australia and 14 of these occur in the northern sector of the EMR (Conand & Byrne 1993; Conand 2001; Skewes et al. 2002; Stutterd & Williams 2003; Roelofs 2004). Most of the species, with the exception of the sandfish (*Holothuria scabra*) are reef species. Bêche-de-mer species are all in the Order Aspidochirotida and are a challenge taxonomically (Uthicke et al. 2004a). Several commercial species of *Stichopus* and *Actinopyga* appear to be complexes and the identity of those currently being fished in northeast Australian waters has not been determined (Byrne 2007).

Holothuroids are fished to make a dried body wall product and the main market is China and Southeast Asia (Conand & Byrne 1993). The bêche-de-mer fishery has provided a source of income for island communities because the processing (boiling, salting and drying) and storage is simple, and does not require costly equipment. Historically, fishers from the island communities to the north of Australia fished bêche-de-mer in Australian waters (Conand and Byrne 1993). Currently there are two commercial fisheries adjacent to, or in the EMR, the Queensland East Coast Bêche-de-mer Fishery (Cape York to Tin Can Bay) and the Moreton Bay Developmental Bêche-de-mer Fishery (Skewes et al. 2002; Roelofs 2004; Young & Ryan 2004). Several of the fisheries for the high value species collapsed in short order (Roelofs 2004; Uthicke et al. 2004b; Uthicke 2005).

The black teatfish (BTF) *Holothuria whitmaei* has been the most sought of the bêche-de-mer species due to its high value (Uthicke et al. 2004b). The Queensland East Coast Fishery for BTF was short lived as the standing stock of these shallow water species was quickly depleted (Uthicke et al. 2004b; Uthicke 2005). The fishery was closed in October 1999 but serious conservation concerns for populations of *H. whitmaei* remain (Uthicke 2005). Populations of this species have been on the decline for some time or have completely disappeared from some localities (Uthicke 2005). After the closure of the BTF fishery, effort switched to the white teatfish (*Holothuria fuscogilva*, misnamed as *H. nobilis* in some reports), which lives in deeper water. Repeating the 'fishing-down' pattern seen in other jurisdictions (Conand & Byrne 1993; Conand 2001; Stutterd & Williams 2003), Australian bêche-de-mer fishers are moving on to less valuable or less accessible (remote areas, deeper waters) stock. Due to the decline in catch the fishery for the high value sandfish (*H. scabra*) in Hervey Bay and Tin Can Bay, the fishery there was closed in 2001. Currently fishers in the Queensland East Coast Bêche-de-mer Fishery are harvesting on a regional-rotation basis in the attempt to avoid over-fishing and allow stock to recover. There are no data available to determine the effectiveness of this fishery management strategy.

Unfished reefs and green zones that support high densities of bêche-de-mer species are key areas for their conservation (Uthicke et al. 2004b). On the GBR, densities on fished reefs are less than 25% of those in no-take-zones (Uthicke & Benzie 2000), however, populations in no-take-zones may also be reduced due to previous fishing cycles. The high density of *H. whitmaei* in highly protected reefs, such as around Raine Island, attests to what might be expected to be a higher population density elsewhere in the region (Byrne et al. 2004b). The Representative Areas Program and Rezoning of the Great Barrier Reef Marine Park in 2004 provide greater protection for bêche-de-mer holothuroids, so recovery of species in previous fished areas, which are now in sanctuary zones, is expected to occur over time.

Holothuroids are particularly susceptible to over-fishing because of their limited mobility, slow growth, late maturity, poor recruitment and density-dependent propagation. Local areas are quickly stripped of valuable species. The general lack of juveniles in sea cucumber populations indicates that recruitment will be slow. The first principle of reproduction, gamete (reproductive cell) contact, is likely to be compromised by the current low densities of spawning individuals on some reefs.

Sea urchin fisheries

There are sea urchin fisheries in the southern area of the EMR for *Heliocidaris* and *Centrostephanus* species (Table 5.1). Sea urchins are fished for their roe for the domestic and Japanese markets. Sea urchin fisheries are unsustainable for the same reasons as the bêche-de-mer fisheries i.e. limited mobility, slow growth, late maturity, poor recruitment and density-dependent propagation. Virtually all the world’s sea urchin fisheries have seen an initial boom followed by bust (Andrew et al. 2002).

Sea urchins have a fundamental ecological role in marine benthic communities as herbivorous grazers (Andrew & Byrne 2007). Removal of sea urchins through fishing activity can have a major effect on benthic ecosystems resulting in a shift to algal dominated communities and a major change in biodiversity (Lawrence 2007). This may further impact on sea urchin population dynamics and recruitment.

Information gaps

Knowledge of the echinoderms in the EMR is patchy and biased towards the larger animals, especially those living in shallow habitats and those associated with commercial harvesting (Ponder et al. 2002). In particular there are gaps in echinoderm taxonomy and several species are now proving to be complexes that differ in important features of their ecology and life history. Echinoderms are an important component of benthic ecosystems of the shelf and deep water, but our knowledge of these communities is poor, although considerable progress has been made for the deepwater ophiuroid fauna (O’Hara and Stöhr 2006; O’Hara 2007).

There is also an urgent need to understand the species diversity that comprises the EMR bêche-de-mer fisheries. Considering the key ecological role that echinoids and holothuroids play in their respective ecosystems, our poor understanding of the ecological impacts of the fisheries for these echinoderms is also a key information gap.

The database with which to follow the anticipated changes that climate change will bring to echinoderm diversity and echinoderm communities in the EMR is also lacking. A decline in invertebrate community diversity in response to ocean warming has been documented in other jurisdictions (Hutchings et al. 2007), but benchmark data for the EMR with which to monitor change has not been compiled. There are a considerable number of undocumented echinoderm specimens in existing collections in Australian museums, the information from these specimens, if placed in an accessible database, would help fill this gap in knowledge. Targeted surveys could be undertaken for a key suite of echinoderm species that are likely to be 'frontier species', colonising new areas as the changes associated with global change provide them the opportunity to move to new areas. It is anticipated that shallow water echinoderm faunas will be most affected with potential for several tropical species with pelagic larvae extending their range to more southern latitudes or deeper water.

Ecologically some of the most important knowledge gaps are in understanding the larval life and early benthic stage of most species. Knowledge of the recruitment dynamics of echinoderms and the locations of sources and sinks of propagules is poor. This is important to benthic communities in general, and is a key knowledge area needed to inform the appropriate design of marine parks.

Key References and Current research

Current Research

Taxonomic study of echinoderms in the EMR is largely focussed on commercially important species such as the bêche-de-mer. Some of this work involves significant species revision and clarification of the fishery (Uthicke et al. 2004; Byrne 2007). Other research on cryptic species is uncovering a suite of new species from the region (e.g. Dartnall et al. 2003; O'Loughlin & Rowe 2005; Byrne & Walker 2007). The crown-of-thorns sea star, *Acanthaster planci*, continues to be the subject of targeted research (Brodie et al. 2005).

The Echinodermata is a sufficiently diverse and abundant taxon comprised of a comparatively small number of species, and so is tractable for taxonomy and bioregionalisation assessments. The recent bioregionalisation of Australian Commonwealth waters based on an integrated data set for the deep-sea Ophiuroidea is an important contribution; the data included will be useful in providing maps of the deep-sea fauna (O'Hara 2007).

The Great Barrier Reef Seabed Biodiversity Project is likely to significantly expand knowledge of tropical deepwater echinoderms, particularly those that inhabit areas between reefs, in an area adjacent to the northern provinces of the EMR (www.reef.crc.org.au/resprogram/programC/seabed/index.htm).

The results of the recent NORFANZ cruise will provide information for deepwater temperate echinoderms, once the identification of the specimens is complete and the data entered into an accessible database, and this will be particularly relevant to the southern provinces of the EMR (http://www.environment.gov.au/coasts/discovery/voyages/norfanz/index.html).

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6 Marine Snakes

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Description

Some 25 species of marine snakes are known, or suspected, to occur in the East Marine Region (EMR) (Table 6.1). They include members of the following four major groups of snakes:

Colubrid snakes (Family Colubridae, subfamily Homalopsinae): 1 of 4 Australian species (Figure 6.1).

These are all inshore snakes that occur mostly in the often turbid waters of protected bays and estuaries where they feed primarily on fish and crustaceans on tidal mudflats and in the intertidal zone of mangrove forests. They possess the broad ventral (belly) scales characteristic of terrestrial snakes, and their most obvious (external) marine adaptations are upwardly-directed nostrils and eyes (to allow the snakes to breathe and to see potential predators with only the tip of the snout and the eyes above water) and valvular nostrils (to prevent water entering the air passages when the snake is submerged or feeding). Members of this group possess a pair of venom (Duvernoy's) glands which can exude venom around the enlarged, grooved rear maxillary teeth when the snake bites, the venom running down the fangs largely by capillary action into the prey.

File Snakes (Family Acrochordidae): 1 of 2 Australian species (Figure 6.2).

These snakes are entirely aquatic. They have tiny eyes and loose flabby bodies in which the skin is covered by very small keeled scales. These scales give the snakes a rough, file-or rasp-like feel and permit them to firmly grasp fish (on which they feed) between body loops prior to ingestion. They are non-venomous and harmless, with only one of the three known species entering the marine environment.

Viviparous Sea Snakes (Family Elapidae, subfamily Hydrophiinae): 16 of 29 Australian marine species (Figure 6.3).

These snakes are closely allied to Australia's proteroglyphous (fixed front-fanged) land snakes, and contain some of the most highly venomous snakes in the world. A venom gland under the skin of each cheek sends venom along a duct to the base of a hypodermic-like enlarged fang located at the front of the upper jaw. This venom can be injected into prey or predator when the snake bites. The majority of species, with the exception of a few smaller species that frequent mud and mangrove flats, never emerge voluntarily from the water. They are, however, often washed ashore, in an exhausted condition, after heavy storms and seas. The primary adaptations to a fully-aquatic life cycle are a viviparous (live-bearing) reproductive mode; a long and highly vascularised right lung (extended in length by a well-developed tracheal lung—all snakes typically have only a single functional lung) to permit submersion for extended periods; a moderate to extreme reduction in the size of the ventral (belly) scales facilitating aquatic serpentine locomotion; a large flattened, paddle-shaped tail to propel the snake through the water; and valvular nostrils that close off the air passages when the snake is under water, including when ingesting prey. The great majority of species feed on fishes, with individual species specialising in particular groups of fishes (e.g. eels, scorpaenids, gobeids and their eggs).

It should be noted that three additional species—*Hydrophis laboutei*, *H. gracilis* and *H. spiralis*—have been recorded from the Chesterfield Reefs and adjacent New Caledonian waters (Minton & Dunson 1985; Ineich & Rasmussen 1997; Rasmussen & Ineich 2000) and are therefore likely to occur on reef complexes within the EMR (e.g. Kenn Reef). A fourth species—*Hydrophis coggeri*—is abundant in the waters of Fiji and New Caledonia, but appears to be disjunct from the only known Australian populations occurring on reefs of the North-west Shelf. However its abundance and proximity to the eastern provinces of the EMR suggest that it may well occur there.

Oviparous Sea Kraits (Family Elapidae, subfamily Laticaudinae): 2 or 3 of 8 Asian-Pacific species (Figure 6.4).

This is a small group (eight species) of semi-aquatic marine snakes in which the majority (six species) occur in the South-west Pacific region. These are mostly reef-dwelling snakes. Members of the group are sometimes carried well away from their normal ranges by storms and currents. All Australian records appear to be of waifs, and despite substantial breeding populations of at least one species in the coastal waters of southern New Guinea, no resident populations have been located within Australian waters. Sea Kraits spend a substantial part of their lives on land, usually within about 100 m of the sea, and produce clutches of parchment-shelled eggs that are laid deep in rock-crevices or above the waterline in caves and overhangs, including caves with only underwater openings. Primary adaptations to a semi-marine existence in this group are enlarged ventral (belly) scales that facilitate terrestrial locomotion, nostrils with fleshy valves to exclude water from the air passages while underwater, and a large flattened, paddle-like tail to propel the snake when swimming.

While only two species have been recorded in the literature from Australia, the scalation of two of three specimens recorded from Australia in Smith (1926) suggests that these may represent a third species—*Laticauda saintgironsi*—otherwise restricted to the waters of New Caledonia (Cogger & Heatwole 2006). A fourth species—*Laticauda guinea*—is also likely to occur in the far northern waters of the Cape Province bioregion. Surveys of the marine snakes of the Coral Sea (Zimmerman et al. 1994) and of New Caledonia (Ineich & Laboute 2002) are very relevant to studies of the marine snakes of the eastern limits of the EMR.

For general information on the biology and ecology of marine snakes see Dunson (1975a) and Heatwole (1999) and for Australian taxa see Cogger (2000a: keys to all taxa), Shine & Houston, (1993: file snakes), Ehmann (1993: colubrid snakes), Heatwole & Guinea (1993: oviparous sea kraits) and Heatwole & Cogger (1993, 1994: viviparous sea snakes). For regional treatments within the EMR see Dunson (1975b), Limpus (1975), Cogger (2000b). The phylogeny of Australian viviparous sea snakes has been recently assessed by Lukoschek & Keogh (2006).

Conservation Status

All of the species listed in Table 6.1 are protected nationally under the general provisions of the Commonwealth's EPBC Act 1999. Most species are also protected under the relevant State wildlife protection Acts, but as many of the species occur beyond the three nautical mile marine limit of State responsibility, the Commonwealth has direct responsibility for these species where they occur within the remaining parts of the 200 nautical mile Exclusive Economic Zone.

Habitat and Distribution

Little information on the relative abundance of marine snakes is available for the EMR. This is in strong contrast to the situation in the Northern Planning Area (Guinea et al. 2004) in which extensive commercial trawling over large areas of shallow seas allows comparisons to be made of catch frequencies for individual species. In Table 6.2 the known geographic range within the EMR of each of the species recorded from the Region is estimated using broad probability criteria. These criteria are subjective estimates based on known latitudinal limits of a taxon from existing records, proximity of a provincial bioregion to existing records and known ecological characteristics (such as preferred depth range and prey). Complicating the estimation of the ranges of most species of marine snakes is the paucity of reliable observations throughout much of their potential range. This is usually a direct result of their ecology, with sparse and random observations derived from recreational divers, beach-stranded individual snakes, or commercial trawl bycatch. Consequently vast areas of potential sea snake habitat remain unsampled. For example, virtually all marine snake records from New South Wales (NSW) are from strandings (Cogger 2000b). Conversely, much of our knowledge of sea snake distribution and ecology in the northern provincial bioregions of the EMR is based on observations and studies undertaken within the Great Barrier Reef Marine Park. Even within the latter there are few sites that have been sufficiently sampled for marine snakes that paucity of observations can be assumed to represent a real paucity of snakes rather than inadequate search effort.

It has long been assumed that reproducing populations of any species of marine snake are those characterised by the year-round presence of the species in readily observable numbers. However, within the EMR Limpus (1975; pers. comm.) has suggested that reproduction in most species of viviparous sea snakes does not extend south of the Bundaberg-Hervey Bay region (ca. 25 °S), although a number of species regularly venture further south.

Life history and reproductive ecology

With the exception of the oviparous Sea Kraits, all other marine snakes in Australian waters are viviparous, with all phases of the reproductive cycle (mating and fertilisation, gestation, birth) and subsequent growth and sexual maturation taking place in the sea. There appear to be few, if any, modifications of the reproductive system found in terrestrial viviparous snakes, except that copulation in many species appears to be preceded by complex courtship rituals in which males perform in front of the female, followed by tandem swimming and head and body contact. Once copulation occurs, the snakes typically float freely, with body contact confined to the cloacal region.

Local or regional seasonal aggregations have been reported in a number of species, but in most cases there is little evidence that such aggregations have an explicit reproductive purpose rather than some other ecological factor (e.g. prey abundance). However Limpus (2001) recorded what he presumed to be a resident breeding aggregation of the Yellow-bellied Sea Snake (*Pelamis platurus*) in the Gulf of Carpentaria in July 1992, where he observed 84 individuals, covering all size classes, along a 99.4 km transect.

Fry et al. (2001) found that in all 13 species that they recorded from trawl bycatch in the Gulf of Carpentaria, reproduction was annual. They further suggested that the finding by Burns (1985) that reproduction in the Olive Sea Snake (*Aipysurus laevis*) at the southern end of the Great Barrier Reef was probably on a 2-year cycle might be due to lower mean water temperatures.

Most viviparous sea snakes live within a fairly narrow stratum of the water column (ca. 0–100 m), with the majority restricting their normal daily activity to the 0–50 m zone. This often results in populations with very high site-fidelity, in which exchange of individuals between reefs separated by deeper bodies of water may be very low. Species occurring at deeper levels (i.e. 50–100 m) are usually those that feed on garden eels (a specialised group within the family Congridae) found on sandy substrates at these depths.

With the exception of the Yellow-bellied Sea Snake, whose eastern Pacific populations have been studied extensively (Kropach 1975), the most studied Australian species is probably the Olive Sea Snake, *Aipysurus laevis* (Burns & Heatwole 1998, 2000; Lukoschek et al. 2007; Burns 1985).

Migration

There are currently no confirmed occurrences of migration events on a large geographic scale for any marine snakes. Whether the breeding aggregations cited above represent migratory or merely local events is unknown. Older reports in the literature (Heatwole 1999) of great masses of intertwined sea snakes extending over many kilometres on the surface of the open ocean have long suggested the occurrence of mass migrations of sea snakes converging on particular oceanic sites to breed, but despite the great increase in shipping over the past century such aggregations (though they may occasionally occur for reproductive or other purposes) have so rarely been reported that they are unlikely to represent regular or typical breeding behaviours. Shuntov (1971) reported seasonal shifts in marine snake populations between offshore and inshore waters in the Gulf of Carpentaria that he attributed to seasonal migratory movements to find improved conditions for food or reproduction. However changes in the frequency of observations on particular reefs suggest that there are significant short- and long-term occupations of reefs within a particular reefal complex (Heatwole 1999, Burns 1985). Further, many species spend extended periods resting and/or basking on the surface in deeper inter-reefal waters. Such species are especially vulnerable to being carried into deeper oceanic waters and beyond their normal ranges by strong currents. The regular sighting of sea snakes in south-east Australian waters in mid- to late-summer is most likely to reflect waif individuals being caught up in the seasonally-active East Australian Current (Cogger 2000b). Whether such summer waifs are able to return to their source populations is unknown, but there currently is no evidence that they make the reverse journey.

Significance of Marine Snakes in the East Marine Region

As top order predators, adult marine snakes are the quarry only of large fishes, such as groupers and sharks, and raptors near land. Snake populations appear to be relatively small in comparison to prey abundance suggesting that they do not have a major or critical limiting role in the ecosystems in which they occur. However, the role of sea snakes in marine ecosystems is poorly understood and the importance of their contribution to the integrity of EMR ecosystems is essentially unknown. This makes conservation strategies difficult to plan. Currently, the most effective approach to marine snake conservation is to optimise the protection of known habitats on a regional basis and to minimise anthropogenic mortality through legislation to protect the various species from commercial exploitation. While sea snakes remain a significant part of the bycatch of commercial fisheries, however, the effectiveness of current protective legislation is constrained.

Impacts/Threats

The paucity of data on marine snake numbers and species richness in the EMR, including meaningful information on bycatch numbers, prevents any reliable assessment of species at risk. The greatest long-term threat to marine snakes is probably the degradation of reefal systems through siltation, eutrophication (excessive input of nutrients) or pollution from agricultural run-off and from the impacts of projected climatic shifts.

The most immediate threat to marine snakes in the EMR, however, is likely to be the high mortality of those snakes taken as bycatch in commercial trawl fisheries (e.g. Ward 2000, Fry et al. 2001). Another significant threat, but one with longer-term implications, is the damage wrought by trawling on the benthic ecology (i.e. snake feeding grounds) of the areas trawled.

Clearly, the overall impacts of trawling on marine snake populations will depend on the geographic extent of trawled snake habitat. There are few data available to determine this, but with the majority of snake bycatch resulting from trawling that occurs in reefal, inshore water, and with the exclusion of the Great Barrier Reef Marine Park from the EMR, impacts of trawling within this region will be largely confined to a narrow inshore coastal zone from Cape York to the NSW-Qld border. Consequently management practices in areas outside the EMR are relevant in this context—especially those within the Great Barrier Reef.

Habitat Loss

While the role of marine snakes in reefal ecosystem services is virtually unknown and their responses to perturbations in those systems difficult to predict, as top order predators they are integral components of tropical shallow-water reefal ecosystems, and it is reasonable to assume that loss or degradation of any part of these systems will result in the decline or loss of the snakes within them. As it is known that some marine snakes are quite sensitive to subtle changes in reef ecosystems, absence of evidence of macrodegradation should not be taken to imply that snake populations are secure. Five species of *Aipysurus* (including three endemics) are recorded from the Northwest Shelf's Ashmore Reef, which together with a further 12 species in other genera, were in great abundance in 1972 (Dunson 1975a) but have declined dramatically in recent years, with few species and few individuals observed in recent surveys (M. Guinea 2007, pers.comm.). Whereas some 500+ individuals were collected or observed by a team of biologists in 1972 in one week of surveying, Guinea (2007) records continuing declines in the period 1992-2007, culminating in the observation of only seven snakes in 10 survey days in March 2007, only two of which could be accurately identified (both being the Olive Sea Snake, *Aipysurus laevis*). The causes of these declines in what would otherwise be considered pristine oceanic reefal habitats are unknown, but ecosystem degradation is clearly implicated.

Information Gaps

Current knowledge of the outer limits of the distribution of most sea snakes is largely based on strandings, virtually all of which are recorded from eastern Australian coastal beaches. Except for the only pelagic species (*Pelamis platurus*), records of marine snakes from open ocean waters are virtually absent in verifiable databases. Other principal sources of information on the distribution and ecology of marine snakes in the EMR are the trawl bycatch and underwater observation by researchers or recreational divers. The latter report many snake sightings, but except for one or two abundant and well-known species such as the Olive Sea Snake (*Aipysurus laevis*), accurate identification is rarely made. Recreational divers should be encouraged to submit photographs of observed snakes to museum specialists for identification. Generalised descriptions usually have little diagnostic value.

Key References and Current Research

Current Research

Current research on marine snakes is primarily targeted on three principal areas, as reflected in recent publications cited in references.

- taxonomic resolution at the species and generic levels and phylogenetic reconstruction
- the service and other roles of marine snakes in marine ecosystems
- the extent and conservation implications of marine snake bycatch in commercial trawl fisheries
- autecological studies of particular species or of populations of species.

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Figure 6.1 ***Fordonia leucobalia*****, the White-bellied Mangrove Snake, is the only marine colubrid snake found in the East marine Region and is restricted to its far northern coastal zone.**

Figure 6.2 ***Achrochordus granulatus*****, the Little File Snake, is the only marine member of its group and occurs widely in coastal waters of the northern section of the East Marine Region.**

Figure 6.3 *Pelamis platurus*, the Yellow-bellied Sea Snake, is a viviparous sea snake and the only species found throughout the East Marine Region.

Figure 6.4 *Laticauda colubrina*, the Yellow-lipped Sea Krait, is an oviparous sea snake recorded only rarely as a waif within the East Marine Region.

Table 6.1 Primary ecological attributes of marine snakes recorded from the East Marine Region either as permanent residents or occasional/potential waifs.

Group/Species	Primary ecological/habitat attributes						
	Inshore waters	Estuaries & tidal rivers	Coral reefal waters & islands	Deeper inter-reefal waters	Continental shelf waters	Offshore waters	Oceanic waters
File Snakes							
Acrochordus granulatus	x	x					
Colubrid Snakes							
Fordonia leucobalia	x	x					
Viviparous Sea Snakes							
Acalyptophis peronii			x	x	x		
Aipysurus duboisii	x		x				
Aipysurus eydouxii	x		x				
Aipysurus laevis			x	x	x		
Astrotia stokesii	x		x	x	x		
Emydocephalus annulatus	x		x				
Enhydrina schistosa	x	x		x	x		
Hydrophis elegans	x	x	x	x	x		
Hydrophis gracilis	x			x	x		
Hydrophis kingii				x	x		
Hydrophis laboutei			x				
Hydrophis macdowelli	x	x	x	x	x		
Hydrophis major	x		x	x	x		
Hydrophis pacificus		x		x	x		
Hydrophis ornatus				x	x		
Hydrophis spiralis							
Hydrophis vorisi							
Lapemis curtus	x						
Pelamis platurus	x			x	x	x	x
Oviparous Sea Kraits							
Laticauda colubrina	x		x				
Laticauda guineai	x		x				
Laticauda laticaudata	x		x				
Laticauda saintgironsi	x		x				

Table 6.1 (cont.).

Group/Species	Primary ecological/habitat attributes							
	Pelagic	Inter-tidal mud flats	Mangroves	Approx. Depth range (m)	Fish predator	Specialist fish eggs predator	Specialist eel predator	Invert. predator
File Snakes								
Acrochordus granulatus		x		0–10	x			
Colubrid Snakes								
Fordonia leucobalia		x	x	0–10	x			x
Viviparous Sea Snakes								
Acalyptophis peronii				0–20	x			
Aipysurus duboisii				0–15	x			
Aipysurus eydouxii				0–20				
Aipysurus laevis				0–20	x			
Astrotia stokesii				0–30	x			
Emydocephalus annulatus				0–20				
Enhydrina schistosa				0–30	x			
Hydrophis elegans				0–30	x			
Hydrophis gracilis				0–30	x	x		
Hydrophis kingii				0–30				
Hydrophis laboutei					x			
Hydrophis macdowelli				0–30	x	x		
Hydrophis major				0–30	x			
Hydrophis pacificus				?	x		?	
Hydrophis ornatus				0–30	x			
Hydrophis spiralis					?			
Hydrophis vorisi					?			
Lapemis curtus				0–30	x			
Pelamis platurus	x			0–10	x			
Oviparous Sea Kraits								
Laticauda colubrina				0–10			x	
Laticauda guineai				0–10			x	
Laticauda laticaudata				0–15	x		x	
Laticauda saintgironsi				0–10			x	

Table 6.2 Known geographic ranges and probability of occurrence of marine snakes recorded from the East Marine Region.

Group/Species	Primary ecological/habitat attributes						
	Cape Province	Northeast Transition	Northeast Province	Central Eastern Transition	Kenn Transition	Kenn Province	Central Eastern Shelf Transition
File Snakes							
Acrochordus granulatus	5	4	1	0	0	0	0
Colubrid Snakes							
Fordonia leucobalia	5	1	0	0	0	0	0
Viviparous Sea Snakes							
Acalyptophis peronii	5	5		5	5	5	5
Aipysurus duboisii	5	5	5	?	?	?	5
Aipysurus eydouxii	5	5	5	5	5	3?	5?
Aipysurus laevis	5	5	5	5	5	5	5
Astrotia stokesii	5	5	5	5	5	5	5
Emydocephalus annulatus	5	5	5	5	5	5	5
Enhydrina schistosa	5	5	5	5	3	1	3
Hydrophis elegans	5	5	5	5	5	5	5
Hydrophis gracilis	0	2	3	0	3	3	0
Hydrophis kingii	5	5	5	5	5	5?	5
Hydrophis laboutei	0	2	3	0	3	3	0
Hydrophis macdowelli	5	5	5	5	5	5	3
Hydrophis major	5	5	5	5	5	5	5
Hydrophis pacificus	5	3	3	2	2	2	2
Hydrophis ornatus	5	5	3	5	5?	5?	5
Hydrophis spiralis	0	2	3	0	3	3	0
Hydrophis vorisi	4	2	2	1	1	1	1
Lapemis curtus	5	5	5	3	3	3	5
Pelamis platurus	4	4	4	5	4	4	5
Oviparous Sea Kraits							
Laticauda colubrina	1	1	1	1	1	1	1
Laticauda guineai	3	1	1	1	1	1	1
Laticauda laticaudata	1	1	1	1	2	2	1
Laticauda saintgironsi	1	1	1	1	2	2	1

0 outside known range of species; ecology minimises potential for waifs

1 absent or any existing records of waifs only (suitable habitats absent)

2 low (no records; distant from known permanent populations or suitable habitats rare or absent)

3 medium (no records; modest distance from known permanent populations; limited suitable habitats available)

4 high (observational records reported; adjacent to known permanent populations; extensive suitable habitat available)

5 present (at least one vouchered record; suitable habitat abundant)

Table 6.2 (cont.).

Group/Species	Primary ecological/habitat attributes					
	Central Eastern Shelf Province	**Central Eastern Province**	**Tasman Basin Province**	**Lord Howe Province**	**Norfolk Island Province**	**Southeast Transition**
File Snakes						
Acrochordus granulatus	0	0	0	0	0	0
Colubrid Snakes						
Fordonia leucobalia	0	0	0	0	0	0
Viviparous Sea Snakes						
Acalyptophis peronii	3	3	3	3	3	1
Aipysurus duboisii	5	?	?	3	3	0
Aipysurus eydouxii	2					
Aipysurus laevis	5	1	1	1	1	1
Astrotia stokesii	5					
Emydocephalus annulatus	4	3	1	3	2	0
Enhydrina schistosa	3	1	0	0	0	0
Hydrophis elegans	5	3	1	2	2	0
Hydrophis gracilis	0	0	0	0	0	0
Hydrophis kingii	5	1	1	2	2	1
Hydrophis laboutei	0	0	0	0	0	0
Hydrophis macdowelli	4	1	0	1	1	0
Hydrophis major	5	3	1	3	3	1
Hydrophis pacificus	1		0	0	0	0
Hydrophis ornatus	5	3	0	2	2	0
Hydrophis spiralis	0	0	0	0	0	0
Hydrophis vorisi	1	1	0	0	0	0
Lapemis curtus	5	5	0	2	2	0
Pelamis platurus	5	5	5	5	5	5
Oviparous Sea Kraits						
Laticauda colubrina	1	1	1	1	1	1
Laticauda guineai	1	1	1	1	1	1
Laticauda laticaudata	1	1	1	1	1	1
Laticauda saintgironsi	1	1	1	1	1	1

0 outside known range of species; ecology minimises potential for waifs

1 absent or any existing records of waifs only (suitable habitats absent)

2 low (no records; distant from known permanent populations or suitable habitats rare or absent)

3 medium (no records; modest distance from known permanent populations; limited suitable habitats available)

4 high (observational records reported; adjacent to known permanent populations; extensive suitable habitat available)

5 present (at least one vouchered record; suitable habitat abundant)

7 Marine Turtles

Author: Colin J. Limpus



Description

Marine turtles are reptiles of the Order Testudines, Sub Order Cryptodira. They have undergone a considerable world-wide reduction in their biodiversity since their peak in the Cretaceous. Of the five marine turtle Families of the Cretaceous, only two are represented among the present day turtle fauna (Pritchard & Trebbau 1984). Both these extant Families of marine turtles occur in Australia and within the Eastern Marine Region (EMR):

Cheloniidae (hard-shelled turtle) with five species from five genera:

Loggerhead turtle (*Caretta caretta*)

Green turtle (*Chelonia mydas*)

Hawksbill turtle (*Eretmochelys imbricata*)

Olive ridley turtle (*Lepidochelys olivacea*)

Flatback turtle (*Natator depressus*)

One genus (*Natator*) is endemic to the Australian-New Guinea continental shelf. The remainder have a global distribution in tropical and temperate waters ranging from lower estuarine and inshore continental shelf to oceanic pelagic habitats. The family is characterised by non-retractable, large, paddle-like flippers, each with one or two claws and keratinised epidermal scutes (horny, scale like structures) on the head, flippers, carapace and plastron (the underside of a turtle's shell). The ribs are fused to the overlying pleural bones which are also fused to each other to form the shield-like bony carapace of adults. The head can be partially withdrawn beneath the carapace and there are no cusps (pointed parts) on the upper jaw sheaths (Limpus & Miller 1993).

Descriptions of the biology of these widely distributed species are available:

C. caretta: Dodd (1998) and Bolten & Witherington (2003).

C. mydas: Hirth (1997), Parsons (1962), Limpus et al. (1994a, 2001, 2003 & 2005), Limpus & Chaloupka (1997) and Chaloupka (2002) provide a representative description of the biology of green turtles for eastern Australia.

E. imbricata: Witzell (1983), Dobbs et al. (1999), Chaloupka & Limpus (1997), Limpus & Miller (2000) and Miller et al. (1998) provide a representative description of the biology of hawksbill turtles in eastern Australia.

L. olivacea: Reichart (1993), Plotkin (2007).

N. depressus: Limpus (2004), Limpus (1971), Limpus et al. (1983a, 1984a) and Parmenter & Limpus (1995) provide a representative description of the biology of flatback turtles in eastern Australia.

Dermochelyidae (leatherback turtle) with a single species: *Dermochelys coriacea.*

The family has a global distribution from tropical seas to sub-Arctic and sub-Antarctic waters ranging from oceanic to coastal waters but avoiding reefs. The leatherback turtle is characterised by large paddle-like flippers lacking claws, the absence of keratinised epidermal scutes except in hatchlings, separate ribs, a mosaic of small, polygonal dermal bones covering the body, a strongly ridged carapace, and pronounced cusps on the upper jaw (Limpus 1993a). The global biology of leatherback turtles has been partly reviewed in the 1996 issue of Chelonian Conservation and Biology 2(2) and by Hamann et al. (2003).

See Wyneken (2001) for a review of the anatomy and morphology of marine turtles.

Conservation Status

Marine turtles attract special attention under Australian legislation because they are listed under international treaties to which Australia is a signatory country:

Convention for International Trade in Endangered Species (CITES): Appendix l species.

Convention for Conservation of Migratory Species of Wild Animals (CMS): Appendix l species.

All six marine turtle species in Australia are listed as threatened under the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999*:

Endangered: *Caretta caretta, Lepidochelys olivacea*

Vulnerable: *Chelonia mydas, Dermochelys coriacea, Eretmochelys imbricata, Natator depressus*

In Queensland, all six species are scheduled as threatened species under *Nature Conservation Act 1992* Regulations:

Endangered: *Caretta caretta, Dermochelys coriacea, Lepidochelys olivacea*

Vulnerable: *Chelonia mydas, Eretmochelys imbricata, Natator depressus*

In New South Wales (NSW), only three marine turtle species are listed as threatened under the *Threatened Species Legislation Amendment Act 2004*:

Endangered: *Caretta caretta*

Vulnerable: *Chelonia mydas, Dermochelys coriacea*

Habitat and Distribution

All marine turtles migrate from their dispersed foraging areas to aggregate for breeding at traditional nesting beaches (Plotkin 2003). The breeding female does not feed, or feeds at a reduced level, while offshore from the nesting beach in the inter-nesting habitat where she prepares her eggs for laying (Limpus et al. 2001; Tucker & Read 2001). Fertilisation is internal and spherical soft-shelled eggs are buried in nests on beaches above the tidal range. There is no parental care. Eggs incubate in sun-warmed sand with incubation period, incubation success and hatchling sex ratio being a function of nest temperature (Miller 1997; Miller & Limpus 2003; Wibbels 2003). Hatchlings are imprinted to the earth's magnetic field as they leave the nest and they navigate across the beach using light horizons (Lohmann et al. 1997). They disperse rapidly from inshore waters without using the waters adjacent to the nesting beach for resting or foraging. When well offshore, the hatchlings cease their swimming frenzy and are then carried by ocean currents into oceanic pelagic habitats, except for flatback turtles which remain in pelagic habitats over the continental shelf (Bolten 2003). While in the pelagic habitats, all species are carnivorous, feeding on a wide range of macro- zooplankton.

The hard-shelled turtles remain in the ocean pelagic environment for a few years (hawksbill and green turtles) or up to about 16 years (loggerhead turtles) before they return to coastal waters where they change to a benthic-feeding life history phase with diet varying with the species (Bjorndal 1997; Lanyon et al. 1989; Limpus & Limpus 2000; Limpus et al. 2001, 2005).

All marine turtles are slow growing with delayed maturity (Chaloupka 1998; Chaloupka & Musick 1997; Chaloupka & Limpus 1997; Limpus & Chaloupka 1997). Green and hawksbill turtles may take about 35 years from hatchling to first breeding. Loggerhead turtles take about 30 years. Leatherback turtles are the fastest growing, reaching maturity at less than 20 years. Analyses of population genetics indicate that widely spaced clusters of breeding aggregations are genetically discrete and that the adult returns to breed at the region of its birth (Bowen & Karl 1997). All species lay multiple clutches of eggs in a breeding season and typically skip years between breeding seasons (Miller 1997, Hamann et al. 2003). Animals with these life history characteristics require annual survivorship to be high throughout all their life history phases in order to maintain stable populations (Chaloupka 2002). As a result, marine turtles are highly vulnerable to even small, long-term increases in mortality.

Within the context of this generalised life history (Figure 7.1), the following specific comments can be made regarding marine turtle habitat and distribution within the EMR:

Caretta caretta (loggerhead turtle): Large immature (curved carapace length > ~70 cm) and adult turtles forage on benthic invertebrates (mostly crabs and shellfish) within a wide range of inner continental shelf and reefal habitats, including coral reefs, rocky reefs, soft bottom benthic habitat, bays and estuaries. These benthic foraging individuals can be found year round along the Continental shelf from the Gulf of Carpentaria in the north through Torres Strait and south to southern NSW. Outside the continental shelf, they forage on the shallow reefal areas such as the Coral Sea platform. The largest concentrations of benthic foraging loggerhead turtles in eastern Australia appear to occur in the Hervey Bay to Moreton Bay area (Limpus et al. 1994b).

Based on tag recoveries, the majority of loggerheads that forage in the EMR from Hervey Bay to NSW can be expected to migrate to breed on nesting beaches in the southern Great Barrier Reef (GBR) and the adjacent mainland near Bundaberg (Figure 7.1). Small numbers of females migrate outside this area to breed in northern NSW and New Caledonia.

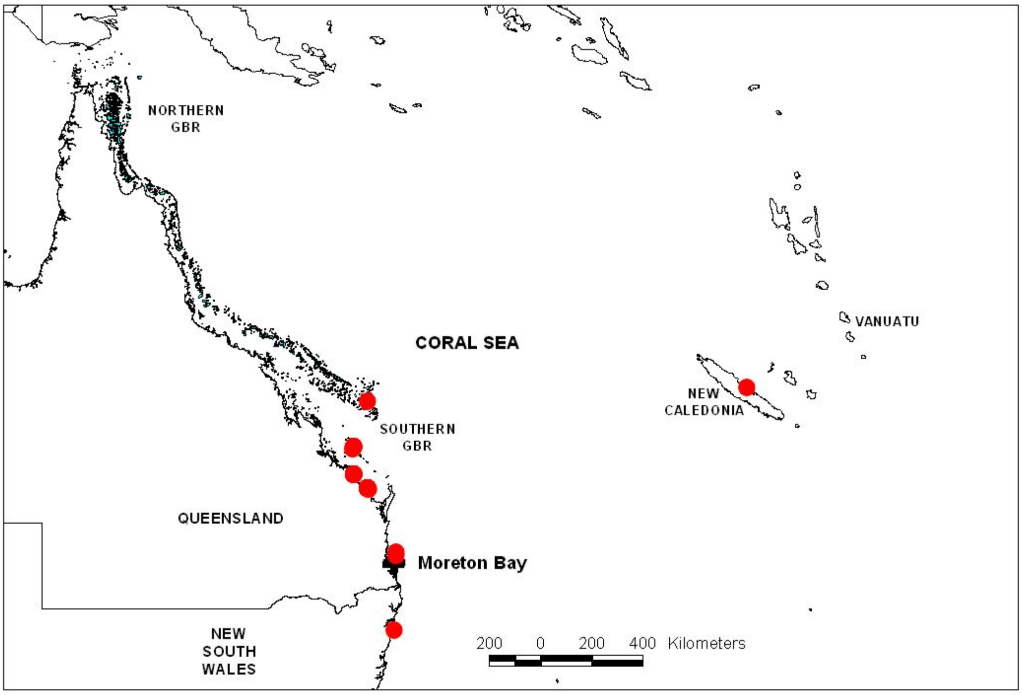


Figure 7.1. Breeding distribution of recaptured tagged adult female loggerhead turtles, *Caretta caretta*, that had migrated from the Moreton Bay foraging area. Dots denote nesting beach capture sites.

Chelonia mydas (Green turtle): Small (curved carapace length >~40 cm) and large immature and adult turtles are mostly herbivorous and forage on benthic plants (sea grass, algae and mangrove fruit) within a wide range of inner continental shelf and reefal habitat. These habitats include coral and rocky reefs and intertidal and subtidal seagrass meadows in inshore coastal areas, especially in bays and estuaries. These benthic foraging individuals have a continuum of year round distribution along the continental shelf from the Gulf of Carpentaria in the north through Torres Strait and south to southern NSW. There are also disjunct foraging assemblages on the shallow reefal areas beyond the continental shelf including the Coral Sea platform, Elizabeth and Middleton Reefs, and reefs associated with Lord Howe and Norfolk Islands. *C. mydas* is particularly abundant as a foraging turtle in the large shallow bays and coral reefs of eastern Queensland to as far south as Moreton Bay (Limpus et al. 1994a). Further south, the abundance decreases markedly with small concentrations of populations foraging year round on the rocky reefs of northern and central NSW and in the NSW estuaries south to about Jervis Bay. Very small numbers of green turtles appear to forage year round to as far south as the Victorian border.

Based on tag recoveries, the majority of green turtles that forage in the coastal areas of the EMR from Hervey Bay south to NSW can be expected to migrate to breed on nesting beaches in the southern GBR (Figure 7.2). Small numbers of females migrate outside this area to breed in the northern Great Barrier Reef, New Caledonia and Vanuatu. There have been no comparable studies to define the breeding areas that supply the green turtles that forage on the reef habitats of the Coral Sea and Tasman Sea.

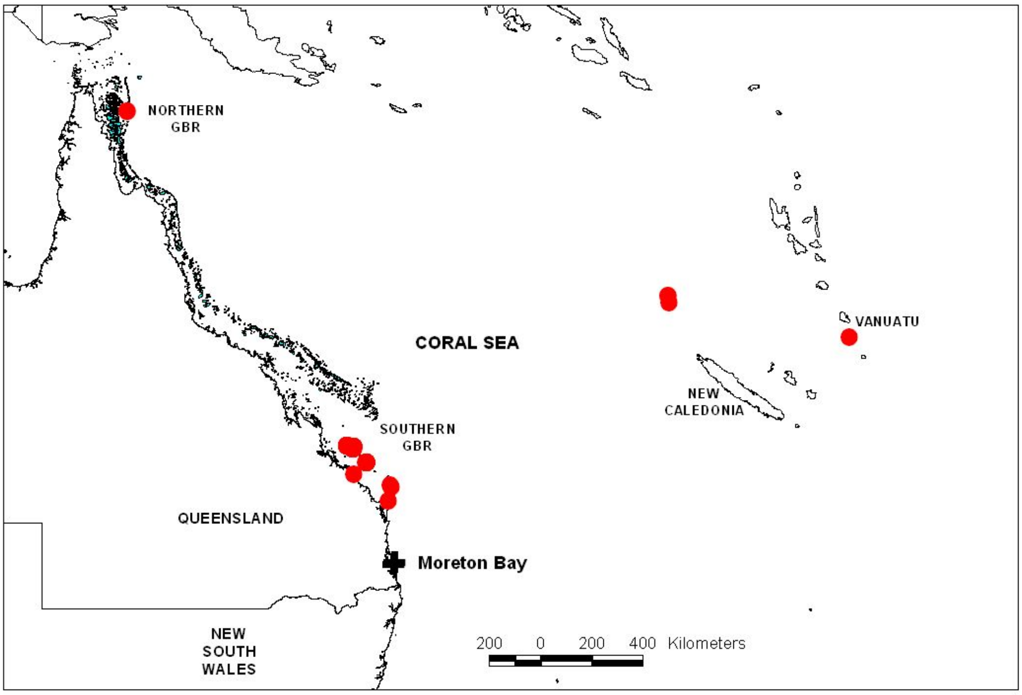


Figure 7.2. Breeding distribution of recaptured tagged adult female green turtles (*Chelonia mydas)* that had migrated from the Moreton Bay foraging area. Dots denote nesting beach capture sites.

Eretmochelys imbricate (Hawksbill turtle): Small (curved carapace length >~32 cm) and large immature and adult turtles are omnivorous, feeding on algae, sponges, soft corals and other soft-bodied invertebrates within mostly reefal habitats of shallow tropical and temperate waters. The main foraging populations for hawksbill turtles in eastern Australia occur at coral and rocky reefs within continental shelf waters of Torres Strait and the Great Barrier Reef. Smaller foraging populations occur on reefal habitat of the Hervey Bay to Moreton Bay area and further south to at least northern (for example, Julian Rocks). Only small disjunct foraging assemblages are found on the shallow reefal areas beyond the continental shelf including the Coral Sea platform, Elizabeth and Middleton Reefs, and reefs associated with Lord Howe and Norfolk Islands.

The locations of the nesting populations, from which hawksbill turtles that forage in south Queensland and NSW coastal waters of the EMR originate, have not been determined. The closest breeding sites occur more than 1,200 km distant in the northern GBR, Solomon Islands and Vanuatu.

Natator depressus (Flatback turtle): Small (curved carapace length >~30 cm), large immature and adult turtles are carnivorous, feeding on soft-bodied invertebrates such as seapens, soft corals, beche-de-mer and jellyfish on soft-bottom benthic communities of the eastern Australian continental shelf to as far south as Hervey Bay in south Queensland. The species is rarely found foraging in reefal habitats or in intertidal and shallow subtidal habitats. It is presumed that the flatback turtles that forage in Hervey Bay originate from the *N. depressus* rookeries of eastern Australia between Townsville and Bundaberg.

Lepidochelys olivacea (Olive ridley turtle): Small (curved carapace length >~40 cm), large immature and adult turtles are carnivorous, feeding mostly on small crabs and molluscs on soft-bottomed habitats of the eastern Australian continental shelf to as far south as Hervey Bay in south Queensland. The species is rarely found foraging in reefal habitats or in intertidal and shallow subtidal habitats. The olive ridley turtle does not breed in eastern Australia. In addition, there is no significant nesting by the species within the Pacific Island Nations of the western Pacific. The origin of the individuals that forage along the eastern Australian continental shelf is undetermined.

Debilitated individuals of the above five species may be carried south of their normal foraging range by the East Australian Current (EAC) and occur as stranded individuals outside their established foraging range.

Dermochelys coriacea (Leatherback turtle): This species is primarily a turtle of oceanic waters. Its distribution and abundance in the oceanic waters of the EMR are poorly documented. Large immature and adult turtles will enter the narrow continental shelf waters from the Sunshine Coast in south Queensland to Bass Strait. While in continental shelf waters they forage on inshore jellyfish, especially *Catostylus mosaicus*, and other large soft-bodied macroplankton throughout the water column. This species is regarded to be in serious decline within the Pacific Ocean basin (Spotila et al. 1996). The decline in the number of leatherbacks that are hooked as bycatch in Queensland Shark Safety Program drum-lines, set off Point Lookout in south Queensland (Figure 7.3), is consistent with a decline of this species entering eastern Australian continental shelf waters over the past two decades.

The location of the nesting populations from which leatherback turtles that forage in south Queensland and NSW coastal waters of the EMR originate has not been determined. The closest significant breeding sites occur more than 1,500 km distant in northern Papua New Guinea and the Solomon Islands.

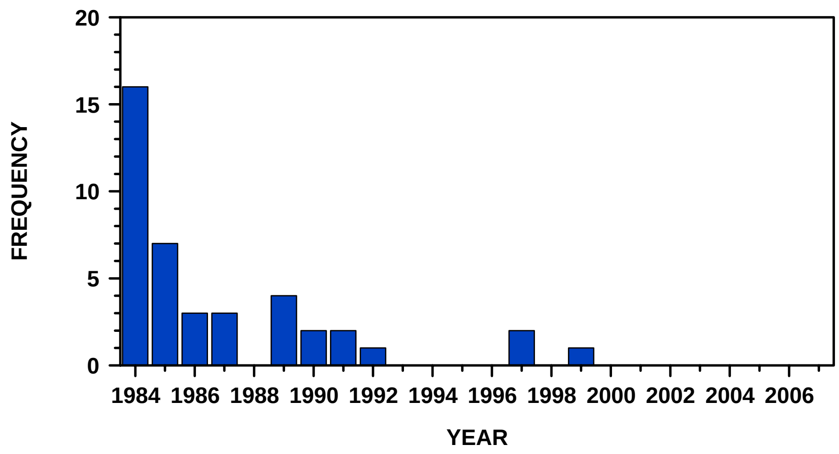


Figure 7.3. Frequency distribution of leatherback turtles, *Dermochelys coriacea*, incidentally hooked on the 24 standard Shark Safety Program drumlines deployed off Point Lookout, south Queensland during 1984–2006. The data for 1984 are from July–December only. Data from other years were collected year round.

Life history and reproductive ecology

On a global scale, each species of marine turtle can be subdivided into genetically separate stocks or management units that are identifiable to the area where they breed. Where clusters of breeding turtles of the same species occur in close proximity, they form an interbreeding population (management unit) while widely separated breeding aggregations can be expected to be genetically different and not interbreeding (Dethmers et al. 2006). These stocks are mixed in the widely distributed foraging areas.

Five species of marine turtle have recorded breeding within the EMR. Miller (1985) has provided a detailed account of embryological development for these species.

Caretta caretta

The loggerhead turtles that breed in the South Pacific Ocean basin are from one interbreeding genetic stock (Dutton et al. 2002; Bowen 2003; Limpus & Limpus 2003a; Limpus et al. 2006) (Figure 7.4). These turtles come ashore to nest on beaches of eastern Australia from the southern GBR and along the adjacent mainland coast to as far south as northern NSW and in New Caledonia. The largest of the five major nesting concentrations for this stock (several hundred females annually) occurs at Mon Repos and adjacent beaches of the Woongarra Coast near Bundaberg adjacent to the EMR. Smaller and decreasing numbers of loggerheads breed on beaches south from Bundaberg. A few tens nest on the Sunshine Coast annually, mostly near Caloundra. About 10 individuals per year breed on the beaches of the islands that enclose Moreton Bay, mostly on Moreton and North Stradbroke Islands. Nesting is rare on the Gold Coast. Isolated individuals nest annually on the northern beaches to as far south as about Ballina. On rare occasions, nesting may occur as far south as Newcastle (Limpus 1985).

Breeding adults migrate, through the EMR, to their traditional nesting beaches in eastern Australian from dispersed foraging areas scattered within a 2,500 km radius of the beaches (from Eastern Indonesia, Papua New Guinea, Solomon Islands, New Caledonia, Northern Territory, Queensland and NSW, Limpus et al. 1992). First breeding occurs at about 30 years of age (Limpus & Limpus 2003b). Individual adult females breed about every two to four years and lay on average about four clutches of 125 eggs per breeding season (Limpus 1985).

For loggerhead nesting populations from eastern Australia, long term census data is available from index beaches on the Woongarra Coast and at Wreck Island within the southern GBR (Figure 7.5). The decline in the eastern Australian nesting population began in the 1970s with the escalation of prawn trawling in northern and eastern Australia and associated mortality of turtles in the trawls. The cessation of the population decline is linked to two management actions: the declaration of the Woongarra Marine park with its associated summer closure of trawling in the inter-nesting habitat off Mon Repos and adjacent beaches in 1991; changes in Federal and State fisheries regulations requiring compulsory use of turtle exclusion devices (TEDs) in prawn trawl fisheries of eastern Queensland and the Northern Prawn Fishery in 2001.

Like all marine turtles, the loggerhead has temperature dependent sex determination with a pivotal temperature of 28.6 ^{o}C —cooler nests at mid-incubation produce mostly males and warmer nests produce mostly females (Limpus et al. 1983b, 1985; Georges et al. 1994). The brown sand mainland beaches near Bundaberg produce mostly female hatchlings while the cooler white sand beaches of the southern GBR coral cays produce mainly male hatchlings. It is unlikely that female hatchlings are produced from any beach from the Sunshine Coast south. Eggs which are laid as far south as Newcastle will not hatch because sand temperatures at nest depth there do not reach 25 ^{o}C, the minimum temperature for successful incubation.

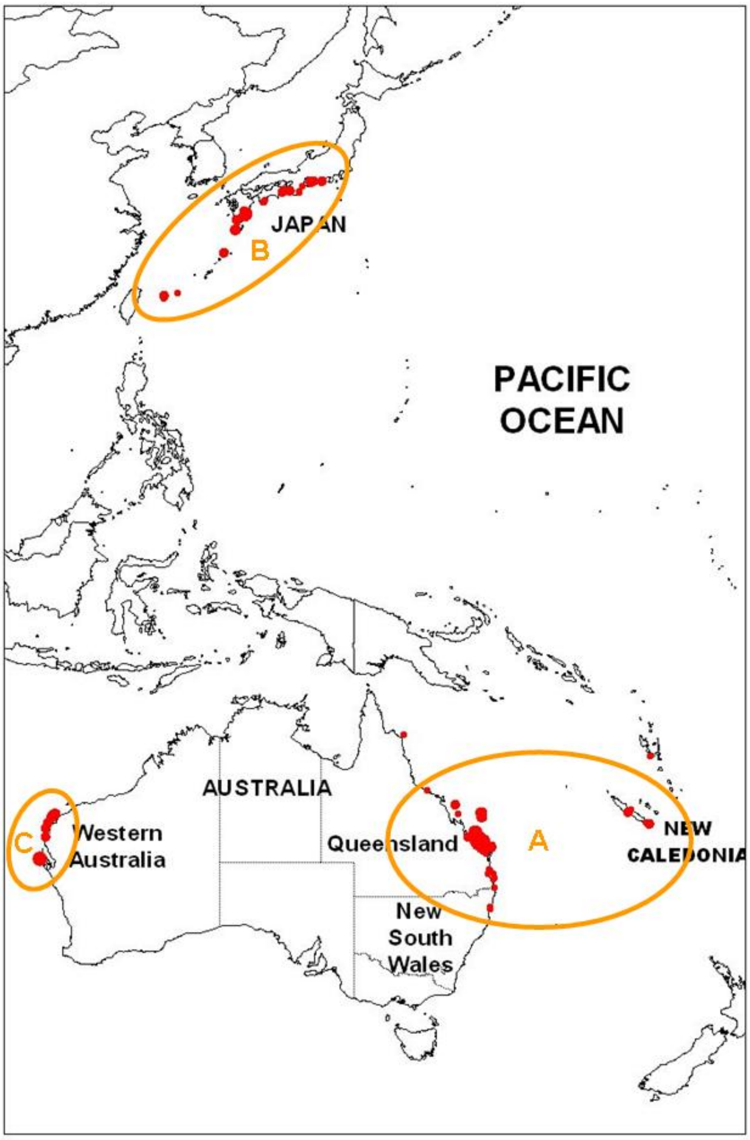
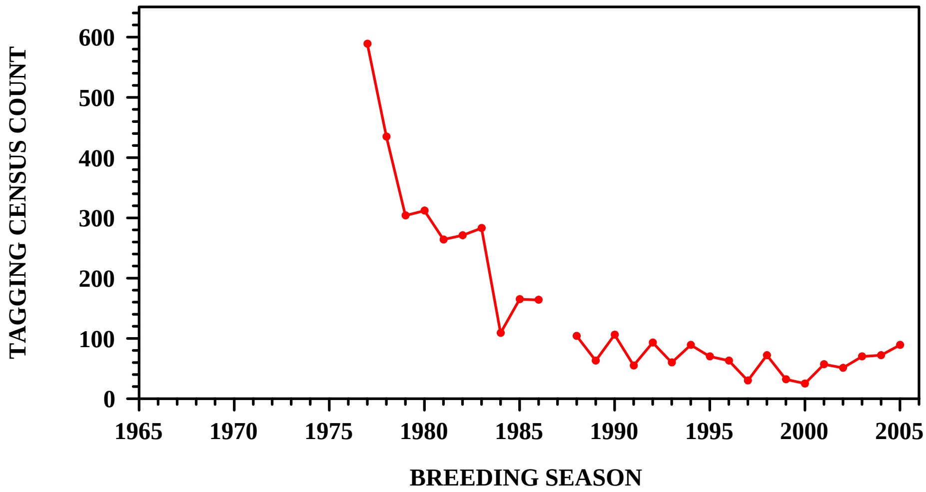
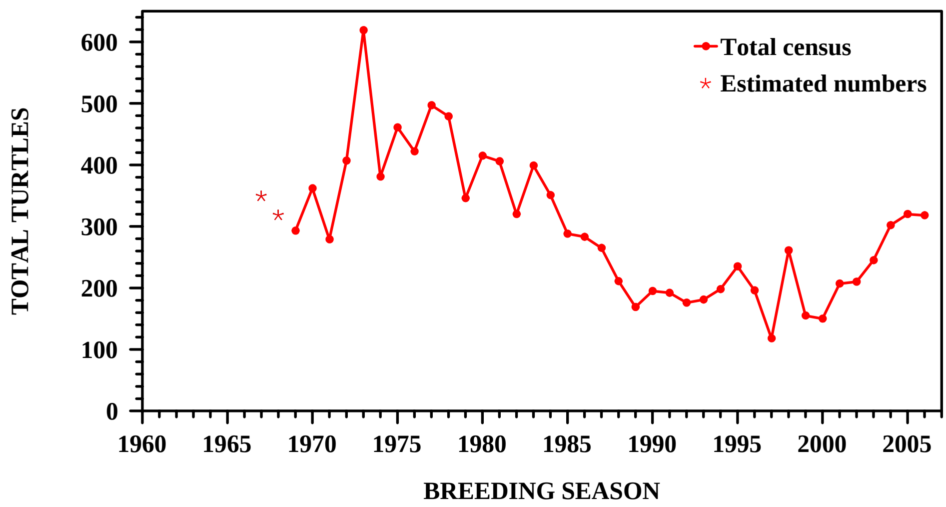


Figure 7.4. Breeding distribution for the three recognised genetic stocks of loggerhead turtles, *C. caretta*, that breed in Australia and the Pacific Ocean basin: A = Coral Sea Stock (In eastern Australia and New Caledonia); B = Japanese Stock; C = Western Australian Stock.



a) Wreck Island. Annual census counts were made of the number of nesting females coming ashore during the peak of the nesting season in the last two weeks of December.



b) Woongarra Coast including Mon Repos. Annual census counts were made of the total number of nesting females tagged during each entire breeding season.

Figure 7.5. Long term decline in the size of the annual population of the loggerhead turtle, *Caretta caretta*, measured at the primary index beach of Woongarra Coast and Wreck Island for the Coral Sea stock.

Chelonia mydas

The green turtle is a widespread and common breeding species within north-eastern Australia and the Western Pacific Ocean (Figure 7.6). While the major breeding populations have been genetically analysed, a number of the breeding populations remain untested. There are currently eight recognised genetic stocks of *Chelonia mydas* identified to breeding areas in north-eastern Australia and the adjacent western Pacific Ocean (Dethmers et al. 2006; FitzSimmons 1997). One of these, the Coral Sea stock (an estimated many hundreds to low thousands of females breeding annually) is restricted to breeding on the Coral Sea Nature Refuge islands within the EMR. The low density rookeries at the southern extremity of the distribution of southern GBR stock (Bundaberg coast—low tens of females annually; Fraser Island—high tens to low hundreds annually; Sunshine Coast —less than ten females annually) also occurs within the EMR. The main breeding population for this latter stock occurs in the southern GBR with some 5–8 thousand females breeding annually. Nesting numbers may fluctuate across three orders of magnitude in successive years in response to El Nino Southern Oscillation climate change events (Limpus & Nicholls 2000) (Figure 7.7). Isolated individuals may nest as far south as northern in high density nesting seasons. The adult turtles remain in their respective foraging areas in the years that they do not breed.

Breeding adults migrate to their traditional nesting beaches in eastern Australian from dispersed foraging areas scattered within a 3,000 km radius of these beaches (from Eastern Indonesia, Papua New Guinea, Vanuatu, New Caledonia, Fiji, Northern Territory, Queensland and NSW) (Limpus et al. 1992). First breeding occurs at about 35 years of age (Limpus & Chaloupka 1997; Chaloupka et al. 2004). Individual adult females breed about every 5–7 years and lay, on average, about five clutches of 115 eggs per clutch per breeding season (Limpus et al. 1984b, 1994).

For green turtle nesting populations represented within the EMR, long term census data is only available from the Heron Island index beach within the southern GBR stock (Figure 7.7). Based on these Heron Island index beach data, there has been a small increase in the size of the southern GBR breeding population over the last four decades, probably as a result of the cessation of the long running commercial harvesting of green turtles in most of Queensland in 1950 (Limpus et al. 1994a).

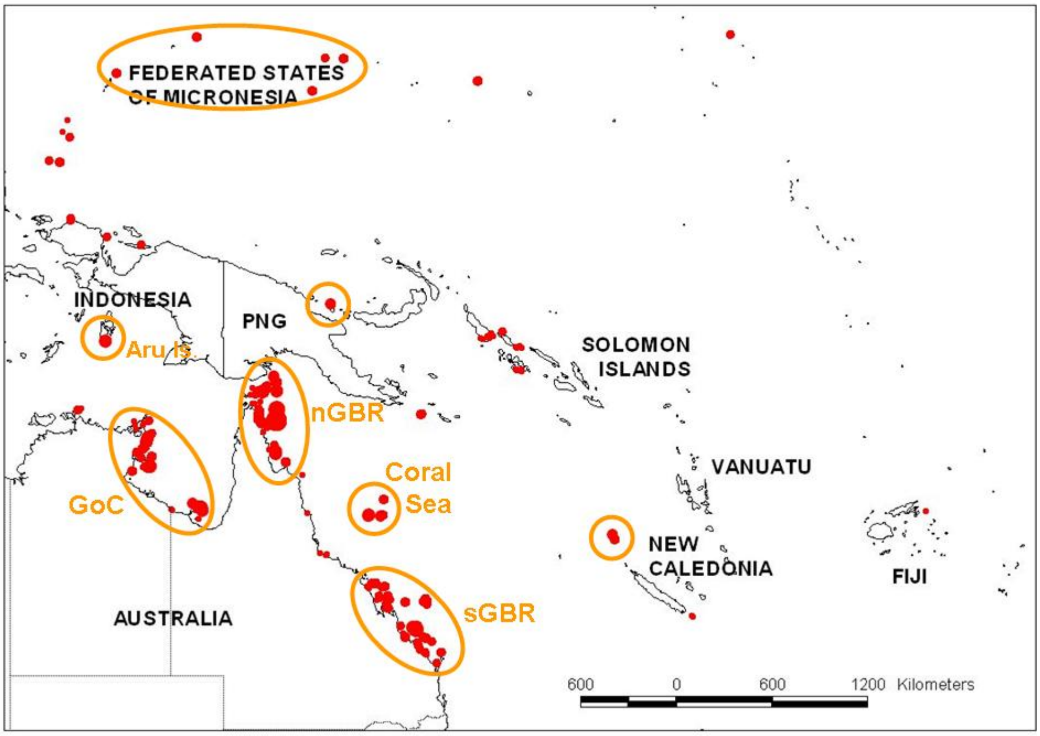


Figure 7.6. Breeding distribution for the eight currently recognised genetic stocks of green turtles (*Chelonia mydas*) that breed in north-eastern Australia and the Western Pacific.

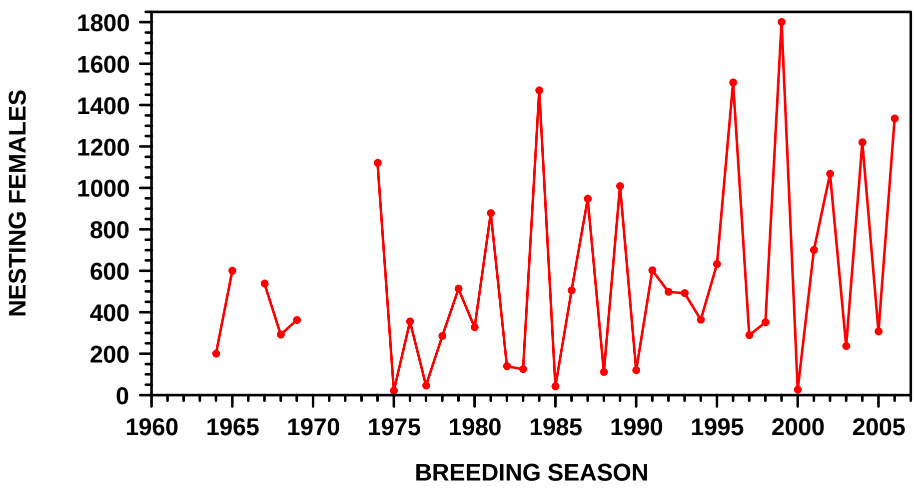


Figure 7.7. Fluctuations in the size of the annual population of the green turtle, *Chelonia mydas*, measured at Heron Island, the primary index beach for the southern Great Barrier Reef stock.

Eretmochelys imbricata

Hawksbill turtle nesting within the EMR is a rare event, restricted to the coral cays of the Coral Sea Nature Reserve. The principal nesting areas for the species in the Coral Sea region lie outside the region in the northern GBR-Torres Strait and Solomon Islands. Different genetic stocks are recognised with this species as well (Broderick et al. 1994)

Natator depressus

Breeding by the flatback turtle is restricted to Australia and occurs from the Ningaloo area of Western Australia across northern Australia to Bundaberg in eastern Australia (Figure 7.8). The nesting population on the central Queensland coast from Townsville to Bundaberg represents a discrete genetic stock for the species (Dutton *et a*l. 2002). This east coast breeding population nest in mid-summer in contrast to the winter peak of nesting for the northern Australian nesting population (Limpus et al. 1993). Only a few tens of flatbacks nest annually on the nesting beaches of mainland south Queensland between Baffle Creek and Hervey Bay within the EMR. This contrasts with approximately 1,000 females nesting annually just to the north within the GBR.

Breeding adults migrate to their traditional nesting beaches in eastern Australian from dispersed foraging areas scattered over 1,300 km of the lagoonal non-reefal habitats inside the GBR between Torres Strait and Hervey Bay. First breeding occurs at about 20 years of age (C. Limpus unpublished data). Individual adult females breed about every 2–3 years and lay on average about three clutches of 50 eggs per clutch per breeding season (Limpus 1971, Limpus et al. 1984a).

Based on census data collected at index beaches within the GBR (Wild Duck Island and Curtis Island) and within the EMR (Woongarra Coast), Limpus et al. (2002) concluded that the eastern Australian flatback turtle nesting population had been approximately stable over the past three decades.

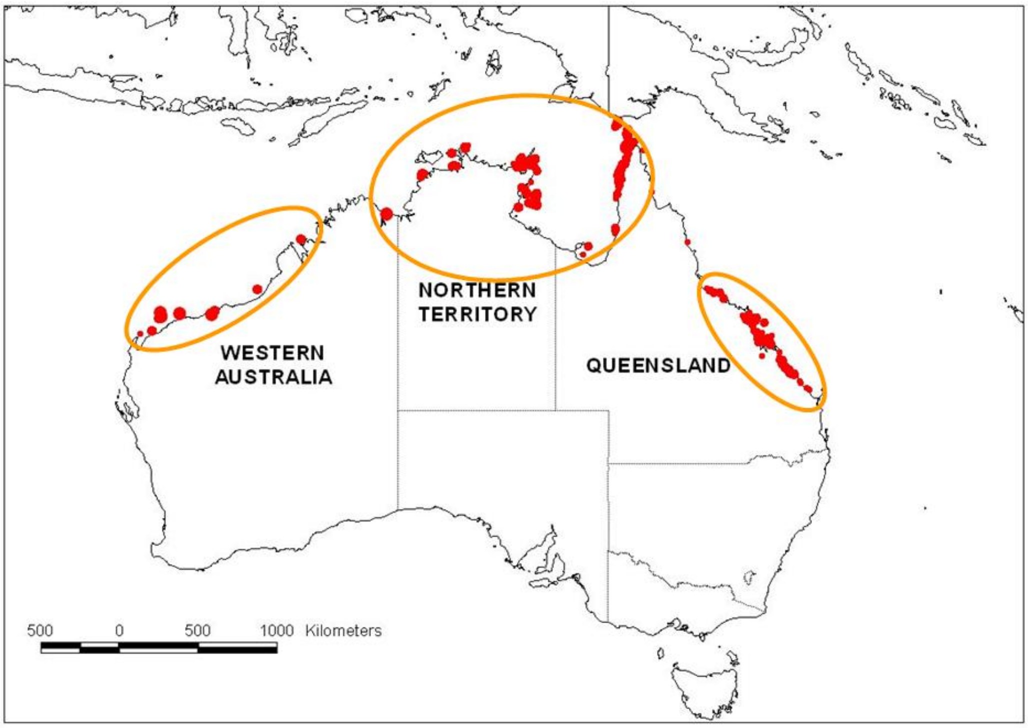


Figure 7.8. Breeding distribution for the three currently recognised genetic stocks of flatback turtles (*Natator depressus*) that breed in eastern, northern and western Australia.

Dermochelys coriacea

There are still sizable nesting populations of leatherback turtles on the north coast of New Guinea in Indonesia and Papua New Guinea and in the Solomon Islands to the north of the EMR (Figure 7.9). This nesting assemblage is currently regarded as forming a single genetic stock (Dutton *et a*l. 2002). When nesting was discovered in eastern Australia in the 1970s there were less than ten females nesting annually (Limpus & McLachlan 1979, 1994). Nesting occurred mainly on Wreck Rock and Rules Beaches (~24.3 ^{o}S) immediately north of Baffle Creek within the GBR area. However, scattered nesting occurred on most mainland beaches adjacent to the EMR north from Bundaberg. Further to the south, successful nesting and incubation was reported from an isolated female at Ballina (~28.8 ^{o}S) in northern NSW (Tarvey 1994). In contrast, a solitary nesting was reported from Forster (~32.2 ^{o}S) in NSW and, although embryonic development commenced within the eggs, no hatchlings were produced because the beach temperature at nest depth was below the lethal minimum for successful incubation. Nesting has declined since that time and the last record of flatback nesting in eastern Australia occurred at Moore Park (~24.7 ^{o}S) near Bundaberg in 1996. The Australian East Coast flatback turtle nesting population appears to be approaching extinction. This decline in eastern Australian nesting parallels the major decline in flatback nesting reported during the same period in the eastern Pacific and attributed to bycatch mortality in oceanic gillnet and longline fisheries (Spotilla et al. 1996).

The flatbacks nesting along eastern Australia are expected to range over thousands of kilometres of oceanic foraging area within the south west Pacific and into sub-Antarctic waters.

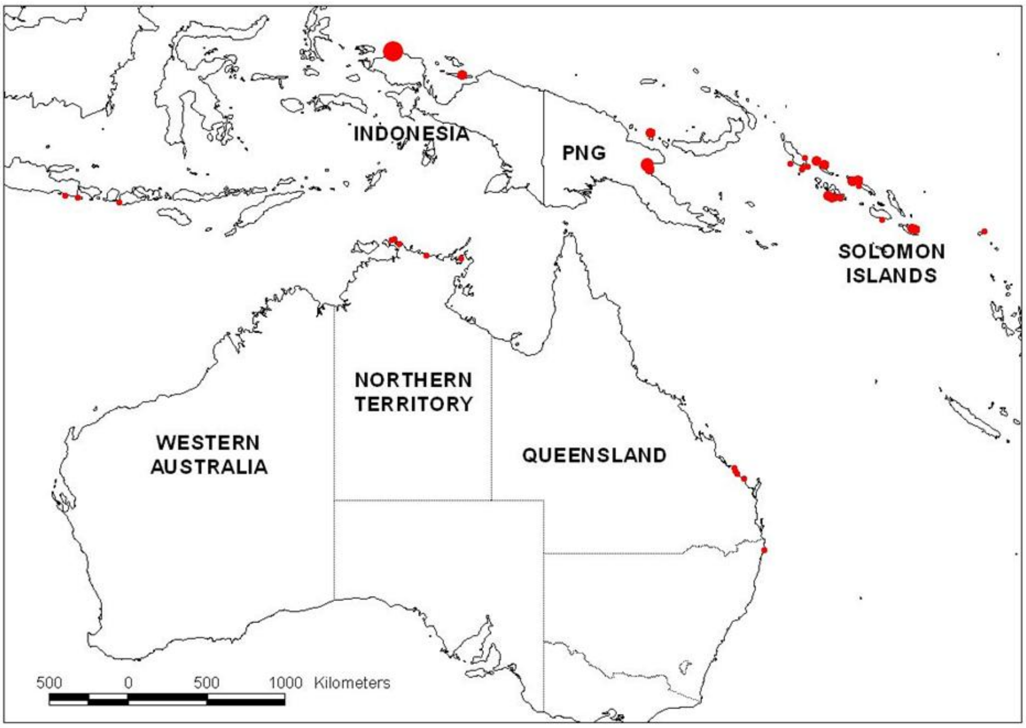


Figure 7.9. Breeding distribution for leatherback turtles, *Dermochelys coriacea*, in Australia and the western Pacific.

Pelagic post-hatchling dispersal and foraging distribution (oceanic migration)

As hatchling turtles leave their respective beaches, they do not stop to eat or rest but swim almost non-stop rest for several days. This swimming frenzy includes a behavioural component that keeps the hatchling swimming perpendicular to wave fronts and hence directs their swimming away from the coast. At the end of this swimming frenzy, their behaviour changes and the hatchlings cease active swimming and seek out planktonic food at the surface. The hatchling can be expected to be some 50–100km off the coast at this time and will be transported by the ocean currents.

Green and loggerhead turtle post-hatchlings originating from nesting beaches of the southern GBR and mainland south Queensland and NSW will be carried by the EAC southward to approximately the latitude (30 S) of Coffs Harbour in NSW (Limpus et al. 1994c; Walker 1994) before being carried eastward to leave the EMR and pass to the north of New Zealand. Post-hatchlings from the New Caledonian rookeries (Figures 7.4, 7.6) can be expected to enter this same gyre and pass through the region.

Based on genetic identification of stock of origin, post-hatchling loggerheads are transported throughout the entire South Pacific Ocean gyre. Approximately half-grown loggerhead post-hatchlings, originating from the Coral Sea stock, are caught regularly in the longline fisheries of Peru and Chile in the eastern South Pacific (Kelez et al. 2004; Shigueto et al. 2006) (Figure 7.10). They re-enter the EMR oceanic waters as large immature turtles as they return to the Coral Sea area. They will leave the oceanic pelagic post-hatchling phase and recruit to the coastal benthic foraging life history phase when they are approximately 80 cm in carapace length and at an estimated 16 years of age.

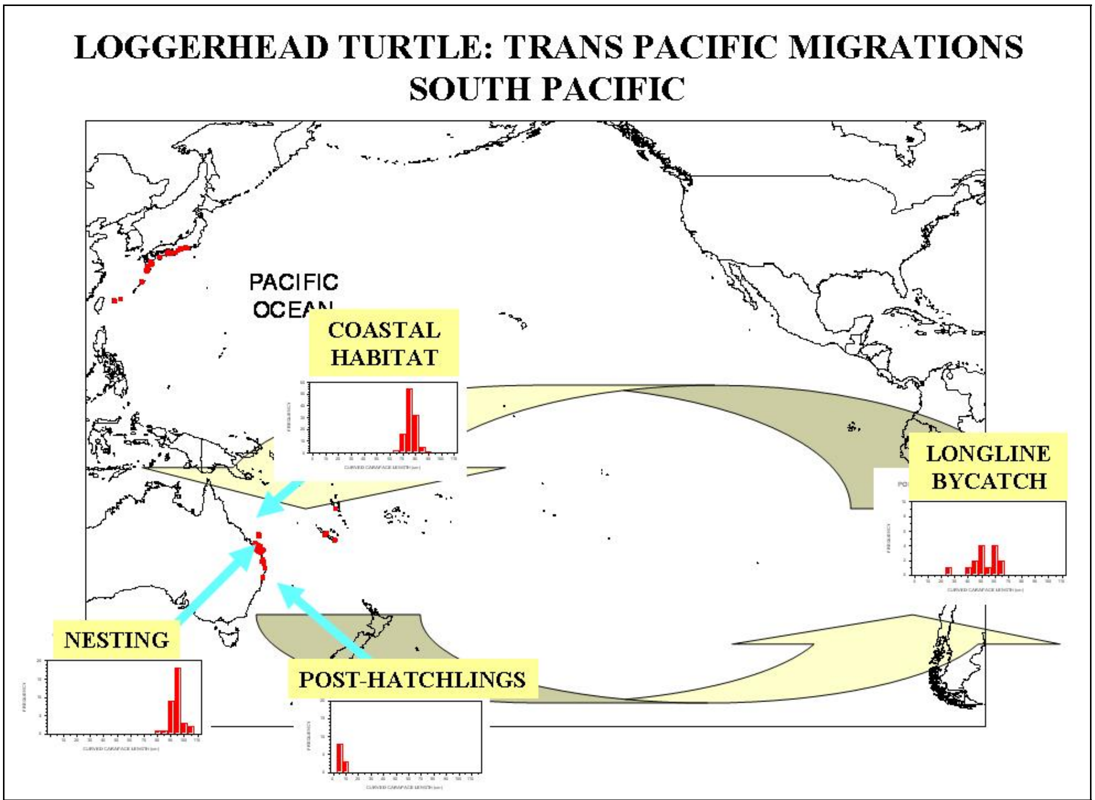


Figure 7.10. Size classes of loggerhead turtles, *Caretta caretta*, at different stages in their life history within the South Pacific Ocean.

Green turtles are much smaller when they leave the oceanic pelagic post-hatchling phase to recruit to coastal seagrass and algal foraging areas (Limpus et al. 2005). It is presumed that they are spending less time in the pelagic phase and may be leaving it at about 8–10 years of age. It is highly likely that the green turtle post-hatchlings do not travel as extensively as loggerheads within the South Pacific. *Green turtle* post-hatchlings from the Coral Sea rookeries may remain entrained within the gyre of the Coral Sea. Little is known of the distribution of the green and hawksbill post-hatchling turtles that enter the ocean currents within the northern Coral Sea.

Leatherback turtles migrate as juveniles and adults through the pelagic environment of the Coral Sea, Tasman Sea including Bass Strait and therefore will occur throughout the oceanic areas of the EMR.

Significance of Marine Turtles in the East Marine Region

Where marine turtles occur in high population densities, they will play a significant role in the ecology of their habitats. The green turtle is one of only two large vertebrate grazing marine animals that can influence the abundance and diversity of seagrass and algal pastures (Jackson et al. 2001). In mangrove communities, green turtles have the potential to influence recruitment of *Avecinnia marina* through predation of its propagules (Limpus & Limpus 2000). The hawksbill turtle is one of the large marine predators of sponges and may play a similar role in shaping sponge communities. The loggerhead is one of the few predators capable of crushing and feeding on medium sized clams and could play a role in limiting densities of clams in coral reef habitats (Limpus 1978). On a more specific scale, marine turtles are the obligate hosts for about a dozen commensal species of barnacles and some thirty species of parasitic worms.

Marine turtles have varying significance within aboriginal communities. For some they are totemic while for others they play a significant part of the cultural practices such as use in initiation ceremonies or they may be traditional food. Indigenous people can legitimately hunt marine turtles and take eggs in the exercise of a native title right, under Section 211 of the *Native Title Act 1993*. Within the EMR, coastal aboriginal communities along the south Queensland coast still hunt large green turtles and occasionally loggerheads as part of their traditional practice. Turtle eggs appear to be less frequently collected for food within this area.

As iconic marine megafauna, marine turtles are an attraction to the broader community wherever they are encountered. In particular, viewing of nesting turtles at the Mon Repos Conservation Park has developed into a million dollar tourist industry (annually) within the Bundaberg District.

Impacts/Threats

Marine turtle populations have been impacted globally through a wide range of impacts from increasing human populations.

Habitat Loss

Human alteration of catchments with the associated change in the quality of the water flowing into coastal habitats, especially with floods, is probably the most pervasive cause of habitat loss impacting marine turtles within the EMR. Land clearing for agricultural and pastoral industries and for urban development can result in increased sediment outflow from rivers which can cause significant losses of marine seagrass and algal pastures (Preen et al. 1995). Associated with human activities within the catchments has been the use and production of a great range of chemicals which find their way into our waterways and hence the outflow into the coastal habitats. For example, chlorinated hydrocarbons derived from land based activities are now widespread in the sediments of coastal estuaries and bays adjacent to the EMR and are concentrated as they pass up the food web from sediments to seagrass to turtles (Gaus et al. 2001; Hermanussen et al. 2004, 2006). In some cases these pollutants can be passed across generations from adult female turtles to their hatchlings via the yolk of eggs (Muusse et al. 2006). The implications of these pollutants on the food resources and health of marine turtle populations is still under investigation.

At the nesting beaches, light pollution from coastal development has the most profound impact on the use of beaches by the nesting females and the survivorship of hatchlings. In the extreme, Kelly’s Beach near Bundaberg has changed from supporting the second highest nesting density of loggerhead turtles within the district prior to the mid 1970s to now supporting a trivial nesting population as a result of changed light horizons associated with motel and housing developments on the dunes. The turtle are choosing not to use this beach with its altered light horizons while they continue to nest in large numbers on the dark beaches a few kilometres away.

Fishing

Bycatch mortality within the pelagic longline fisheries of the South Pacific has been identified as a serious threat, particularly to leatherback and loggerhead turtles (Spotila et al. 2000, Lewison et al. 2004). While the mortality of marine turtles in the longline fisheries operating within eastern Australian waters and hence the EMR may be low (Robins et al. 2002) it is the pooled mortality, from all the longline fleets operating across the entire south Pacific (for loggerheads) and within the entire Pacific Ocean (for leatherbacks), that is the issue. Even with low bycatch mortality, Australian longline fisheries are contributing to the problem.

In coastal waters, bycatch mortality in prawn trawl fisheries in eastern and northern Australia was the major contributing factor to the decline of the loggerhead nesting population of eastern Australia since the 1970s (Limpus & Limpus, 2003a). This decline in the eastern Australian nesting populations has ceased since the mandatory use of turtle exclusion devices within these prawn trawl fisheries was introduced in 2001 (Figure 7.5). In the past two decades there has been increasing recognition of the entanglement and mortality of green and loggerhead turtles in the floatlines of crabpots with some tens of large individuals for each species being killed annually in Hervey Bay and Moreton Bay (Greenland et al. 2004). In the broader area of Bass Strait, appreciable numbers of leatherbacks are drowned annually through entanglement in the floatlines of crayfish traps (Bone 1998). The mortality of marine turtles in coastal gillnet fisheries has been poorly documented in eastern Australia. Many tens of green, loggerhead and hawksbill turtles are estimated to die annually from ingestion of hooks and ingestion of or entanglement in lost/discarded fishing line (presumed to originate from recreational fishers) within Hervey Bay, Moreton Bay and the estuaries of northern NSW.

Boatstrike and propeller cuts

In recent decades there has been an increasing incidence of turtles killed by collision with vessels and chops from propellers (Greenland et al. 2002). It is estimated that many tens of large green and loggerhead turtles are killed annually in the Hervey Bay–Moreton Bay area. With increasing numbers of vessels being used in our coastal waters, this problem is expected to increase. There has been some success in reducing boatstrike at localised sites using zoning of “go-slow” areas within the Moreton Bay Marine Park.

Ingestion of synthetic debris

While small numbers of turtles from the foraging populations within coastal habitats are recorded dead each year from gut blockages resulting from ingestion of synthetic debris including plastic sheeting, plastic bags, balloons and fragmented plastic containers, it appears to be a much more significant issue for the post-hatchling turtles foraging in the pelagic waters off shore. The high incidence of appreciable amounts of synthetic debris in the guts of turtles being examined from the pelagic life history phase within the EMR and the difficulty in quantifying mortality from this ingestion in offshore habitats is of concern. The majority of strandings of post-hatchling green turtles in south Queensland that can be identified as recently derived from the pelagic habitats have gut blockages of synthetic debris. While some of this marine debris being ingested by the turtles may be derived from vessel operations, a high proportion is almost certainly derived from land based sources, not necessarily from Australia, and has drifted into oceanic habitats.

Traditional hunting

The loggerhead, green and hawksbill turtle populations that breed in eastern Australia are derived from foraging populations spread throughout, eastern Indonesia, Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia and Fiji as well as in the Northern Territory, Queensland and NSW. Similarly, Green turtles that breed in Papua New Guinea, Solomon Islands, Vanuatu and New Caledonia have part of their dispersed populations foraging in eastern Australia. Throughout these countries, green, hawksbill and loggerhead turtles are hunted for food. Indeed, the largest collective take of green and hawksbill turtles for human consumption globally occurs in the area of eastern Indonesia, Papua New Guinea, northern Australia and the western Pacific island nations. There are strong concerns that the collective harvest of these species within this area is not sustainable. The impact of the combined harvesting of turtles within the south-western Pacific region is seen as a threat to maintaining sustainable populations of marine turtles in the EMR for the above three species.

When the impacts of the individual threats are considered collectively, serious concern must be expressed for the long term sustainability of leatherback, loggerhead, green and hawksbill within the EMR.

Information Gaps

One of the most significant information gaps regarding marine turtle population dynamics is the poor quantification of turtle mortality from the diverse human related impacts on the species. At the same time, the impact of climate change on the distribution and abundance of suitable foraging habitat for each of the species needs to be addressed. In particular, information is needed to identify shifts in distributions in response to changing climate and habitat. At the biological level, a significant gap in knowledge is the application of aging methodology to provide age structure data for our populations. There a pressing need for the development of heuristic population dynamics models for marine turtles within the EMR to provide tools for investigating management options for these long lived, delayed maturity, highly migratory species with dispersed populations.

The pelagic life history phase is the most poorly understood aspect of marine turtle life history. This area of investigation is logistically difficult but, with longline fishing and ingestion of synthetic debris impacts, an understanding of the population dynamics of the species in this phase of their life cycle is crucial.

Key References and Current Research

Current Research

The principal research and monitoring projects relevant to the EMR include:

- documenting stranding and mortality
- monitoring of loggerhead, green, leatherback, hawksbill and flatback nesting populations in eastern Australia by Queensland EPA
- monitoring of and tagging-recapture studies of green and loggerhead populations within Hervey Bay and Moreton Bay to define the population dynamics of these species and to define changes in these characteristics in response to climate change and human impacts
- tagging studies to define growth, migration and dispersal of loggerhead and green turtles are continuing with several agencies.

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8 Molluscs

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Description

Molluscs are a large group of invertebrates that occur in all marine habitats in the East Marine Region (EMR). Several thousand species from six classes are known from Australasian waters. They include familiar forms such as the chitons (Polyplacophora), clams, scallops, oysters and mussels (Bivalvia), snails and nudibranchs or seaslugs, (Gastropoda) tusk shells (Scaphopoda) and octopus, squid, cuttlefish and nautilus (Cephalopoda) and the less familiar Aplacophora (worm-like and lacking a shell).

Molluscs are characterised by an unsegmented soft body, and most have an internal or external shell, a mantle (fold in the body wall that lines the shell), and a muscular foot and/or tentacles. Most forms possess one or two gills. Molluscs (with the notable exception of the bivalves) feed using a row of teeth attached to a moveable ribbon —the radula. The muscular foot is modified to arms in cephalopods. Chambered nautiluses are unique among living cephalopods in possessing a coiled, pearly, external shell.

Generally, the largest component of each class in the EMR is comprised of tropical species, with broad Indo-Pacific distributions, followed by the temperate species in the southern regions and a small component restricted to the Central Eastern Transition. Offshelf, the fauna of the Coral Sea is almost exclusively tropical, while Lord Howe Island, and Elizabeth and Middleton Reefs have primarily tropical species with a few numerically dominant endemics. In all of these areas, the larger shelled molluscs are better known than the micro species (<5mm), or those without adult shells. There have been many taxonomic studies dealing with molluscs within the EMR and many species are included in the more popular 'shell' books that deal with Australian and Indo-West Pacific molluscs. The most significant publication collating knowledge about Australian molluscs is *Molluscs: The Southern Synthesis* edited by Beesley et al. (1998).

However, apart from species that are commercially exploited, there is very little research specifically directed at molluscs within the EMR. Therefore the focus of this report will be on commercial species caught in fisheries operating in the region. This includes a number of cephalopod and bivalve species (Table 8.1) and occasionally marketable quantities of some gastropod species (Appendix B; Courtney et al. 2007). The most abundant species of molluscs in the discarded bycatch component of trawl fisheries are discussed further in the 'Trawl Bycatch' section of this report.

Table 8.1 Molluscs caught in the EMR that are recognised as primary (P) or key secondary (K2) and secondary (S) species in the NSW Ocean Trawl Fishery (OTF) and Queensland trawl fisheries (QTF).

Family	**Group or Species**	**Main Species**	**OTF**	**QTF**
Octopodidae	Octopuses (*Octopus* spp.)	Qld*: O. australis, O.* cf. *kagoshimensis* NSW: *O. australis, O.* cf. *kagoshimensis, O. tetricus, O. pallidus, O. maorum*	P	K2
Sepiidae	Cuttlefishes (*Sepia* spp.)	Qld: *S. plangon, S. opipara, S. whitleyana* NSW: *S. rozella, S. plangon, S. opipara, S. apama, S. hedleyi*	P	K2
Loliginidae	Southern calamari	Qld: *Sepioteuthis* spp. NSW: *Sepioteuthis australis;*	P	S
Loliginidae	Pencil squids	*Uroteuthis* sp.(slender) *U. etheridgei*	K2	K2
Pectinidae	Scallops	*Amusium japonicum balloti*		P

Conservation Status

No molluscan species found in the EMR are listed or protected under any International, Commonwealth or State legislation, apart from fishing quotas for some species. None of the species dealt with in this report are regulated as a Commonwealth-managed fishery. The CITES listed Tridacnidae (giant clam) occur in shallow habitats adjacent to the EMR.

Habitat and Distribution

Molluscs are widely distributed and a major component of communities in both hard and soft-bottom habitats and in the water column. They are found from the coast to deeper waters off the continental shelf. In soft-bottom, nearshore benthic habitats on the shelf off Sydney, a highly diverse molluscan fauna was recorded comprising 215 species of bivalve, gastropod and scaphopod molluscs (Jones 1977). Molluscan collections (held in the Australian Museum) by RV *Kapala* in offshore waters along the coast of NSW include more than 160 families, 400 genera and nearly 550 species. There has, however, been insufficient research to give details on any cross-shelf and latitudinal trends in mollusc abundance or diversity within the EMR. Deepwater shelf and slope habitats within the EMR are relatively poorly studied, and the potentially highly diverse fauna of the seamounts off the central east coast is largely unknown. However, collections made during the recent NORFANZ expeditions will assist in addressing this knowledge gap. Figure 8.1 shows the combined sampling sites from Australian and Queensland Museum collections, and the Australian Biodiversity Information Facility, where data and specimens have been collected for molluscs. This indicates that the Queensland provincial bioregions and those off the coast of NSW and not immediately adjacent to the coast, are poorly sampled apart from clusters off Brisbane and Sydney.

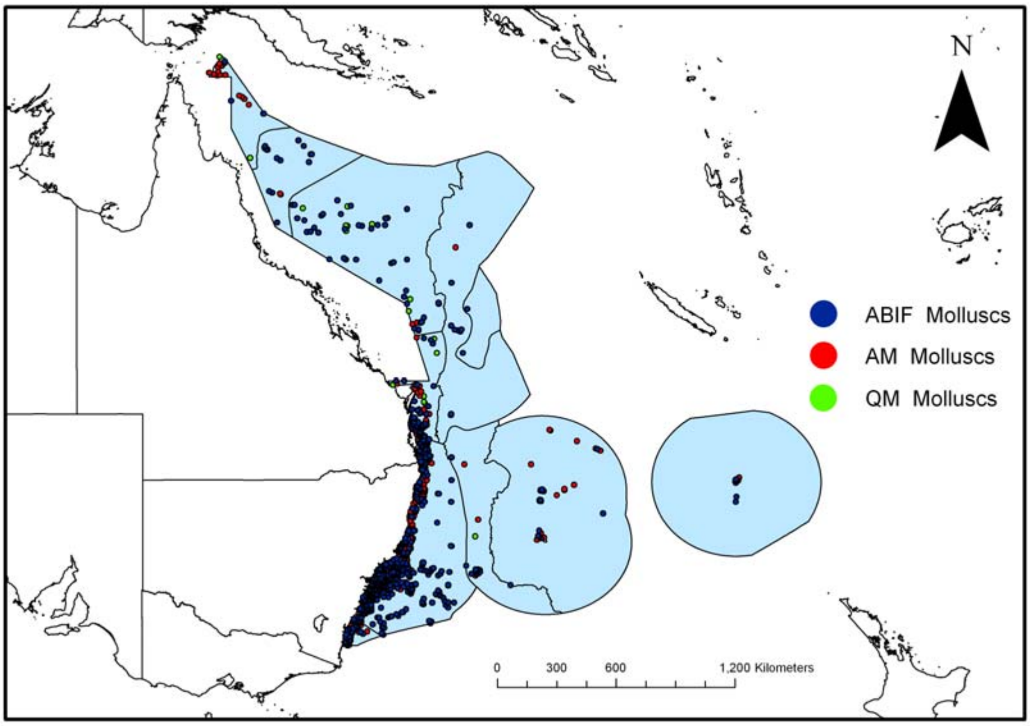

Figure 8.1 Molluscan records from the EMR based on datasets from the Australian (AM) and Queensland Museums (QM) and from the Australian Biodiversity Information Facility (ABIF).

The two groups of molluscs that are a significant commercial component of EMR fisheries are cephalopods and bivalves. Habitat, feeding and life history information for these is summarised in Table 8.2.

Cephalopods

All cephalopods are marine and found from shallow intertidal reefs to deep sea trenches. The Australasian region (from southern Asia and New Guinea to Australia and New Zealand) has the greatest diversity of cephalopods in the world (Norman & Reid 2000). The taxonomy and biology of cephalopods, particularly mid to deep water species, are not well understood with the taxonomy of some species harvested in trawl fisheries remaining undefined (Appendix B; Ponder et al. 2002; Courtney et al. 2007). Cephalopods caught in trawl fisheries in the EMR include a variety of octopuses, cuttlefishes and squids (Table 8.1; Appendix B; Courtney et al. 2007). Although they are an important component of these fisheries little is known of the habitat preferences, distribution and basic biology of most of these species (see Table 8.2).

Two species of nautilus, *Nautilus pompilius* and *N. stenomphalus* (taxonomy being revised—now proposed as morphs of the same species, *N. pompilius*) occur in the waters of the EMR (A. Dunstan pers. comm.). *Nautilus pompilius* is the most widely distributed and best known species occurring throughout the Indo-West Pacific; Andaman Islands; Ambon; the Philippines, New Guinea to Fiji; north-eastern and north-western Australia. They are mobile benthic animals that live at depths of 300–500 m during the day and rise to shallower waters (about 200 m) at night to feed (Norman 2000; Norman & Reid 2000; Jered & Roper 2005).

Bivalves

The only bivalve species of commercial significance in the EMR is Ballot's saucer scallop, *Amusium japonicum balloti*. Saucer scallops have been recorded in waters from 10 to 75 m deep living on bare sand, rubble or soft sediment surfaces. They are present off the east of Queensland and NSW coasts from Innisfail to Jervis Bay and are also found in waters off New Caledonia. These scallops are known to have patchy distributions, occurring in discrete beds (up to 15 km in length with densities of up to 1 per square metre) separated by areas with few or no individuals (Kailola et al. 1993). They are most abundant in areas south of 20 S in water depths greater than 40 m (Williams 2002).

Many other bivalves such as oysters, mussels and are part of valuable commercial fisheries restricted to coastal waters and estuaries adjacent to the EMR. These species are broadcast spawners and the early planktonic life stages are likely to be present in the waters of the region. Much of the research on these species has focussed on the post-settlement stages rather than the planktonic stages of the life cycle.

Life history and reproductive ecology

Molluscs have a wide range of reproductive strategies. The deposition of egg clusters on the substrate is common in most classes, except for bivalves where free or broadcast spawning is the preferred reproductive mode. While the majority of groups have single sex individuals, there is little sexual dimorphism except in some cephalopods. Most marine molluscs produce a pelagic larval stage which aids dispersal. However, in some groups (e.g. many cephalopods), small replicas of the adults emerge from egg capsules ready to feed (Beesley et al. 1998). Available life history and reproductive data for commercially important species is summarised in Table 8.2. A general overview of the biology of these species is presented below.

Cephalopods

<u>Octopus</u>: are voracious predators, generally more active at night, foraging for crabs, crustaceans and fish. All octopus species grow relatively fast and have short life cycles of one to two years (Wells &Wells 1977; Joll 1983; Van Heukelum 1983). Females produce a single mass of eggs, which they deposit in crevices or

lairs, and protect and clean them during incubation. The females die soon after the eggs hatch (Norman &Reid 2000). Some octopuses produce small numbers of large eggs that hatch as benthic juveniles while others lay large numbers of small eggs that hatch as pelagic young (Kailola et al. 1993; Grubert et al. 2000).

Cuttlefish: are primarily demersal ranging from shallow waters to the upper contintental slope (about 600 m, see Appendix B). Many cuttlefish species bury themselves in the sediment with only their eyes exposed. This allows them to hide from predators and to ambush prey such as fish, prawns and crabs. They have fast growth rates and typically live for one to two years. They usually produce one batch of large eggs that are attached to the substrate in clusters. Eggs hatch as juveniles and commence feeding immediately. Adults generally spawn only once and die soon after spawning (Beesley et al. 1988; Norman & Reid 2000; Courtney et al. 2007)

Squid: most commercially fished squids are schooling species, typically associated with the bottom during the day but distributed throughout the water column and surface waters at night. They are voracious predators of fish, crustaceans and often other smaller squid. Generally, squid grow rapidly and are short-lived (to 12 months). Some inshore species such as southern calamari produce clusters of finger-like egg capsules or medium sized gelatinous eggs that are attached to the substrate (Norman & Reid 2000) while arrow squids of the family Ommastrephidae typically release hundreds of thousands of small eggs in large, transparent, jelly-like masses which drift in currents in mid-water. All species of squid release their eggs and leave them unattended, usually dying after a single spawning event (Norman & Reid 2000).

Nautilus: are mainly scavengers foraging on dead or dying animals; they have an excellent sense of smell and find their prey mainly by following scent trails. Nautiluses have a range of predators including sharks and other fishes. Maturity is reached at an estimated age of 5 to 15 years. Egg capsules have not been observed in natural habitats but captive female nautilus lay eggs throughout the year. Eggs are laid singly and attached to hard substrates. Unlike other cephalopods nautiluses do not die after spawning and continue to reproduce for several years. They are thought to live for up to 20 years (Norman, 2000).

Bivalves

The biology of saucer scallops is relatively well known; they are suspension feeders, filtering microscopic particles from the water. Saucer scallops are ‘broadcast spawners’ releasing eggs and sperm into the water where fertilisation takes place. Spawning occurs between May and September, with peaks in June and August. Juvenile scallops settle, in aggregations or beds, on the ocean floor after a two to three week pelagic larval phase. Growth is rapid and a size of 90 mm is reached in 6–15 months (depending on location). They live for a maximum of three to four years, spawning annually (Kailola et 1993; Williams 2002).

Table 8.2 Summary of life history characteristics for species that are targeted or permitted byproduct in fisheries operating in the EMR (sources: Kailola et al. 1993; Norman & Reid 2000; DPIW 2005).

Species	Habitat	Feeding	Reproduction	Longevity
Bivalves				
Scallops				
Amusium japonicum balloti	Live on bare sand, rubble or soft sediments between 10 and 75 depths.	Suspension feeders.	Sexes are separate. Release gametes into water where fertilisation occurs – spawning temperature 18–23 C. Spawning peaks from June to August. Pelagic larvae settle onto ocean floor after 2–3 weeks.	Live for 3–4 years.
Cephalopods				
Octopuses			Females generally produce one batch of eggs – adults die after eggs are brooded.	
Octopus australis	Seagrass beds in bays and coastal waters. Only off eastern Australia.	Mainly isopod crustaceans and molluscs.	Produce 50 to 130 large eggs. Eggs attached singly to the substrate.	Short-lived:18–20 months.
O. maorum	From inshore coastal reefs and sand flats to continental shelf and slope (up to 549 m). Southern half of Australia.	Feed on crustaceans, fish and shellfish, including abalone, and rock lobsters.	Produce large numbers of small ovoid eggs. Eggs hatch after approx. 11 weeks. Strong brood care by female – feed little during this period.	Lifespan of 2–3 years.
O. pallidus	Primarily inshore but also found at 275 m – on soft sandy or muddy substrates. South-eastern Australia.	Diet unknown.	Produce 50–150 eggs. Eggs attached singly to the substrate. Hatch well developed young.	Lifespan of 1–2 years.
O. tetricus	Seagrass beds in bays and coastal waters. Only off eastern coast.	Feed primarily on shellfish and crustaceans.	Brood up to 150 00 eggs which are laid in strings on the roofs of rock crevices or burrows. Eggs hatch into planktonic young.	Short lived: unknown.

Species	Habitat	Feeding	Reproduction	Longevity
O. cf. *kagoshimensis*	Sand and rubble substrates to at least 100 m. Eastern Australia.	Feed primarily on shellfish.	Lays numerous small eggs. Hatch into planktonic young.	Short-lived
Squid				
Pencil squids - *Urotheuthis (Photololigo)* spp,	Estuarine and inshore coastal waters	Feed primarily on crustaceans, fish and other squids.		
Sepioteuthis spp.				
Sepioteuthis australis -southern calamari	Mainly an inshore species. From Moreton Bay to Geraldton. Shallow estuaries to up to 100 m.	Feed on fish and prawns, typically form small schools. Often eat small calamari.	Spawning aggregations in waters less than 15m deep. Lays its eggs on the seafloor in fleshy white strings of 2–6 eggs per string. Or eggs are laid in groups of 4–5 in finger-like capsules. Attached to rocky substrates or vegetation often in masses of 50 to several hundred capsules.	Live for about 18 months.
Arrow squid *(Omnastrephidae)* *Notodarus gouldi*	From estuaries to depths of about 500 m. From Western Australia to southern Queensland.	Eat pelagic crustaceans, fish and other squid.	Sexes are separate – males transfer spermatophores during mating. Eggs released in a jelly-like mass into water column.	Probably live for 12 months only, die shortly after spawning.
Cuttlefish				
Sepia spp.	Shallow habitats to upper continental slope (about 600 m).	Prey on fish, prawns and crabs.	Eggs are usually large and attached to substrate. Hatch as juveniles and begin feeding immediately.	Typically live for 1–2 years. Adults generally die after spawning.
Metasepia pfefferi	From Queensland around northern Australia to Broome.	Fish, crustaceans and crabs.	Lays round white eggs attached singly to hard surfaces.	Probably 1–2 years?

Migration

Dispersal in many molluscs follows the typically marine strategy of planktonic larval transport. There are breeding aggregations in some molluscs, but no large scale migration has been recorded. Arrow squid tagged in Bass Strait moved large distances but no significant migratory pattern was identified (AFMA 2004). Saucer scallops are active swimmers but there is no evidence of regular migrations for these species (Kailola et al. 1993).

Significance of Molluscs in the East Marine Region

Molluscs are an important and conspicuous component of the marine invertebrate fauna of the EMR. They are a major source of food for a wide variety of invertebrates and vertebrates. The importance of the ecological role of molluscs, particularly in food chains of benthic and pelagic ecosystems, cannot be overestimated.

Cephalopods are extremely important ecologically in the food pyramids of all oceans and they are regular and significant components of the diets of oceanic birds, large fish such as sharks and tunas, seals and cetaceans (Beesley et al. 1998). Squid, for example, are important elements of food webs in temperate ecosystems representing both predators and prey (Morejohn et al. 1978).

Octopuses, squids and cuttlefishes are primary or key secondary components in prawn and fish trawl fisheries along the coast of NSW and southern Queensland. Although there are no fisheries solely targeting cephalopods in the EMR there is a squid jig fishery in Tasmania and Victoria targeting Gould’s squid (*Nototodarus gouldi*). Significant quantities of this species are also taken as a byproduct of southern trawl fisheries. There are plans to further develop octopus fisheries in Tasmania for *O. pallidus and O. maorum*; two species also found in the EMR (DPIW 2005).

Nautilus are not of commercial interest in Australia but are intensively harvested for the ornamental shell trade elsewhere in the Indo-Pacific (e.g. Indonesia, Fiji, New Caledonia and the Philippines) (Jered & Roper 2005). *Nautilus pompilius* is the most common species in the shell trade and is seriously threatened by overfishing (Norman 2000; Norman & Reid 2000). Most of the knowledge on *Nautilus* spp. comes from studies of captive animals; little is known about the biology of these animals in the wild. Studies currently underway of the Coral Sea populations of *N. pompilius* (at Osprey Reef and other locations) are providing information on life history, movement patterns and population structure that will aid the management of *Nautilus* fisheries in the Indo-Pacific region (A. Dunstan pers. comm.).

The saucer scallop is the most important bivalve harvested from the wild in the EMR. The main harvest area for Ballot’s saucer scallops is off the southern Queensland coast where it is a significant component of the Queensland East Coast Trawl Fishery. The average annual landing is approximately 900 t with a wharf side value of approximately $18 m representing approximately ten percent of the Queensland total trawl landings by weight and 20% by gross value (Jebreen et al. 2003). The bulk of Queensland’s scallop harvest is sold overseas, mainly in South-east Asia where it is regarded as the highest quality scallop in the world (Williams 2002).

Impacts/Threats

Habitat Loss and Climate Change

Commercial trawling may have an impact on molluscs by decreasing the complexity of soft bottom environments reducing sponges, soft corals and gorgonians and available habitat (Ponder et al. 2002). Unless retained for marketing, most gastropods and bivalves probably survive discarding by trawls; cephalopods are mostly retained but those discarded are unlikely to survive; however their life history characteristics make them less vulnerable to fishing pressures (see below).

Virtually all molluscs rely on calcium deposition, for shell development, in at least one phase of their life cycle, and oceanic acidification (due to rising CO_2 levels) has the potential to disrupt this calcium utilization. Planktonic larval shells and pelagic adults are usually the most lightly calcified and potentially vulnerable to structural malformation.

Fishing

Targeted fishing for offshore molluscs is a minor activity in the EMR. Most of the commercial oysters, abalone, trochus, pearl oysters, mussels and scallops (except for saucer scallops) are in shallow inshore waters. However, there are commercial quantities of squid, cuttlefish and octopus taken as bycatch in trawl fisheries operating in the region. Given the very short life span of these cephalopods, their great reproductive potential and their extensive distribution (Table 8.2) they are not currently considered at high risk from fishing operations (Ponder et al. 2002).

Although nautiluses are not harvested in the EMR they are unsustainably fished in many areas of the Indo-Pacific; fisheries have either crashed (Philippines) or are in the process of crashing (New Caledonia) (A. Dunstan pers. comm.). Nautiluses are at high risk of being overfished as they are slow growing and long-lived (Norman 2000).

The open habitats occupied by scallops and their occurrence in discrete beds makes stocks vulnerable to depletion under heavy fishing pressure. The fishery is currently under a range of controls that include a minimum legal-size (varying seasonally), a seasonal fishery closure and a series of rotationally fished spatial closures designed to protect stocks (Jebreen et al. 2003; DEH 2004).

Of greater concern is the bycatch of molluscs with ‘direct’ development such as the larger members of the family Volutidae (Appendix B). While interest has been expressed in the commercial exploitation of these, they are quite susceptible to over-fishing because of their limited dispersal, slow growth and presumed low fecundity (Beesley et al. 1998; Ponder et al. 2002). Currently, limited quantities of volutes such as *Cymbiolena magnifica* and *Livonia mamilla* are marketed in NSW. In a risk assessment of the Otter Trawl Fishery in NSW volutes were considered at high risk (DPI 2004).

Information Gaps

Identification

Several species taken in commercial fisheries remain unnamed and undescribed. Accurate identification is important as life history characteristics such as size at maturity and maximum size show considerable variation among species and are essential for stock management.

Distribution and abundance

Past sampling methodologies in the EMR are biased to larger molluscs and the majority of species (which are mostly less than 1cm) have not been adequately sampled. The bias towards larger species is also reflected in the taxonomic difficulties in identifying, classifying and naming the vast majority of molluscs. Consequently, baseline distributions, abundances and habitat preferences are unknown for most species and any variation in response to impacts or changes is unlikely to be detected. The problem is exacerbated by the nature of sampling programs, with major emphasis on shallower shelf soft-bottoms, less on slopes and deeper water, and virtually nothing on steep, hard substrates. This is compounded by an increasing trend to use coarse sampling gear in recent surveys which excludes the majority of mollusc species.

Little research has focussed on understanding distributions and life history of cephalopod species. Only opportunistic snapshots, collected during fisheries research surveys targeting prawns and fin-fish, indicating aspects of spatial and temporal distribution, relative abundance and life history are available for most species found in the EMR.

Fisheries management needs

There is a need for more detailed information on the following aspects:

Definition of spawning grounds

Identifying the location of spawning grounds for squid and other cephalopods should be a priority to ensure their conservation. Demersal trawling is potentially damaging to egg capsules attached to the seabed and aggregating behaviour for mating and egg laying around spawning grounds may also be interrupted by trawling. Demersal trawling is not permitted in known spawning grounds for loliginid squid off southern Japan and South Africa under current fisheries management regimes. Similar measures might be applicable in the EMR if spawning grounds were identified.

Population (stock) discrimination

The level of movement and migration in cephalopod species in the EMR remains unknown. Little is known of population age structure and there are no estimations of available biomass for targeted species.

For large ‘direct’ developing species vulnerable to fishing, such as the Volutidae or baler shells, the population genetics need to be elucidated to understand stock structure and implement appropriate management strategies if necessary.

Key References and Current Research

Current Research

The results of the 2003 NORFANZ cruise will provide information for deepwater temperate molluscs, once the identification of the specimens is complete and the data entered into an accessible database, and this will be particularly relevant to the southern provinces of the EMR (http://www.environment.gov.au/coasts/discovery/voyages/norfanz/index.html).

Ongoing research of nautilus populations at Osprey Reef and other locations in the Coral Sea and the Great Barrier Reef to investigate the biology and ecology of *Nautilus pompilius* in the wild. This will provide valuable data that can be used to predict sustainable fishing levels for fisheries elsewhere in the Indo-Pacific (A. Dunstan pers. comm.).

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9 Plankton

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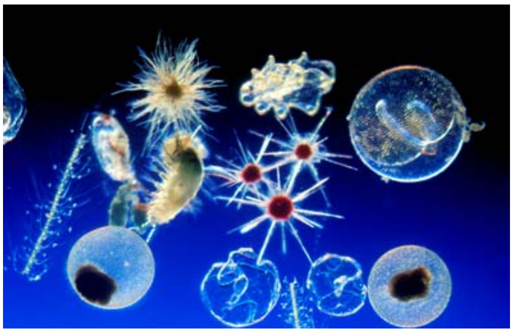

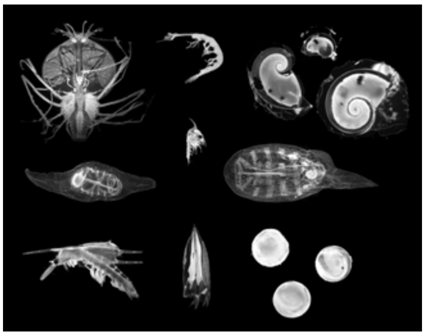

Description

The term 'plankton' is derived from a Greek word meaning 'wanderer', referring to any small biota living in the water, ranging from bacteria to jellyfish, drifting at the mercy of currents. Plankton also often refers to jellyfish and krill which are active swimmers and, along with fish and squid are technically referred to as 'nekton'. Therefore, the broadest definition of plankton includes organisms of any size that inhabit any level of the water column and, although capable of some degree of swimming, are not entirely independent of the movements of ocean currents or other water bodies. Free-swimming medium to large-sized organisms such as jellyfish, larval fishes, krill, and crustacean and molluscan larvae would be included using these criteria. The narrowest definition would include only microscopic organisms that spend all or part of their lives in the water column, passively carried by ocean currents. The plant component of plankton is termed phytoplankton and the animal component is known as zooplankton. The picoplankton (or bacterioplankton, 0.2–2 µm) are a sometimes forgotten component, and yet may be the most diverse and pharmaceutically valuable.

The term 'plankton' as used in this report refers to nanoplankton (2–20 µm; mostly phytoplankton), microplankton (20–200 µm; large phytoplankton but also ciliates and other grazers, predators), mesoplankton (0.2–20 mm) and macroplankton (>20 mm). This includes small marine organisms that spend all of their lives ('holoplankton', such as copepods or salps) or part of their lives ('meroplankton', such as larval fish or jellyfish) in the water column and are not independent of the movements of ocean currents or other water bodies. That is, they are small and predominantly passive drifters. Approximately 50% of the living biomass of the oceans is <1 mm in size (based on size distribution theory), and more than half of the vast biomass of plankton is <0.5 mm. The species diversity of plankton is large (hundreds of thousands of species, not including picoplankton), including phytoplankton and the meroplanktonic larvae of most marine invertebrates and fish. All the animal phyla are recorded as occurring at some stage in the plankton. There are even marine insects included as plankton—the carnivorous marine water strider (*Halobates* spp.) found walking on the surface of the Coral Sea.

Phytoplankton species found in Australian waters belong to the major groups of planktonic algae: diatoms, dinoflagellates, small flagellates, coccolithophores and cyanophytes. New fundamentally important cyanobacteria genera (a component of the picoplankton) are now recognised such as *Prochlorococcus* and *Synechococcus*. There are also many species that are ecophenotypes (varieties that are adapted to local environmental conditions) of species known from elsewhere in the world. There is virtually no endemism in the phytoplankton (Hallegraeff 1995; Kunz & Richardson 2006).

Zooplankton consists of species that are permanent members as well as transient (meroplankton) representatives such as the pelagic life stages of fish, crabs, molluscs, worms and sea stars. There is some evidence of regional populations or stocks of copepods (small crustaceans) and some meroplanktonic larvae exhibit marked endemism. Remarkable examples of this endemism are evident in larval coral reef fish, which are able to return to their natal reef after spending two to four weeks in the plankton (Jones et al. 2007). With new genetic fingerprinting tools, it is likely that similar fine scale structuring will be evident in the distribution of larvae of other benthic animals such as crustaceans and bivalves.

Conservation Status

No species of holoplankton are known to be under threat, although those that rely on precipitating calcium carbonate shells in an increasingly acidic ocean with rising CO_2 levels are predicted to be threatened (e.g. pteropods or planktonic snails, see later). Rising temperatures will alter seasonal and spatial distributions but no holoplanktonic species is threatened with extinction. Meroplanktonic larvae of some endemic estuarine species may be under threat if the adult population is threatened by development. Conversely, benthic species can be under threat if their planktonic larvae are restricted by a sandbar or changed currents.

Habitat and Distribution

Jeffrey & Hallegraeff (1990, cited in Hallegraeff 1995) recognise three distinct marine phytoplankton assemblages in Australian waters. Two of these occur in the East Marine Region (EMR): a tropical oceanic species assemblage in the offshore waters of the Coral Sea, and a temperate neritic (coastal) species assemblage in coastal waters off (NSW). The dominant water movement system, the East Australian Current (EAC), produces warm-core eddies on the eastern coast which take parcels of Coral Sea water and plankton southward into the cooler Tasman Sea (see Figure 9.1—prepared by GM Hallegraeff for CSIRO and National Oceans Office).

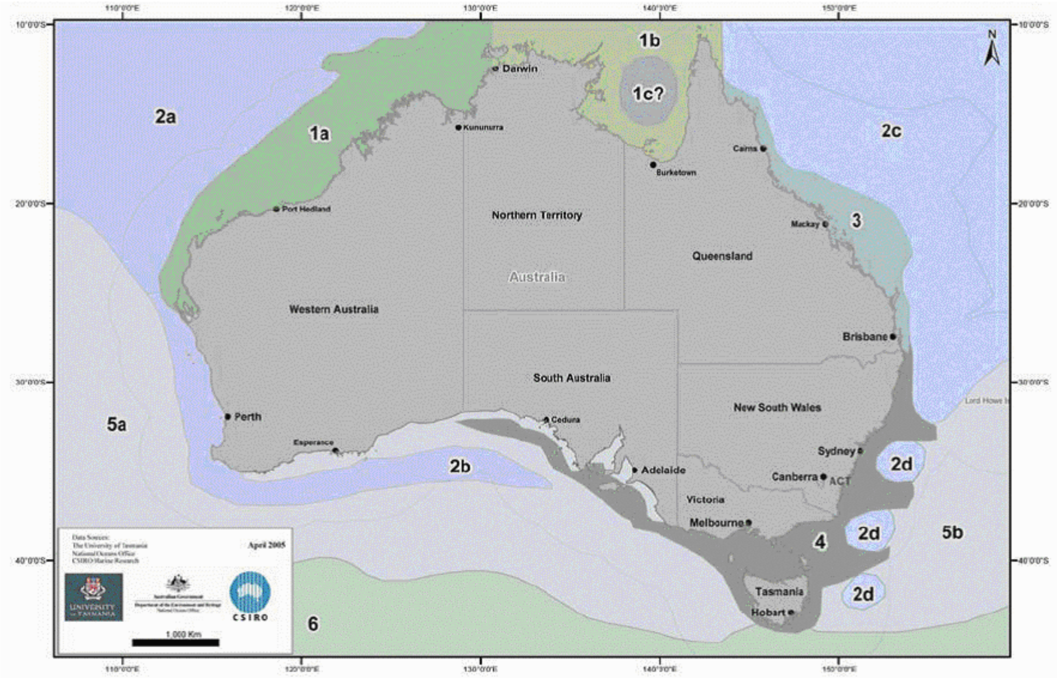

Figure 9.1 Phytoplankton provinces around Australia

In the EMR the deeper waters of the Coral Sea are characterised by a tropical oceanic flora (2c) that is dominated by dinoflagellates and follows the EAC and its eddies (2d). South-eastern coastal waters harbour a temperate phytoplankton flora (4) with seasonal succession of different diatom and dinoflagellate communities (Figure 9.1). Some studies have documented the characteristic flora and fauna of these assemblages (Dakin & Colefax 1933, 1940; Thompson 1948; Sheard 1965; Jeffrey & Carpenter 1974; Hallegraeff & Reid 1986; Jeffrey & Hallegraeff 1987; Andrijanic 1988) but there has been little consistent long-term monitoring. There is a strong case for continuous monitoring of plankton for climate change, pollution, CO2 concentrations, ultraviolet radiation and fisheries effects (Hays et al. 2005; Richardson & Kunz 2006; Hobday et al. 2006). The only set of long-term phytoplankton and temperature-salinity-nutrient data available for the EMR is that of the two CSIRO stations off Port Hacking (NSW), just south of Sydney. A 20 year oceanographic monitoring station was maintained off Lord Howe Island. A continuous plankton recorder series will commence soon, under the auspices of IMOS, between Brisbane and Melbourne (see later).

Australian open ocean waters are generally poor in nutrients and the warm oligotrophic waters of the Coral Sea are characterised by low phytoplankton concentrations (15–20 mg/m^2). Local concentrations of phytoplankton and zooplankton are evident downstream of isolated reefs in the southern Coral Sea (for example Cato Reef), due to flow disturbance and injection of deep ocean nutrients (Rissik et al. 1996; Suthers et al. 2006). The larval fish community in such island wakes can be different to the surrounding ocean. Similar effects are also evident downstream of Middleton Reef and Balls Pyramid (Suthers, unpublished data; RV *Southern Surveyor* Cruise report). Distinctive plankton populations may occur over seamounts (e.g. Taupo), even though the summit is 100 to 200 m below the surface.

Natural enrichment of oceanic waters within the EMR results from upwelling along the outer margin of the Great Barrier Reef, and the NSW coast between the Queensland border and Port Stephens. The northern NSW continental shelf off Smoky Cape (ca. 31ºS), narrows by half in <0.5 º latitude to just 16 km wide, generating marked upwelling signatures in Sea Surface Temperature (SST) and chlorophyll a off Diamond Head, Forster and Seal Rocks (Middleton et al. 1997; Oke & Middleton 2001, 2002; Roughan & Middleton 2002). Circulation within and along the edge of warm-core eddies can inject nutrients in the surface of the Tasman Sea. Eddies off eastern Australia have a large impact on the regional climate, and probably on coastal biodiversity and fisheries—as evident in studies of the Kuroshio, Angulhas, California and Florida Currents. The behaviour of the EAC has many physical and biological similarities with the Kuroshio Extension (Watanabe 2002), the Angulhas Current (Beckley 1993) and the Florida Current (Grothues & Cowen 1999; Pitts 1999). Knowledge of the dynamics of cold core (cyclonic) and warm core (anticyclonic) eddies from the EAC is essential for detecting and understanding changes in plankton communities. For example, the presence of a naturally occurring cold core eddy could influence the seasonal abundance of plankton communities which could be wrongly attributed to climate change or other factors.

Coastal waters off Sydney are characterised by a series of sharp chlorophyll peaks (more than ten times normal algal biomass) due to short-lived diatom blooms which usually occur in spring, early summer and autumn. This was first recognised in the 1930s (Dakin & Colefax 1933) and was documented in more detail in 1958–60 (Humphrey 1963), 1971–72 (Jeffrey & Carpenter 1974) and 1978–79 (Hallegraeff 1981). Surveys in 1981 and 1984 (Hallegraeff & Jeffrey 1993) demonstrated that these diatom blooms are a feature of the entire NSW coastline, from Cape Hawke in the north (32 °S) where the EAC separates from the coast, to Maria Island off Tasmania in the south (43 °S). These blooms (100–280 mg chlorophyll/m^2) result from nutrients brought into surface waters by the shoreward transport of deep continental slope waters, induced by the action of the EAC and its associated eddies. This source of nutrients is greater than any coastal runoff or anthropogenic sources such as the three deepwater sewerage outfalls near Sydney (Pritchard et al. 2003).

The composition of zooplankton is highly diverse, with representatives from almost all animal phyla and families. Australian zooplankton communities range from those with tropical affinities in the north to those adapted to the cold temperate seas in the south. The East Australian open ocean is poorly sampled in terms of zooplankton distribution and abundance as shown in Figure 9.2 (source: Hobday et al. 2006). The coastal studies by Dakin and Colefax (1942) and the ocean survey of salps by Thompson (1948) are unsurpassed. The continental shelf off NSW has been reasonably sampled for zooplankton and ichthyoplankton by the Sydney Water deep ocean outfalls campaign of the late 1980s, and subsequent cruises by the National Research Facility off Sydney (1994) and off northern NSW (1998/99).

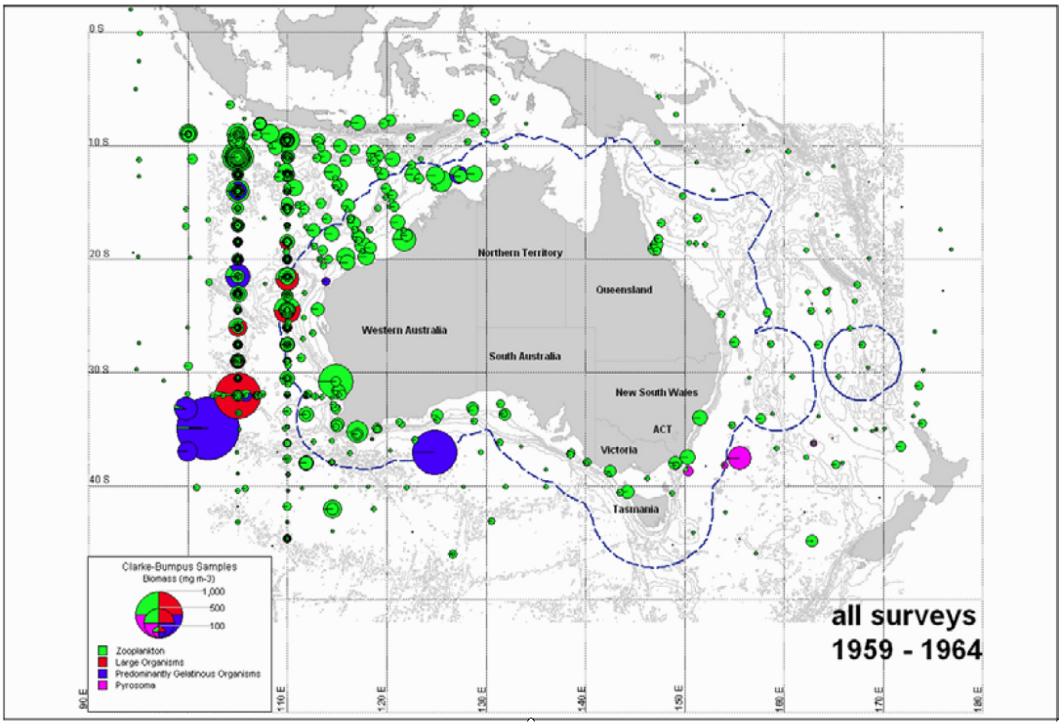

Figure 9.2 Distribution and abundance of some zooplankton around Australia. Note that Eastern Australia is poorly sampled.

Life history and reproductive ecology

Because there is such a diversity of species in the plankton there is also a large diversity of life histories. For unicellular plankton the life histories are complex, ranging from simple, asexual binary fission through to the production of gametes. The life histories of zooplankton may be classified as holoplanktonic (the entire life history is planktonic) or meroplanktonic (only a portion of the life history is planktonic). For example copepods and krill are holoplanktonic, hatching from planktonic eggs into nauplius larvae and growing through a number of moults or instars into dioecious (separate sexes) adults. Chaetognaths, ctenophores, salps and larvaceans are also holoplanktonic, with salps also exhibiting asexual reproduction (e.g. during spring there are blooms of salps). There are also a few holoplanktonic molluscs, polychaetes and cnidarians. In contrast, most typical benthic invertebrates and also fish have meroplanktonic larvae, while the typical cnidarian jellyfish is only planktonic during the distinctive adult (medusa) phase, with a benthic asexual reproductive polyp stage.

Significance of Plankton in the East Marine Region

Phytoplankton forms the basis of the entire oceanic marine food chain. These organisms are the primary producers in the open sea, converting nutrients, water, carbon dioxide and sunlight into the food or energy sources used by other non-photosynthesising organisms. They play a fundamental role in the global biogeochemical cycle by: consuming and converting mineral nutrients (including human and industrial waste); acting as a sink for carbon dioxide (which is necessary for photosynthesis); and producing over 50% of the atmospheric oxygen (Hobday et al. 2006).

Zooplankton feed either directly on phytoplankton or on other zooplankters that have fed on phytoplankton. They in turn are eaten by pelagic organisms, including commercially-fished species within the EMR. Zooplankton, therefore, transfer the energy of the primary-producer phytoplankton to higher trophic levels, either directly or indirectly. Valuable pelagic fish such as tuna tend to congregate at temperature discontinuities associated with eddy systems and the spring-time spawning migrations of gemfish coincide with coastal phytoplankton blooms (Hallegraeff 1995; Prince & Griffin 2001).

Some phytoplankton species produce toxins and can be a problem if they become too numerous—the so-called red tides or harmful algal blooms. Reports of algal blooms in NSW coastal waters have increased considerably since 1990 but it is not clear whether this reflects a real increase in the occurrence of blooms or an increased awareness and recording of such blooms (Ajani et al. 2001). The most common but relatively harmless bloom species in south-eastern Australian waters is now the dinoflagellate *Noctiluca scintillans*. Increased anthropogenic nutrient input has been suggested as a possible contributing factor. Although population growth of *Noctiluca* is stimulated by sewerage discharge from the Sydney region, the dominant factor is the southward advection of *Noctiluca* cells by the EAC (Dela-Cruz et al. 2002; 2003). This species has increased its dominance in the last twenty years but the reasons for this increase are not clear (Ajani et al. 2001). Long term monitoring of phytoplankton using remote sensing, molecular probes and new ocean re-analysis products would be invaluable (Ajani et al. 2001). Blooms of toxic and potentially harmful species have been documented in estuarine and inshore NSW waters (Ajani et al. 2001) but there are no records of toxic blooms in the oceanic waters of the EMR. This is possibly due to a lack of documentation rather than an absence of blooms. The only known example of a pelagic disease is the introduction of a herpes-like virus that decimated Australian pilchard stocks in 1995.

A summary of zooplankton taxa found in the south Coral Sea (sampled with a 330 µm mesh) and representative of the Tasman Sea during summer is found in Rissik et al. (1997). One other species requiring particular mention is the seasonally abundant salp *Thalia democratica* that may have a key role for fisheries and benthic ecosystems.

Impacts/Threats

Overfishing

Frank et al. (2005) established that phyto- and zooplankton abundance on the open continental shelf of Nova Scotia can be affected by the cascading effects of overfishing. The most conclusive examples of this, however, were from relatively small, semi-enclosed water bodies and not from the open oceanic waters as found in the EMR (Hobday et al. 2006).

Nutrient input

Eutrophication (excessive input of nutrients into waterways resulting in algal blooms) is usually a major threat only in enclosed coastal waters, but may have a small effect in shallow coastal seas if sewerage disposal and sea temperatures continue to increase.

Invasive species

A possible threat to coastal plankton communities is the introduction of plankton species from elsewhere around the world via the ballast water of commercial vessels (Hallegraeff & Bolch 1992). Australia has a relatively good record of ballast water awareness and combined with the future implementation of the 'International Convention for the Control and Management of Ships' Ballast Water and Sediments' it may be possible to limit the number of future plankton introductions. The only control in place at present is mid-ocean exchange, but this is not well policed. The implementation of the International Convention is being progressively introduced over (2006–2009) depending on when the ship was built (G. Hallegraeff pers. comm.).

Climate change

The greatest threat to plankton communities and the Tasman Sea ecosystem is, however, climate change. A recent report has addressed this issue in detail (Hobday et al. 2006). General findings regarding impacts on plankton (Kunz & Richardson 2006; Richardson & Kunz 2006) were that:

- increasing sea-surface temperatures combined with the EAC will cause large southward shifts in the distribution of many tropical and sub-tropical plankton, displacing many local species (as already observed during ENSO events, Ajani et al. 2001)
- changes will be observed in the abundance of particular species
- the production peak of some phytoplankton and the resulting secondary productivity of zooplankton will occur earlier (as already observed in the North Sea)
- changing seawater chemistry may alter the relative abundance of phytoplankton groups.

Increasing acidity may have detrimental effects on species with calcareous shells. The approximate doubling of atmospheric CO_2 expected by 2100 will increase ocean acidity (decrease pH). Acidification reduces the concentration of calcium carbonate necessary for the formation of shells. The shells of pelagic molluscs such as pteropods, with the more sensitive aragonite form of $CaCO_3$ will be particularly affected, and those with calcite shells such as coccolithophores, crustaceans, echinoderms and molluscs may not be able to maintain shell integrity in a more acidic ocean.

Overall, climate change will alter the distribution, abundance, seasonality and composition of plankton communities. This will have repercussions for fish, crustaceans, marine reptiles and mammals higher up in the food web both in the EMR and elsewhere. To date, however, there have been no confirmed observations of climate change impacts on this group in Australia but this is most likely due to the paucity of sampling (Hobday et al. 2006).

Information Gaps

Phytoplankton and zooplankton are not only useful for measuring ocean change but also provide a simple method for biodiversity surveys, through the biodiversity of their planktonic larvae.

There is no modern key to the classification of zooplankton off eastern Australia. Apart from guides to ichthyoplankton off SE Australia (Neira et al. 1998), the most useful zooplankton guides in use today were published half a century ago (Dakin & Colefax 1942; Thompson 1954). Consequently our knowledge of zooplankton species diversity and recent population changes is poor. Our knowledge of the phytoplankton community and recent changes in community composition is better, with the comparison of studies off Port Hacking over 20 years (Ajani et al. 2001). Nevertheless, there is no monitoring of potentially harmful algal species off eastern Australia, despite the documented occurrence of potentially toxic species in our waters. Modern methods such as genetic microarrays, or optical recognition of signature pigments is a pragmatic possibility.

Plankton monitoring is a simple and inexpensive way to assess regional biodiversity, climate change and to monitor marine health. The 70 year continuous plankton recorder program of the North Sea, and recently the 12 year program by the Australian Antarctic Division are proving to be invaluable in placing short term fluctuations into a longer term context. Apart from the proposed continuous plankton recorder survey between Brisbane and Fiji as part of IMOS (see IMOS section below and website), there is no monitoring of the Tasman Sea, which is recognised as having the fastest rise of temperature of any regional sea in the world. A major gap therefore in our knowledge is the sea between the mainland and Lord Howe Island or New Zealand. In this regard, the plankton communities at the shelf break (200 m isobath) and the seamounts off eastern Australia are our greatest information gaps in the EMR.

Phytoplankton and zooplankton are two of the five groups of marine organisms recommended to be monitored as practical indicators of climate change affects on Australian marine diversity (Hobday et al. 2006). The major climate changes to the planktonic environment of the EMR will be water temperature, vertical stratification of the ocean, ocean acidity, and possibly ultraviolet radiation and nutrient levels. Of these, water temperature, stratification and the southward penetration of the EAC will have the greatest immediate effect on plankton biodiversity. Smaller, tropical plankton will increase while temperate species will decline in the region.

There are two major information gaps that hamper our understanding of the major threats to the plankton community of the EMR. The first is the effect of warmer water, stratification and EAC activity on ecosystems processes of the Tasman Sea, and how these effects cascade onto fisheries production. Certainly the strength of the EAC and South Pacific gyre will increase (D. Griffin, pers. comm., AMSA 2007). The second major gap is the response by salps and appendicularians (larvaceans) to this ecosystem change, as they play a key role in carbon sequestration models. Our knowledge of salps in the region is limited to the seminal work by Thompson (1948) and Heron et al. (1988) and there are virtually no studies of appendicularians. Salps exhibit strong seasonal (spring) blooms and effectively short-circuit the normal food chains by filter-feeding on the vast picoplankton resource.

Key References and Current Research

Current Research

BlueNet

BlueNet (http://www.bluenet.org.au**)** is an Australian government-funded project to provide a secure, professionally-managed on-line facility to manage, discover and access Australian marine science data. It is intended that the project will increase awareness of, and access to, multi-disciplinary marine data held by universities and government agencies; enable on-line integration and re-use of marine data; prevent duplication of research effort; facilitate a broader understanding of marine systems across time and space; and provide a long-term, secure and accessible repository for marine data.

BlueNet could be used to integrate long time sequences of zooplankton data from Australia's eastern seaboard and because zooplankton communities are considered key indicators of climate change help answer questions about the effects of climate change in the region (Prof. C. Johnson, University of Tasmania; Chief Investigator for Blue Net).

IMOS

IMOS (Integrated Marine Observing System) is a collaborative program to observe the oceans around Australia, including the coastal oceans and the 'bluewater' open oceans. IMOS will provide data to support research on many of the critical marine issues facing Australia, including climate change and sustainability of ecosystems. IMOS is composed of five nodes, running eleven facilities of which the Australian Coastal Mooring Network and the Ships of Opportunity are the most relevant to this report. There are two plankton monitoring components for at least the next four years: AusCPR, which is likely to have a six-weekly route from Brisbane to Melbourne (or Sydney to New Zealand). There will also be the continuing route from Hobart to Antarctica. The second component will be water quality monitoring at the nine National Marine Reference Stations. These will be sampled monthly for water chemistry, phyto- (by pump) and zooplankton (by dropnet). On the east coast, there will be one off Townsville (Queensland), one at Port Hacking (NSW), and one at Maria Island (Tasmania).

IMOS partners comprise most of the Australian universities and agencies with capability in ocean and marine research. The program has strong links with similar international programs and agencies and is funded under the National Collaborative Research Infrastructure Strategy. The data collected by the IMOS will help answer questions about species composition changes in phytoplankton communities and how changes in the composition and abundance of phytoplankton will affect zooplankton across multiple time scales (www.imos.org.au).

Research Vessel Franklin and RV Southern Surveyor voyages

The National Research Facility completed two biological oceanography cruises in the region from Sydney to the continental slope in January and April 1994 and in the upwellings regions off Smoky Cape in November 1998 and January 1999. In September 2004 the RV *Southern Surveyor* examined the biological oceanography of the Tasman Front and North Solitary Islands, and in October 2006 she surveyed the Tasman Front and flow disturbance around Taupo Seamount, Middleton Reef, and Lord Howe Island-Balls Pyramid. On the return voyage, the first ever plankton samples were taken from a cold core eddy off Port Stephens, as well as in coastal waters. All these samples have been sorted for the larval fish community and the plankton size-frequency distributions determined with an optical plankton counter (from net-samples or an in-situ counter). Nets and mesh sizes ranged from a 20 cm diameter, 0.1 mm mesh net, to 0.3 or 0.5 mm mesh gear, to a 1.5 m2, 1 mm mesh net. There are no plans to sort and identify this plankton.

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10 Seabirds

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Description

The term 'seabird' is used informally for a range of birds that inhabit the marine environment to some degree. The main purposes are for either breeding, or feeding, or both. The extent of such use is highly variable, with some species moving into marine, estuarine or coastal environments for short term, opportunistic periods, whereas others are obligatorily tied to these situations for all aspects of their life cycle. Taxonomically, seabirds encompass members from several avian orders. Most important of these are Sphensciformes (Sphensicidae: penguins), Procellariiformes (Procellariidae: petrels and shearwaters; Diomedeidae: albatrosses; Hydrobatidae, Oceanitidae: storm-petrels), Pelecaniformes (Fregatidae: frigatebirds; Phaethontidae: tropicbirds; Sulidae: gannets and boobies) and Charadriiformes (Laridae: gulls and terns; Stercorariidae: skuas). Several pelecaniform groups (pelicans, Pelecanidae; cormorants Phalacrocoracidae; darters, Anhingidae), are less dependent on marine settings, the bulk of their populations occupying non-marine habitats. Charadriiform groups ('shorebirds') such as Haematopodidae (oystercatchers), Charadriidae (plovers) and Scolopacidae (sandpipers) are prominent along shorelines and estuarine settings, as are some Ciconiiformes (Ardeidae: herons, egrets; Threskiornithidae: ibises). The raptorial Osprey (Accipitridae; Accipitriformes) is extensively a bird of coastlines. Other species have limited excursions into estuarine regions (some waterfowl and grebes).

The species considered for this report are constrained by the geographical limits that have been set. The limits of the East marine Region (EMR) exclude most of the coastal breeding islands of southeastern Australia (e.g. Five Islands, etc.) and those of the Great Barrier Reef. It also excludes birds that use estuarine environments along the coast. Islands of relevance are the Lord Howe Island group (including Ball's Pyramid, and Roach, Muttonbird and other satellite islands and rock stacks), surrounded by the Lord Howe Island Marine Park; Norfolk Island group (including Phillip and Nepean Islands); Solitary Islands

(Solitary Islands Marine Reserve); and small reefs and atolls of the Coral Sea, such as Willis Reef and several national nature reserves (Coringa-Herald, Elizabeth and Middleton Reefs, and Lihou Reef). Threats to birds that breed on these islands are a major concern. In addition, there is another suite of threats in the open seas. A number of species that breed close to the mainland but forage away from the coast and potentially move into the EMR. Species generally limited in their movements to within a few kilometres of the coast are of limited direct relevance here.

For the purposes of this review, the following taxa are considered further: penguins, petrels and shearwaters, albatrosses, storm-petrels, frigatebirds, tropicbirds, gannets and boobies, gulls, terns and skuas. Shorebirds and herons are addressed as a single group. These groups are also represented along eastern Australia by a number of species that have been recorded only as vagrants. These stragglers are not specifically addressed here, but would be affected by the same risks as related species. A list of species expected to occur in the review area on a regular basis, or breeding species that may on occasion do so, is given in Table 10.1.

There are also north-south components in the distribution of seabirds. Penguins, albatrosses, many petrels and shearwaters, and gannets are generally limited to the temperate and/or subtropical regions of the EMR. Although a few nest on islands along the southeastern coast, most breed in the New Zealand region or on subantarctic islands and move into the EMR to forage. Boobies, frigatebirds and several species of terns that nest on islands in the Great Barrier Reef and Coral Sea are largely restricted to the tropical northern part in their foraging. A small number of species, such as the Wedge-tailed Shearwater (*Puffinus pacificus*) occur widely along the entire length of eastern Australia.

Conservation Status

Garnett and Crowley (2000) reviewed the status of Australian bird species of the mainland and island territories, and gave conservation ratings based on a number of criteria. For some species, different ratings applied to birds breeding in Australia (including island territories) and to those populations represented by birds occurring in Australia waters. Because the EMR is more than 3nm from the coast, most of this area falls outside legislation by the relevant states. Exceptions are Lord Howe Island and surrounding areas, and the Solitary Islands. The exposed land and immediate waters are subject to the legislative protection of the New South Wales government, with special Commonwealth protection areas bounding these.

Australia has a number of agreements with other countries and Commonwealth legislation that are relevant to the protection of seabirds. These include:

JAMBA – Japanese and Australian Migratory Bird Agreement

CAMBA – Chinese and Australian Migratory Bird Agreement

CMS – Convention for Conservation of Migratory Species of Wild Animals (Bonn Convention)

ACAP – Agreement for the Conservation of Albatrosses and Petrels

EPBC Act – *Environmental Protection and Biodiversity Conservation Act 1999*.

Other measures are the Protection of the Sea (Prevention of Pollution from Ships), bycatch action plans and various fisheries management initiatives.

Under the EPBC Act, it is an ‘offence to kill, injure, take, trade, keep, or move any member of a listed marine species on Australian Government land or in Commonwealth waters without a permit’. While it provides protection under the law for birds at sea, it is primarily directed towards breeding sites.

Table 10.1 indicates the conservation status for each species as given by Garnett and Crowley (2000). It also shows which of these are listed on relevant treaties; all are included on EPBC Act and the CMS treaty.

Habitat and Distribution

Species of sea birds occurring in the EMR are listed in Table 10.1 and information for them is summarised here.

Penguins

Although a number of penguin species have been recorded in Australian waters as stragglers or vagrants, only one breeds here. Within the EMR, the Fairy Penguin (*Eudyptula minor*) nests on islands along the coast of New South Wales and Victoria and a few mainland sites. This species extends northwards into subtropical waters but it is uncertain how far beyond coastal areas it moves.

Petrels and shearwaters

Around 30 petrels, shearwaters, prions and diving-petrels are found in the EMR on a regular basis. A number of other species have been recorded as vagrants. Several species breed on islands along the coast, or in the Great Barrier Reef and Coral Sea. There are also some that nest in the Lord Howe or Norfolk Island groups. In some cases, these species are extinct on the main islands and now breed only on satellite islands.

Albatrosses

No albatrosses breed in or near the EMR, instead nesting mainly on islands in the subantarctic and near mainland Tasmania. A number of species of albatrosses have been recorded in temperate waters along eastern Australia during non-breeding periods. The number of species recognised varies among treaties depending on the taxonomy adopted, and ranges from 8 to more than 20. Albatross are long-lived, slow breeding birds.These characteristics mean that they are unlikely to recover from significant threats, it also makes it difficult to assess this, as well as their susceptibility to various factors.

Storm-petrels

Five species of storm-petrels occur regularly in eastern Australian waters, mainly in temperate and subtropical zones. The White-faced Storm-petrel (*Pelagodroma marina*) breeds on islands along the southeast coast. The White-bellied Storm-petrel (*Fregetta grallaria*) formerly bred on Lord Howe Island, but is now restricted to smaller islands in that vicinity.

Frigatebirds

Two species, the Great Frigatebird (*Fregata minor*) and Lesser Frigatebird (*F. ariel*) nest on islands in the Great Barrier Reef and Coral Sea and move into the tropical sections of the EMR when foraging.

Tropicbirds

The Red-tailed Tropicbird (*Phaethon rubricauda*) nests on islands in the Great Barrier Reef and Coral Sea, as well as on Lord Howe and Norfolk Islands. A second species, the White-tailed Tropicbird (*P. lepturus*), does not breed in the vicinity but, like the other species, forages throughout the northern (tropical) part of the EMR.

Gannets and boobies

Within Australia, the Australasian Gannet (*Morus serrator*), breeds in a few Victorian sites adjacent to the EMR, it also has many nesting sites around New Zealand. There is extensive movement across the Tasman Sea and through the southern half of the EMR. The Red-footed Booby (*Sula sula*) and Brown Booby (*S. leucogaster*) breed on islands in the Great Barrier Reef and Coral Sea, and forage widely through the tropical northern section of this region.

Osprey

The single species of Osprey (*Pandion haliaetus*) occurs around almost the entire mainland coast. It occasionally extends to the Solitary Islands.

Gulls

Australia has three breeding species of gulls. All seem confined to coastal areas, with little movement into pelagic waters.

Terns

Of the 15 species of terns that occur regularly along eastern Australia, nine breed on islands along the coast or in the Great Barrier Reef or Coral Sea. Three breed in both the Lord Howe and Norfolk Island groups, and two widespread species are found throughout. Two species are restricted to coastal areas, while the others occur widely in the EMR.

Skuas and jaegers

The four species that are found regularly in the EMR do not breed near the Australian mainland, but forage widely through temperate and subtropical waters.

Shorebirds, egrets and herons

About 14 sandpiper and 3 plover species occur in small but regular numbers on the coasts of the Lord Howe and Norfolk Islands groups. Several species are non-breeding visitors, usually as migrants but occasionally as vagrants. Only the Masked Lapwing (*Vanellus miles*) breeds in the EMR (at Lord Howe Island). The White-faced Heron (*Egretta novaehollandiae*) breeds in small numbers. The Cattle Egret (*Ardea ibis*) is a regular, non-breeding visitor. On the Solitary Islands, two species of oystercatcher, usually confined to the mainland coast, also occur. Because all these species spend much of their time feeding along the water's edge, they are potentially at risk from oil or other pollution.

Migration

A number of species have regular movements into, or through, the EMR beyond foraging excursions by birds from neighbouring islands. These are associated with post-breeding shifts, usually northwards when birds leave breeding islands and subsequent passage back through the EMR on their return. Several species of shearwaters that nest on nearby islands move through the EMR after breeding, heading to areas east of Asia. The most spectacular of the migrations is that of the Short-tailed Shearwater (*Puffinus tenuirostris*). At the end of the breeding season, more than 25 million birds depart from islands in Bass Strait and along the southeast coast on a migratory path that extends to the Bering Sea and back. Birds nesting further away (around New Zealand or on sub-Antarctic islands) shift into Australian waters in non-breeding periods. Although not the only group to exhibit this movement, the albatrosses are most conspicuous as they forage in this region, particularly during winter. Upwellings off the coast bring food items to the surface, where these are a major food source for significant numbers of many species, such as the Wandering Albatross.

Significance of Seabirds in the East Marine Region

Most of the species are protected under Commonwealth legislation, in particular, the EPBC Act. A range of species across several taxonomic groups are included on bilateral agreements between Australia and other nations (Japan, China). Seabirds under the greatest threat, and thus attracting the greatest conservation attention, are the albatrosses. All these species, as well as some petrels, are granted protection under several pieces of national and international legislation. None of these species breed in the EMR. The region, nonetheless, is of considerable importance for their conservation during the non-breeding season and when breeding birds are feeding well away from the islands on which they nest. Human activities in the EMR, particularly those related to the fishing industry, can have serious impacts on world populations of these birds.

Breeding and roosting seabirds are an important component of the natural heritage values of areas in EMR that have been set aside for special protection. Surrounded by the Lord Howe Island Marine Park, the island itself has been recognised as a World Heritage Area in part for its biodiversity significance. Similarly, the Solitary Islands Marine Reserve, off New South Wales, Coral Sea National Nature Reserves (Coringa-Herald, Lihou Reef) and Elizabeth and Middleton Reefs Marine National Park have been established because of their biodiversity values, including birds.

Seabirds can be an important tourism attraction. While most of this occurs in the Great Barrier Reef and near coastal areas, there is a small but regular component, in the form of pelagic seabird trips, which extend into the western fringe of the EMR. These trips originate from several locations along the east coast. Bird-related tourism is also important for Lord Howe, Norfolk and Solitary Islands.

Impacts/Threats

Threats to seabirds cited in the Action Plan for Australian Birds (2000) primarily involved either mortality through longline and other fishing activities or disturbance to nesting birds and predation by feral animals. The EPBC Act specifically identifies three major threatening processes: (1) longline fishing, (2) feral cats and (3) competition with, and environmental damage caused by, rabbits. The latter two are of relevance on breeding islands, notably on sub-Antarctic Macquarie Island, outside the EMR.

Fishing-related impacts and disturbance/predation on breeding islands are the most relevant to seabirds within the EMR. Other threats to seabirds, such as pollution, are of major concern. Discarded plastics are a global threat to both adults and chicks, and can be encountered anywhere in the EMR. Some forms of pollution are more likely to be confined to areas within near proximity of coastal Australia but could occur near the Lord Howe and Norfolk Islands groups in the EMR. These threats and others are discussed in detail below in relation to the EMR.

Human disturbance

This can be a severe threat in the vicinity of breeding sites. Historically, human impact on breeding seabirds has been substantial. Settlers on Norfolk Island harvested breeding Providence Petrels for food, starting in 1790. This bird was extirpated from that island within a few years - by the turn of that century. The Providence Petrel survived on Lord Howe Island and in recent years this species has recolonised Philip Island, off Norfolk Island. Several species of petrels once bred on the main island of each group, but have been extirpated there and now persist only on satellite islands (e.g. White-bellied Storm-petrel *Fregata grallaria* in the Lord Howe Island group). The Sooty Tern (*Sterna fuscata*) nests on Lord Howe Island; in the Norfolk Island group does so only on islands adjacent to the main one.

Human disturbance on Lord Howe Island is now greatly reduced because much of the island is protected. On Norfolk Island, some breeding areas are difficult to access, being on cliff faces or offshore stacks, but others rely on protection from private landowners. Several other islands are specially protected, but their combination of difficult access or remoteness contributes as least as much to their security. Human-related disturbance to nesting seabirds in the Great Barrier Reef has been studied, and the findings are applicable to the Coral Sea. While human intrusion does have an impact on seabirds, this can have minor detrimental effects if properly managed. Considerable more work is still required for various groups of birds and in different situations (e.g. burrow vs surface nesting, roosting vs breeding).

Introduced predators and domestic animals

This is a threat of considerable significance on the few islands in the EMR with seabird populations. Rats were inadvertently introduced to Lord Howe Island in 1918 by a shipwreck. Within a few years, several of the native breeding birds had become extinct. Masked Owls (*Tyto novaehollandiae*), a native species to mainland Australia, were released on Lord Howe Island to control the rats. These preyed extensively on White Terns (*Gygis alba*) and other native island species. Despite efforts to remove these owls, a few individuals remain. Release of predators near colonies on smaller, uninhabited Coral Sea atolls could be devastating for breeding birds.

Domestic pets, particularly cats, have caused considerable mortality in some petrel colonies on Norfolk Island.

Boats and planes

Birds become accustomed to the presence of boats and planes and associated noise, provided a minimum distance is maintained. As long as people stay within boats and collisions with birds are avoided, these are minor threats.

Mining

At present, this is probably of minimal concern for the EMR, although having potentially significant impact on birds elsewhere. Spillages from mainland-based mining activities could wash into feeding areas or in the vicinity of breeding sites.

Oil and pollution

Oil spills are devastating to seabirds. Oil can coat the birds, reducing insulation and waterproofing, and resulting in problems with foraging. If ingested during preening, the oil can be toxic. If not fatal to the bird, it can have flow on effects with breeding. Winds can move spilt oil towards the shore and in the vicinity of breeding areas and feeding sites. In the EMR, shorelines in the Norfolk and Lord Howe island groups are the most likely to be affected, and any spill could present a major threat to non-breeding, migrant shorebirds.

Heavy metals and organic compounds (e.g. organochlorines) also have the potential to be major threats. These can be ingested by the birds directly or bio-accumulated from points further down the food chain. Contamination by organic chemicals is widespread and has been found in almost all procellariiforms tested for their presence. Individuals that are older or higher up the food chain, exhibit more elevated levels of chemicals (shown in Wandering Albatrosses (Hindell et al. 1999). Direct mortality may not be as pervasive as more indirect effects. Higher levels of ingested contaminants can manifest themselves in faulty calcium deposition in eggshells or inviability or developmental abnormalities of embryos. Effects of this nature have been documented in giant-petrels (Luke et al. 1989).

Marine debris

Discarded debris at sea has been shown to be a threat to seabirds. Evidence indicates that most of this is deliberately thrown from ships. Fish lines and nets can entangle birds, impeding their ability to forage to the point of starvation, if not killing them outright. Of other substances jettisoned, plastic is by far the most hazardous. This is frequently ingested. While it can be toxic, it is perhaps more of a problem by becoming an obstruction in the digestive tract. Plastic debris has been recorded in the stomachs of a number of species and has been observed being regurgitated by adults in food for their young.

Loss of food stock

Breeding cycles of many species have evolved to exploit seasonal occurrence of food sources. Fish stocks in many areas are already known to be reduced or depleted. Combined with natural fluctuations in population densities, these decreases in available food, particularly at critical times, could cause extensive mortality in seabirds. A high adult mortality and a poor breeding season of Little Penguins followed immediately widespread mortality of pilchards (*Sardinops sagax*) in autumn-winter 1995 (Dann et al. 2000).

Fishing

Incidental bycatch of seabirds, particularly albatrosses, has been explicitly identified as a threatening process. The major fishing techniques posing threats are the use of longlines and trawling.

Longline fishing has been described as the single most pervasive threat to seabirds, and is listed in the EPBC Act as a major threatening process. Although the extent of mortality associated with longline fishing is poorly known worldwide, it is recognised that tens of thousands of birds are killed annually in licensed fisheries and even more in illegal, unreported and unregulated fishing. Longline fishing uses a weighted main line sporting side branches with baited hooks. Given that a typical single line may be up to 10 km long and have 10,000 hooks, it is not surprising that millions of hooks are set annually in the EMR. Each hook is baited, and as a line is set, this remains on or near the surface for a period before sinking. Birds attempt to take the bait while still on or near the surface. In doing so, they may ingest hooks and subsequently be dragged underwater and drowned as the line sinks. Longline fishing occurs in Australian waters. There are regional differences in the effects on seabirds depending on the techniques and equipment used, as well as seasonal and geographical variations. A range of measures has been implemented to reduce seabird mortality from fishing in Australian waters. The target level is 0.05 birds killed per 1000 hooks set (Department of the Environment and Heritage 2006). However, much of the fishing occurring in the high seas adjacent to the EMR, where seabirds forage, have ineffective or no seabird bycatch mitigation measures in use.

During trawl fishing, birds may be injured or killed when nets are being set or hauled. Birds can collide with trawl wires, become entangled in the nets or caught in the mechanisms withdrawing the nets as they attempt to take captured items. They are also recorded striking ships or protruding structures when flying about awaiting an opportunity for a feeding attempt. There is growing evidence that mortality related to trawl fishing can be important, but this mostly comes from outside the review area in other Australian waters or globally. Information on domestic trawl seabird catch is minimal; while some reports suggest that trawl bycatch in southeastern Australian waters is low (DPI 2004). Trawl seabird bycatch is difficult to assess in the absence of significant observer coverage dedicated to this issue and there are probably insufficient data to make a meaningful assessment.

Seabird bycatch appears low in the longline billfish and tuna fishery, which is concentrated along the entire east coast of Australia. Monitoring of seabird mortality has increased on domestic longline boats. Nonetheless, experience globally indicates that a dedicated observer regime during longline and trawl fishing is the only reliable method of assessing the level of seabird mortality.

Gill nets can capture and kill birds, but these are essentially used in coastal areas. Ghostfishing by discarded or lost nets is problematic; however, there are few, if any, data to assess its significance in the EMR.

Birds have learnt to follow fishing boats, taking discarded fish remains. While this can have local beneficial effects if it occurs near nesting sites, increasing food available to parents and offspring, it also increases the likelihood of mortality and injury as it brings birds into closer contact with ships, nets and lines, and is overall an undesirable situation.

Climate change

The range of impacts that climate change will have is uncertain. It is likely that warming of ocean waters will affect aspects of the food chain. For example, warming water will hold reduced levels of oxygen, which, in turn, could cause reductions in primary production and a subsequent decrease in the amount of krill. This would have ramifications up the food chain for birds that feed directly on krill or those dependent on prey species that do. Changes in water temperatures could also shift preferred feeding areas. Breeding patterns might change, with birds breeding earlier (Hobday et al. 2006). In Little Penguins, breeding success and chick weight can be affected by ocean temperatures at a local scale (Chambers 2004). Changes in severity of storms could affect breeding sites. Control of these factors is not amenable to direct human intervention.

Summary

Several of the risks outlined above could have, or are having, severe impacts on seabirds that occur in Australian waters, including the EMR. Some of these, however, occur mainly outside the EMR. Species that breed on islands within the EMR face threats similar to those confronting those breeding on sub-Antarctic breeding islands (e.g. feral predators). In pelagic waters, fishing, pollution and marine debris are the threats of major concern at present. Loss of food stocks and climate change could be problems in the future.

Information Gaps

Monitoring of birds killed by longline fishing is one of the few direct sources of information on seabird mortality in the EMR. While it is known that different species have preferred feeding zones, and significant data sets exist for some, for others there is little additional information on their requirements away from breeding sites. Likewise, assessing the impacts of pollution and marine debris is very difficult however there is growing evidence to suggest this poses a serious threat to seabirds. One indicator of the magnitude of the problem is the consistently high level of plastics and other pollution found around nests. In other circumstances, an impact assessment can often only be done when an affected bird is recovered, frequently well away from where the incident occurred. That there is little routine formal surveying of seabirds through this area reflects both the difficulties in performing such work and the lack of resources to do so in any but a most cursory fashion. Rarely would there be notice taken of mortality of seabirds and unless there was a large oil spill or other pollution event, such threats would not be detected.

For each species, there needs to be an assessment of its conservation status. An important aspect of this is to identify the conservation threats, their significance and appropriate responses. Given the highly migratory nature of many of these species, and the fact that different parts of their life cycles often take place in the jurisdictions of different countries, conservation actions will often need to be international in scope.

The most detailed knowledge of the natural history of seabird species is not surprisingly centred on their breeding activities. Surveys on breeding islands have documented changes in population sizes of a number of species. In contrast, much less is understood about their requirements away from these sites. Many attributes of the foraging behaviour are poorly known. Principal among the gaps for each species are an awareness of the foraging range, the precise dietary preferences, the availability of food, and the variability in all these geographically and through time on both annual and seasonal bases.

It is important to know how far a bird moves while it is Australian waters because this directly influences which impacts could affect it. Satellite tracking has been used successfully with some albatrosses and other larger species, but has been rarely undertaken on smaller species, and is probably impractical for many. Genetic sampling of albatrosses killed by fishing activities has permitted identification of which breeding populations are affected (Abbott et al. 2006). Similar programs might be extended to other species of seabirds of particular conservation concern that are impacted by fishing-related activities.

Key References and Current Research

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Table 10.1 Species are included if they occur regularly along the eastern coast of Australia and extend into pelagic waters, or if they are listed as migrants to either the Lord Howe or Norfolk Island groups. Albatrosses are listed using the narrowly circumscribed species limits, with the relevant conservation rating for broadly delimited species extended to all component taxa.

		Breeding			Action	Listing			
Species	**Common name**	**E. Aust**	**LH**	**NI**	**Plan**	**CAMBA**	**JAMBA**	**CMS**	**ACAP**
PELECANIFORMES									
Fregatidae									
Fregata ariel	Lesser Frigatebird	X				X	X		
Fregata minor	Great Frigatebird	X				X	X		
Sulidae									
Morus serrator	Australasian Gannet	X			LC				
Sula dactylatra	Masked Booby	X	X	X	V		X		
Sula sula	Red-footed Booby	X				X	X		
Sula leucogaster	Brown Booby	X				X	X		
Phaethontidae									
Phaethon rubricauda	Red-tailed Tropicbird	X	X	X	NT				
Phaethon lepturus	White-tailed Tropicbird						X		
PROCELLARIFORMES									
Oceanitidae									
Oceanites oceanicus	Wilson's Storm-Petrel				LC		X		
Garrodia nereis	Grey-backed Storm-Petrel				E/LC				
Pelagodroma marina	White-faced Storm-Petrel	X							
Fregetta tropica	Black-bellied Storm-Petrel								
Fregetta grallaria	White-bellied Storm-Petrel		X		V				
Diomedeidae									
Diomedea exulans	Wandering (Snowy) Albatross				CE/V			II	II
Diomedea dabbenena	Tristan Albatross				E			II	II
Diomedea antipodensis	Antipodean Albatross				V (V)			II	II
Diomedea amsterdamensis	Amsterdam Albatross				CE			I	I
Diomedea epomophora	Southern Royal Albatross				V			II	II
Diomedea sanfordi	Northern Royal Albatross				E			II	II
Thalassarche cauta	Shy Albatross				V			II	II
Thalassarche steadi	White-capped Albatross				V			II	II
Thalassarche salvini	Salvin’s Albatross				V			II	II
Thalassarche eremita	Chatham Albatross				CE			II	II
Thalassarche bulleri	Buller’s Albatross				V			II	II
Thalassarche chrysostoma	Grey-headed Albatross				E/V			II	II
Thalassarche sp. nov. (plateni)	Pacific Albatross				V			II	II

		Breeding			Action	Listing			
Species	**Common name**	**E. Aust**	**LH**	**NI**	**Plan**	**CAMBA**	**JAMBA**	**CMS**	**ACAP**
Thalassarche melanophrys	Black-browed Albatross				E/NT			II	II
Thalassarche impavida	Campbell Albatross				V			II	II
Thalassarche carteri	Indian Yellow-nosed Albatross				V			II	II
Thalassarche chlororhynchos	Atlantic Yellow-nosed Albatross				V			II	II
Phoebetria fusca	Sooty Albatross				V			II	II
Phoebetria palpebrata	Light-mantled Sooty Albatross				V/V			II	II
Procellariidae									
Macronectes giganteus	Southern Giant-Petrel				V			II	II
Macronectes halli	Northern Giant-Petrel				NT			II	II
Fulmarus glacialoides	Southern Fulmar								
Daption capense	Cape Petrel				LC				
Halobaena caerulea	Blue Petrel				LC				
Pachyptila vittata	Broad-billed Prion								
Pachyptila salvini	Salvin's Prion								
Pachyptila desolata	Antarctic Prion				V				
Pachyptila belcheri	Slender-billed Prion								
Pachyptila turtur	Fairy Prion								
Puffinus pacificus	Wedge-tailed Shearwater	X	X	X			X		
Puffinus bulleri	Buller's Shearwater								
Puffinus carneipes	Flesh-footed Shearwater		X				X		
Puffinus griseus	Sooty Shearwater	X				X	X		
Puffinus tenuirostris	Short-tailed Shearwater	X					X		
Calonectris leucomelas	Streaked Shearwater					X	X		
Puffinus gavia	Fluttering Shearwater								
Puffinus huttoni	Hutton's Shearwater								
Puffinus assimilis	Little Shearwater		X	X	V				
Pseudobulweria rostrata	Tahiti Petrel								
Lugensa brevirostris	Kerguelen Petrel								
Pterodroma neglecta	Kermadec Petrel		X	X	NT				
Pterodroma heraldica	Herald Petrel	X			CE/LC				
Pterodroma pycrofti	Pycroft’s Petrel				Ex				
Pterodroma lessonii	White-headed Petrel				LC				
Pterodroma macroptera	Great-winged Petrel								
Pterodroma solandri	Providence Petrel		X	X	V				
Pterodroma inexpectata	Mottled Petrel								
Pterodroma leucoptera	Gould's Petrel	X			V				
Pterodroma cervicalis	White-necked Petrel			X	V				
Pterodroma nigripennis	Black-winged Petrel		X	X	LC				
Pelecanoides urinatrix	Common Diving-Petrel								

		Breeding			Action	Listing			
Species	**Common name**	**E. Aust**	**LH**	**NI**	**Plan**	**CAMBA**	**JAMBA**	**CMS**	**ACAP**
SPHENISCIFORMES									
Spheniscidae									
Eudyptula minor	Little Penguin	X							
ACCIPITRIFORMES									
Accipitridae									
Pandion haliaetus	Osprey	X							
CICONIIFORMES									
Ardeidae									
Egretta novaehollandiae	White-faced Heron		X	X					
Ardea ibis	Cattle Egret						X		
CHARADRIIFORMES									
Charadriidae									
Vanellus miles	Masked Lapwing			X					
Pluvialis fulva	Pacific Golden Plover					X	X		
Charadrius bicinctus	Double-banded Plover								
Charadrius mongolus	Lesser Sand Plover					X	X		
Haematopodidae									
Haematopus longirostris	Australian Pied Oystercatcher	X							
Haematopus fuliginosus	Sooty Oystercatcher	X							
Scolopacidae									
Limosa lapponica	Bar-tailed Godwit					X	X		
Numenius phaeopus	Whimbrel					X	X		
Numenius minutus	Little Whimbrel					X	X		
Xenus cinereus	Terek Sandpiper					X	X		
Actitis hypoleucos	Common Sandpiper					X	X		
Tringa brevipes	Grey-tailed Tattler					X	X		
Tringa incana	Wandering Tattler					X	X		
Tringa nebularia	Common Greenshank					X	X		
Tringa stagnatilis	Marsh Sandpiper					X	X		
Arenaria interpres	Ruddy Turnstone					X	X		
Calidris canutus	Red Knot					X	X		
Calidris alba	Sanderling					X	X		
Calidris ruficollis	Red-necked Stint					X	X		
Calidris melanotos	Pectoral Sandpiper						X		
Calidris acuminata	Sharp-tailed Sandpiper					X	X		
Calidris ferruginea	Curlew Sandpiper					X	X		
Stercorariidae									
Stercorarius maccormicki	South Polar Skua								
Stercorarius antarcticus	Brown Skua				LC		X		

		Breeding			Action Plan	Listing			
Species	**Common name**	**E. Aust**	**LH**	**NI**		**CAMBA**	**JAMBA**	**CMS**	**ACAP**
Stercorarius pomarinus	Pomarine Jaeger					X	X		
Stercorarius parasiticus	Arctic Jaeger						X		
Stercorarius longicaudus	Long-tailed Jaeger								
Laridae									
Anous stolidus	Common Noddy	X	X	X		X	X		
Anous minutus	Black Noddy		X	X					
Gygis alba	White Tern		X	X	LC				
Procelsterna cerulea	Grey Ternlet		X	X	E				
Sterna anaetheta	Bridled Tern	X				X	X		
Sterna fuscata	Sooty Tern	X	X	X					
Sterna albifrons	Little Tern	X			LC	X	X	II	
Sterna nereis	Fairy Tern	X			LC				
Sterna dougallii	Roseate Tern	X							
Sterna striata	White-fronted Tern				LC				
Sterna sumatrana	Black-naped Tern	X				X	X		
Sterna hirundo	Common Tern					X	X		
Sterna paradisaea	Arctic Tern								
Sterna bengalensis	Lesser Crested Tern	X				X			
Sterna bergii	Crested Tern	X					X		
Larus pacificus	Pacific Gull	X			LC				
Larus dominicanus	Kelp Gull	X							
Larus novaehollandiae	Silver Gull	X							

BREEDING: E Aust – islands along southeastern Australian coast, in Great Barrier Reef and Coral Sea; LH – Lord Howe Island and satellite islands; NI – Norfolk Island and satellite islands

ACTION PLAN: conservation categories from Garnett and Crowley (2000): LC – least concern, V – vulnerable, NT – near threatened, T –threatened, E – endangered, CE – critically endangered, Ex – extinct. If two codes given, first refers to Australian breeding birds and second to populations that occur in Australian waters

LISTING: species included on external treaties to which Australia is a signatory

CAMBA – Agreement between the Government of Australia and the Government of China for the Protection of Migratory Birds in Danger of Extinction and their Environment
JAMBA – Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment
CMS – Convention on the Conservation of Migratory Species of Wild Animals (Appendix I and II)
ACAP – Agreement on the Conservation of Albatrosses and Petrel

11 Seals/Dugong

Seals

Authors: Vicky Tzioumis & Peter Shaughnessy

Description

There are ten species of seals recorded in Australian waters. This report focuses on the only two species breeding in continental Australia that are likely to be encountered in the East Marine Region (EMR). These are the Australian fur seal (*Arctocephalus pusillus doriferus*) and New Zealand fur seal (*Arctocephalus forsteri*). There are no known breeding colonies of either species in the EMR but there are historical records of Australian fur seals breeding at Seal Rocks, near Port Stephens and Montague Island in southern New South Wales (NSW). At present Montague Island is the major haul-out site along the coast of NSW for both species (Shaughnessy 1999). Although there have been a number of reports of fur seal pups on Montague Island it is considered as supporting haul-out sites rather than breeding sites (Shaughnessy et al. 2001).

New Zealand fur seals can be distinguished from the Australian fur seal by their uniformly darker coat colour, high pitched call (Australian fur seals have a deep bark), and relatively long pointed nose. They also move differently on land. New Zealand fur seals “hop” with fore-flippers moving together whereas Australian fur seals “waddle” from side to side as they move one fore flipper after the other (Goldsworthy et al. 1997).

Conservation Status

All marine mammals occurring within Australian waters are protected by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) which came into force on 16 July 2000. Under the EPBC Act, the Australian fur seal and New Zealand fur seal are listed marine species, which means it is an offence to kill, injure, take, trade, keep or move any member of either species in Commonwealth waters without a permit.

In NSW both species are listed as “vulnerable” under the *Threatened Species Conservation Act 1995* which means that the Scientific Committee (established by the *Act*) is of the opinion that they are likely to become endangered unless the circumstances and factors threatening their survival or evolutionary development cease to operate. Listing of species under the *Act* affords increased legal protection for them. It triggers an assessment and approval process for any actions that are likely to have an adverse impact, placing specific responsibilities on proponents and consent and determining authorities.

All marine mammals are protected fauna in NSW under the *National Parks and Wildlife Act*. The *Act* prohibits unauthorized people from harming fauna. The definition of ‘harm’ includes hunt, shoot, net, snare, spear, pursue, capture, trap, injure or kill but does not include harm by changing the habitat of the animal (Smith 2001).

The Australian fur seal and the New Zealand fur seal are listed under Appendix II of the Convention on International Trade in Endangered Species (CITES). This means they are not necessarily threatened with extinction now but that may be the case unless trade is closely controlled.

Habitat and Distribution

Important habitats for seals include those which support:

- breeding colonies, and waters adjacent to these colonies
- haul-out sites
- feeding grounds (for which there is little information).

Australian fur seal

Breeding colonies of Australian fur seals are restricted to Bass Strait with four colonies on islands off the Victorian coast and five on islands off the Tasmanian coastline. Haul-out sites extend from southern Tasmania into southern NSW (Montague Island and Steamers Head, Jervis Bay) and Kangaroo Island in South Australia (Shaughnessy 1999).

Australian fur seals typically inhabit rocky parts of islands with flat, open terrain. They occupy flatter areas than New Zealand fur seals at sites where they both occur (Shaughnessy 1999).

The total population of Australian fur seals is estimated to be 92 000 animals (Kirkwood et al. 2005). Despite recent increases in population size, numbers of Australian fur seals are considered to be lower than they were prior to the advent of commercial sealing. Australian fur seals are more abundant at Montague

Island than New Zealand fur seals (Shaughnessy et al. 2001) and are likely to be the more abundant species in the EMR.

New Zealand fur seal

New Zealand fur seals breed in New Zealand, on the south coasts of Western Australia and South Australia, and at Maatsuyker Island, Tasmania. Recently, New Zealand fur seals have established small breeding populations on several islands in Bass Strait (Pemberton & Gales 2004).

The preferred habitats of New Zealand fur seals are rocky parts of islands with jumbled terrain and boulders. In South Australia, they prefer sites with smoother igneous rock to rough limestone (Shaughnessy 1999).

There are an estimated 57 400 New Zealand fur seals in Australian waters. These numbers are lower than they were prior to the advent of commercial sealing (Goldsworthy et al. 2003).

Life history and ecology

The life history characteristics of the Australian and New Zealand fur seals are summarised in Table 11.1.

Table 11.1 Summary of life history, feeding and population information for Australian and New Zealand fur seals (sources: Shaughnessy 1999; DAFF 2007).

	Australian Fur Seal	**New Zealand Fur seal**
Scientific name	*Arctocephalus pusillus doriferus*	*Arctocephalus forsteri*
Abundance	92 000	57 400
Feeding	Feed primarily on fish and cephalopods, also seabirds	Feed primarily on fish and cephalopods, also seabirds (incl. little penguins)
Longevity	Male:19 years; female :21 years	Male: 15 years; female: 26 years
<u>Reproduction</u>		
Age at sexual maturity	Females: 3–6 years; males – hold territories at 8 to 13 years	Females: 6 years; males – hold territories at about 9 years
Pupping interval	1 year	1 year
Gestation	8–9 months	8–9 months
Pupping season	late October and late December	Late November to mid-January
Mating season	November–January	Mid-November–mid-January

Movements/migration

Movements of tagged fur seals have been recorded occasionally along the NSW coastline which indicates that they travel large distances but there are no records of large numbers in the EMR. Tagging studies have shown that the Australian fur seals at Montague Island come from several of the breeding colonies in Bass Strait. Tagged New Zealand fur seals from colonies in South Australia and from New Zealand have been recorded on the coast of NSW (Shaughnessy et al. 2001).

Significance of Seals in the East Marine Region

Although there are no breeding colonies of Australian or New Zealand fur seals in the EMR and the haul-out sites for both species fall within State waters, it is likely that they traverse both State and Commonwealth waters, and that they have feeding areas in Commonwealth waters of the EMR. Montague Island and Steamers Head should be considered as key areas as they are the only haul-out sites in NSW, are used by many animals for resting and are far removed from breeding grounds. There are likely to be key feeding areas nearby and research using instrumented (fitted with transmitters) animals would be required to identify these areas.

The major haul-out site at Montague Island is only 8 km from the continental shelf margin, an area typically high in primary production supporting relatively high concentrations of fish and seabirds on which the seals feed (Irvine et al. 1997). These feeding grounds are mostly in Commonwealth waters.

Fur seals in the EMR interact with the fishing industry and are the focus of tourist operations at Montague Island and Steamers Head (see below).

Although Australian fur seals currently breed at a small number of islands in Bass Strait, this range was previously more widespread. Adjacent to the EMR Australian fur seals are reported to have bred at Seal Rocks, near Port Stephens and Montague Island, off Narooma in NSW (Shaughnessy 1999). Shaughnessy (1999) recommended that long term planning for conservation should not overlook the possibility that this species may re-colonise some of its former breeding sites.

Known Interactions, threats and mitigation measures

A comprehensive summary of threatening processes to seals in Australian waters is given by Shaughnessy (1999).

Seals may be affected by several human activities including: conflict with commercial fishing; entanglement in fishing gear and other marine debris; reduction in food supply; human disturbance, including tourism, aircraft and vessels; oil spills and chemical contaminants; and diseases.

The three most important of these occurring in the EMR are considered below. To ensure the conservation of seal species management plans put in place by State authorities need to be considered in order to protect animals traversing and feeding in Commonwealth waters of the EMR.

Fishing

The main problems for fur seals in the waters of mainland Australia result from interactions with fishing operations. Australian fur seal populations are still recovering from over-exploitation during past commercial sealing operations and despite recent increases in numbers are estimated to be about half of pre-harvesting levels (Kirkwood, in Shaughnessy et al. 2003a). Similarly the New Zealand fur seal is recovering from earlier harvesting (Shaughnessy et al. 1995). As fur seal numbers increase there is potential for an increase in operational interactions between these marine mammals and fisheries in Australian waters (Shaughnessy et al. 2003b).

Interactions of seals with fisheries in the EMR are most likely to occur with the Ocean Trawl Fishery. This fishery is managed by the NSW Department of Primary Industries (DPI) which is undertaking a project to identify the broad-scale interactions that occur between fishing operations and mammals, reptiles and birds in NSW waters (DPI 2004). A scientific observer program is being introduced across all commercial fisheries in NSW. The purpose of this program is to document interactions of fishing operations with non-retained and threatened species (including seals) and to collect information on the use and effectiveness of bycatch reduction devices (DAFF 2007). The data collected from the observer program will be used to assess the need to introduce seal-excluder devices and other measures to minimise impacts between seals and fishing operations (DAFF 2007). Methods for decreasing bycatch of seals in the trawling sector are set out in the ‘Code of Fishing Practice to Minimise Seal Bycatch’ (AFMA 2001). The code also includes suggestions on how to avoid attracting seals to the fishery grounds. These are voluntary guidelines and standards of behaviour for responsible fishing practices.

There is currently limited observer data but anecdotal reports indicate that fur seals take fish from nets and interrupt fishing operations in the Ocean Trawl Fishery. The Australian fur seal may interact with the fishery in a number of ways: capture or contact with fishing gear; entanglement in discarded or lost fishing gear; competition; and illegal shooting by fishers. However, the risk to both the Australian and the New Zealand fur seal is currently considered low-medium with only a small proportion of the population affected by operations of the fishery (DPI 2004).

Seal interactions with the Ocean Trap and Line Fishery operations in the EMR are also likely, particularly south of Jervis Bay (DPI 2004). As in the Ocean Trawl Fishery there is limited observer data however there are anecdotal reports of fur seals interacting with fishing operations (DAFF 2007). In interviews conducted in 1999 with fishers from the drop-line, trawl and hand-line fisheries on the south coast of New South Wales, between Jervis Bay and Eden, drop-liners, hand-liners and trappers reported most problems with seals. Trawlers reported fewer interactions and long-liners even less. Interactions with seals occurred more often in winter (when they were more abundant in the area) than summer. More interactions were reported around Montague Island than north or south of it. The two main causes of interactions appeared to be seals preying on fish being targeted in fishing operations, and seals becoming entangled in gear (Hickman 1999).

The Lobster Fishery operating off the NSW coast has no recorded interactions with fur seals and the potential impact is currently considered low (DEH 2006).

Seals also interact with the operations of the Commonwealth Trawl Sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF). Although this fishery extends southwards from Sandy Cape in Queensland to Cape Jervis in South Australia the majority of operators fish in southern Australia—mainly off Tasmania, Victoria and South Australia. Observer programs in these regions have documented female fur seal interactions with sectors of this fishery (DAFF 2007).

A study of the seasonal overlap between the foraging areas of female Australian fur seals and fishing activity in the Commonwealth Trawl Sector found that considerable overlap occurs between the South East Trawl Fishery and the areas used by fur seals from colonies at Lady Julia Percy, The Skerries and Kanowna Island (off Victoria). This overlap does not, however, coincide with areas of the highest fishing activity. Interactions in the EMR (mainly the southern coast of NSW) are more likely to occur in spring when female fur seals undertake more dispersed foraging trips unencumbered by dependent pups (Arnould 2004).

Little is known of the interactions of seals and the recreational fishing sector in the EMR but in a comprehensive review of marine mammal interactions with fisheries it was concluded that interactions which lead to the death and entanglement of some marine mammals and economic losses for the fishing industry are inevitable (Shaughnessy et al. 2003b).

Marine debris

Apart from direct interactions with fishing operations seals can become entangled in discarded or lost fishing equipment (classed as harmful marine debris). Marine debris is considered a Key Threatening Process under the EPBC Act 1999 (see: http://www.environment.gov.au/cgi-bin/sprat/public/publicgetkeythreats.pl). In the listing of harmful marine debris as a Key Threatening Process under the EPBC Act, six endangered species and fourteen vulnerable species and one critically endangered population of Grey Nurse Shark were identified as being adversely affected by harmful marine debris.

Entanglement of fur seals in discarded fishing gear usually results in death (Shaughnessy et al. 2003b). Although impacts of this mortality on Australian seals in the EMR have not been evaluated, it is likely that fur seals in the region will become entangled based on data collected elsewhere in their range. For Australian fur seals, Pemberton et al. (1992) recorded that 1.9% of animals at haul-out sites in southern Tasmania were entangled in marine debris; this is the highest incidence of entanglement recorded for a marine mammal. A number of juvenile Australian fur seals were observed with man-made debris around their necks at Montague Island (Shaughnessy et al. 2001) and the authors stressed that fur seals are vulnerable to fishing related marine debris throughout their foraging range.

Page et al. (2004) collated data on entanglements of Australian sea lions and New Zealand fur seals on Kangaroo Island for each year between 1988 and 2002. The incidence of entanglement for fur seals was 0.9% in 2002, which was the fourth highest rate reported for a seal species. This rate did not decrease after government and fishing industry associations introduced guidelines in 2000 to reduce the impact of fishing on non-target species (Page et al. 2004). Loops of packing tape from the rock lobster fishery and trawl net fragments from the trawl fishery were found on seals most frequently. An estimated 295 New Zealand and 1119 Australian fur seals die, as a consequence of entanglement, each year in southern Australia (Page et al. 2004). At present rates of entanglement and mortality of seals in lost or discarded fishing gear in EMR waters are not systematically assessed and are likely to be underestimated (DAFF 2007).

Tourism

In southern NSW there are several haul-out sites of fur seals, most of which are of Australian fur seals, but they also include some New Zealand fur seals. Tourist operators provide seal viewing opportunities at two of these, Montague Island, off Narooma, and Steamers Head, near Jervis Bay.

The effects of tour boat operations on fur seals at Montague Island were investigated by Shaughnessy et al. (2007). As a result a minimum approach distance of tour boats to fur seal colonies of 40 m has now been gazetted as a regulation (NSW Government 2006). It has also been recommended that visitors and staff should not walk to seal colonies because the seals are likely to flee to the water when approached from on shore, especially if the wind is blowing from behind the people toward the seals, as they are sensitive to odours (Shaughnessy et al. 2007).

Monitoring of the fur seal colony at Steamers Head, near Jervis Bay has shown that seals at this haul-out site are affected by a range of disturbances such as landslides, tourist boats and bombardment at a nearby weapons range (Burleigh et al. 2007a, 2007b). The authors recommended that researchers and tourists should remain at least 75 m from the colony when animals number less than 50 and at least 100 m when there are more than 100 seals present at the haul-out site.

In reviewing the effects of seal-focussed tourism in the southern hemisphere Kirkwood et al. (2003) concluded that guidelines and regulations will need to be implemented to ensure the protection and conservation of these animals, and the sustainability of the industry.

Information Gaps

Shaughnessy (1999) identified a number of areas where research is required.

- better estimates of abundance preferably using mark-recapture of pups in breeding colonies
- monitor trends in abundance at selected colonies
- investigate feeding ecology and foraging behaviour

- obtain information on diet to assess possible ecological interactions with the fishing industry
- obtain information on operational interactions with fishers
- obtain information on movements and feeding areas using satellite linked radio transmitters and time-temperature-depth recorders.

A clearer understanding of how seals interact with many of the fisheries in the EMR is particularly important as resolution of marine mammal conflicts will come from higher levels of observer monitoring and improved education and collaboration between fishers, researchers and managers (Shaughnessy et al. 2003b).

In a review of the trophic interactions of marine mammals with fisheries Goldsworthy et al. (2003) concluded that fur seals are major consumers of marine resources in Australian waters, including species that are fished commercially. Expected increases in populations of fur seals are therefore likely to result in increased interactions of seals with fisheries operations and fished species. These interactions may have negative ecological and economic implications and, as our current understanding of trophic interactions between fisheries and fur seals is limited, there is a clear need for additional research in this area (Goldsworthy et al. 2003; Arnould 2004).

Key References and Current Research

Current Research

There is little research effort directed at seals off the NSW coast. In Victoria, research on Australian fur seals is focussed on foraging ecology using animals that have been caught and instrumented (fitted with transmitters) in breeding colonies (Roger Kirkwood, Phillip Island Nature Park, and John Arnould, Deakin University, Melbourne). Similar research is required in the EMR to identify the locations of key foraging areas for fur seals.

In South Australia, research on New Zealand fur seals is directed at foraging ecology by Simon Goldsworthy and Brad Page, SARDI Aquatic Sciences, Adelaide (e.g. Page et al. 2006), and on following trends in abundance at Kangaroo Island and the Neptune Islands (Peter Shaughnessy, South Australian Museum, Adelaide and Simon Goldsworthy).

A scientific observer program being introduced across all commercial fisheries in NSW will document interactions of fishers with seals and other marine life (DAFF 2007).

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Dugong

Dugongs occur in the inshore waters adjacent to most of the East Marine Region (EMR) including: (1) much of the Great Barrier Reef Marine Park and the Great Barrier Reef Coast Marine Park (GBR region) north of Cooktown; (2) the inshore waters of the GBR region south of Cooktown; (3) Queensland coastal waters south of the GBR region especially Hervey Bay and Moreton Bay; and (4) estuaries on the NSW central coast (~32 °S –33.5 °S) (Marsh et al. 2002; Allen et al. 2004). Stranded dugongs have been occasionally recorded further south on the coast (Allen et al. 2004). However, there is no evidence that dugongs occur in the EMR *per se* and they are no longer considered a key species for the purposes of this report.

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12 Sharks and Rays

Author: Ken Graham

  

  

Description

Sharks and rays (including ghostsharks or chimaerids) are fishes belonging to the class Chondrichthyes, which are characterised by having a skeleton made entirely of cartilage. Approximately 300 species of chondrichthyans, including 97 undescribed species, were identified from Australian waters by Last and Stevens (1994) with around 200 species occurring in the waters off New South Wales (NSW) and eastern Queensland (Appendix E). A significant proportion of this fauna was discovered in the last 30 years during exploratory research trawling of continental slope depths (200–1200 m). Although there are still many unresolved taxonomic issues with the Australian chondrichthyan fauna, ongoing research has resulted in a number of recent publications describing many new species (e.g. Last et al. 2002; Last et al. 2007). Names used in this report for undescribed species follow Last and Stevens (1994).

The most visible group of sharks in EMR waters are the large pelagic sharks and rays including the mackerel sharks (Lamnidae: white, mako sharks), whaler sharks (Carcharhinidae), hammerhead sharks (Sphyrnidae) and devilrays (Mobulidae). Some, such as the white shark, are protected in all areas, while off Queensland and northern NSW there is significant commercial exploitation of whaler and hammerhead sharks for meat and fins.

Over 80% of the Australian chondrichthyans are demersal species and, in some areas of the EMR, this group is heavily impacted by demersal fisheries, particularly by trawling on the continental slope (e.g. Graham et al. 2001). As a consequence, management authorities have instigated trip-limits for deepwater dogfishes, and several species have been listed by the IUCN as endangered or threatened (see below). In NSW, several species of demersal sharks are important components of the landed catch from the Ocean Trawl Fishery (OTF) and the Ocean Trap and Line Fishery (OTLF) and are listed in the Environmental Impact Statements (EIS) for these fisheries (DPI 2004; DPI 2006) as primary or key secondary target species. A high number of chondrichthyans, mainly small species, are also caught and discarded as bycatch in trawl fisheries with most, particularly from deepwater, not surviving capture (Graham pers. obs.).

Conservation Status

Because of their inherently slow growth rates and conservative reproductive strategies, chondrichthyans are more prone to overexploitation than other fishes. This has led to the International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) developed by the Food and Agricultural Organization (FAO) which recognises that these fish require special management, research and monitoring if they are to be harvested sustainably (Walker et al. 2005). In response, the Australian Government has developed a National Plan of Action for the Conservation and Management of Sharks (NPOA-Sharks) requiring the preparation of a Shark Assessment Report (SAR) to regularly assess the status of Australian shark stocks (AFFA 2003). For the same reasons, the Species Survival Commission of the International Union for the Conservation of Nature and Natural Resources (IUCN) has focussed on chondrichthyans, listing many Australian species under their various 'risk of extinction' categories (IUCN 2006).

The IUCN Redlist includes more than 140 chondrichthyans found in EMR waters. Three species are listed as critically endangered, one as endangered and 23 as vulnerable (Table 1); the remainder are either assessed at a lower level of risk or are data deficient (IUCN 2006). The critically endangered species include two sawfishes, usually found close inshore or in estuaries, and the Harrisson's dogfish which is endemic to the eastern Australian continental slope and is impacted by deepwater trawling off NSW. The purple eagle ray is listed as endangered as it is only known from a few specimens collected from offshore trawls off NSW and Queensland.

In Australia, the SAR lists 38 species found in the EMR (see Last and Stevens 1994) that were reported by observers in Commonwealth managed non-shark target fisheries and are considered to be sharks of concern (Table 12.1). Under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the iconic grey nurse shark is listed as critically endangered on the east coast, while the white and whale sharks are listed as vulnerable. The grey nurse and white sharks are protected in Queensland and NSW waters. In addition, the Herbst's nurse (sandtiger) shark is also protected in NSW to obviate any mis-identification with the grey nurse shark.

Habitat and Distribution

The chondrichthyan fauna of the EMR is very diverse with 200 species (125 sharks, 68 rays and 7 chimaerids) recorded from the region (Appendix E). Approximately 80% are primarily demersal (living on or near the seabed) species occupying a range of habitats from near-shore shallows and/or reef areas to deeper continental shelf and slope substrates (Table 12.2). The deeper outer-shelf and slope species are usually caught by trawl, indicating a habitat of a relatively smooth and firm sandy or muddy substrate. Species-rich families with primarily demersal habits include the catsharks (Scyliorinidae), dogfishes (Squalidae, Centrophoridae, Etmopteridae and Somniosidae), skates (Rajidae), stingrays (Dasyatidae) and stingarees (Urolophidae). While a small number may utilize both the demersal and pelagic zones, about 15% of species such as mackerel sharks (Lamnidae), whaler sharks (Carcharhinidae) and hammerheads (Sphyrnidae) are typically pelagic, some preferring inshore and coastal areas whereas others are fully oceanic. A few species, such as the white and tiger sharks, at times inhabit inshore waters but also make long oceanic migrations.

Information on distribution, habitat and depth preferences of the chondrichthyans identified from the EMR is summarised in Table 12.2.

Life history and reproductive ecology

In general, chondrichthyans are characterised by relatively slow growth, late age at maturity, low fecundity and low natural mortality. Most reach reproductive maturity at more than 75% of maximum size and either bear live young (viviparous, ovoviviparous, or oviphagous) or produce small numbers of single eggs encased in a tough horny cover (oviparous). Numbers of offspring can range from one or two every two or more years (e.g. *Centrophorus* spp.) to the whale shark which was recently found to produce as many as 300 young at a time. While the biology of many sharks and rays is unstudied, some general life history patterns are evident. Many coastal and shelf species have seasonal reproductive cycles with annual breeding, whereas in the majority of deepwater demersal species reproduction is non-seasonal and asynchronous with gestation periods up to two years or more (see Kyne & Simpendorfer 2007 for review). Chondrichthyans found in the EMR exhibit a full range of these reproductive modes and fecundity ranges (Table 12.3).

Migration

Little is known of the migratory habits of most sharks and rays. However, several species of pelagic sharks (e.g. dusky whaler, spinner shark, and hammerheads) are known to seasonally move into shallow coastal waters to breed, leading to the targeting of the young sharks by commercial and recreational fishers.

In an effort to learn more about the daily and seasonal movement patterns and the extent of the home ranges of sharks, CSIRO Marine and Atmospheric Research and state-based institutions are currently involved in a number of shark tagging studies in coastal and offshore EMR waters. Using satellite-tracking, acoustic and pop-up archival tags, the studies have focussed on grey nurse, white, and whitetip reef sharks (CSIRO 2007; Shark Research 2007), while the NSW Recreational Fishing Trust is funding the tagging of gamefish, including pelagic sharks. In addition, one hundred blue sharks were reportedly tagged by participants in the Eastern Tuna and Billfish Fishery (ETBF) during 2004–2005 (Lynch 2005).

Significance of Sharks and Rays in the East Marine Region

Given that all sharks and rays are predators they have considerable ecological significance with several species at the top of the marine food chain. The removal of top predators from marine ecosystems by various fisheries may have long-term consequences for the ecological balance of those fishery areas

(Stevens et al. 2000). Most large pelagic species feed on other fish but some, such as the white and bull sharks, opportunistically include marine mammals and birds in their prey. Their impact can therefore reach into shallow waters and interact with people. The consequence has been the implementation of protection programs along popular swimming beaches in NSW and Queensland where mesh nets and drum-lines (Queensland) are used to capture sharks at these sites. However, there are some conservation concerns about these beach protection practices because protected species such as the white shark and marine mammals are occasionally caught.

Impacts/Threats

As almost all sharks and rays occurring in the EMR are entirely marine and mobile, it is likely that very few are impacted by habitat modification or loss. There is, however, a continuing and increasing threat to many through commercial and, to a lesser extent, recreational fishery activities. Exploited species can be taken in targeted fisheries or caught incidentally in mixed-species fisheries. Non-targeted catch is either retained (byproduct) or discarded (bycatch). Beach protection programs also impact on inshore sharks but these activities do not occur within the EMR.

Fishery Impacts

Several state-based fisheries, and the Commonwealth-managed ETBF and South East Shark and Scalefish Fishery (SESSF) exploit sharks and rays in EMR waters. The Queensland East Coast Inshore Fin Fish Fishery (ECIFFF) principally targets small whaler and hammerhead sharks (see Appendix E) with over 90% of the catch taken inshore by mesh netting (Anon 2005; DPI&F 2006). Less than 20% of the 1500 t harvest, however, is caught in the EMR off southern Queensland and the main target species for this area are not reported separately (Gribble et al. 2005). In a recent Queensland east coast shark fishery assessment, sustainability risks were assigned to 20 commercially exploited sharks and rays in the ECIFFF (Gribble et al. 2005); assessments for 6 species that contributed to 80% of observed catches are included in Table 12.4. The NSW catch of pelagic sharks by participants in the OTLF is now in excess of 150 t per annum (NSW DPI data) but new management plans are being formulated to cap effort in the fishery. In coastal and offshore waters, recreational fishers in NSW and Queensland also target pelagic sharks but, in gamefish tournaments at least, over 70% of sharks are tagged and released (Murphy et al. 2002).

The main impact on pelagic sharks in the EMR is by the ETBF, both as byproduct and bycatch. While the jurisdiction of this fishery extends from Cape York to the Victoria-South Australia border, almost all fishing is in EMR waters. Effort is concentrated off the northern half of NSW and southern half of Queensland and spans the width of the Australian Fishing Zone including waters around Lord Howe and Norfolk Islands (DAFF 2005). Reported shark production exceeded 330 t in 2001/02 but declined to about 130 t in 2004/05, partly because of reduced effort (Lynch 2005). Over 20 species were reported in the catch of almost 12000 sharks (including a small number of rays), although more than 70% of this number and 80% of the retained catch was comprised of just three species: blue shark, bronze whaler, and shortfin mako

(Table 12.5). While over 80% of the mako catch was retained, more than 90% of blue sharks and 50% of bronze whalers were discarded; overall, only 32% of the total number of sharks caught was retained.

Rose and McLoughlin (2001) highlighted the high levels of shark bycatch and the practice of 'shark-finning', particularly in the ETB Fishery. With an increasing world-wide demand for shark fins, the Australian Fisheries Management Authority (AFMA) (with complementary State legislation) banned the practice of shark finning at sea by prohibiting the possession or landing of fins separate from the carcasses and also enforcing a limit of 20 sharks per vessel per fishing trip (DAFF 2005).

There appears to be only minor fishery impact on manta rays in the EMR. Last and Stevens (1994) report up to four species in tropical waters off Queensland although only two (*Manta birostris* and *Mobula eregoodootenkee*) appear to be common in Australian waters. Manta rays mainly inhabit shallow continental shelf and coral reef areas but are occasionally caught by the ETBF: 23 captures were reported in the 2004/05 fishery logbooks and 19 captures were recorded by onboard observers; none was retained (Lynch 2005). Manta rays are commercially exploited in Indonesia but they are particularly susceptible to fishing mortality as they produce only single young after a 1–3 year gestation period (White et al. 2006).

Demersal sharks in the EMR are mainly exploited by the NSW ocean trawl (OTF) and ocean trap and line (OTLF) fisheries, and the NSW trawl sector of the SESSF. Landings from the Queensland trawl fishery are now negligible since the 1999 mandatory introduction of turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) (DPI&F 2006). Over 600 t of sharks and rays were reported from waters off NSW in 2000–01 (DPI 2004; DPI 2006) although this represents less than 10% of the total NSW fishery production. Gummy shark and wobbegongs are Primary and Key Secondary species in the OTLF being at times targeted by line fishers. In contrast, the OTF shark and ray catch is non-targeted, being mostly taken as byproduct when trawling for prawns or teleosts. The shovelnose ray is a Primary trawl species contributing almost 20% of the total chondrichthyan catch, while angel and saw sharks are ranked as Key Secondary species. All these sharks have been assessed as being at High or Intermediate-High risk from fishery exploitation because of their low reproductive resilience and factors such as low refuge availability, poor selectivity of fishing gear, low survival during capture processes and inadequate stock assessments (Table 12.4).

Stocks of upper slope sharks, particularly *Centrophorus* dogfishes, have been greatly depleted through trawling over the last 30 years (Graham et al. 2001) with landings now very low and less than 5% of the total shark catch. In response, AFMA has imposed limits for Harrisson's, Endeavour and southern dogfishes, and has implemented a closed area to trawling on the upper slope off Sydney (DAFF 2006). There are also concerns for sharks in mid-slope depths (> 600 m) which are occasionally targeted by SESSF trawlers off central and southern NSW. Several species of potentially commercial dogfishes were identified in mid-slope surveys in the 1980s with the brier shark (*Deania calcea*) contributing to more than half of the total catch in depths between 700 and 1200 m (Graham 1990). Quota management for deepwater dogfishes was introduced by AFMA in 2005 and covers species of the genera *Centroscymnus*, *Centroscyllium*, *Centroselachus*, *Deania*, *Etmopterus*, and *Proscymnodon* that occur in southern EMR waters (Appendix E).

Non-commercial chondrichthyans are an important component of trawl bycatch biomass and, like commercially exploited species, equally vulnerable to fishery impact as few survive the trauma of capture. Compared to other bycatch, they are relatively large in size and, while they usually contribute a small fraction of catch numbers, they often form a significant proportion of total catch weight. More than 75 non-commercial demersal species have been recorded from trawl grounds off NSW (Appendix E) although many of these are infrequently caught by commercial vessels. Key bycatch chondrichthyans on EMR trawl grounds (off NSW) are indicated in Table 12.6. On the continental shelf and upper slope, these were Port Jackson sharks (inshore), stingarees (Urolophidae) and skates (Rajidae), while at midslope depths over 90% of the shark and ray bycatch was comprised of deepwater catsharks (*Apristurus* spp.) and lantern sharks (Etmopteridae). The NSW OTF EIS process determined that many of these trawl bycatch species were at high risk from fishery impacts (Table 12.6).

Information Gaps

In fisheries where sharks and rays are taken as byproduct and bycatch, there is often poor recording at a species level leading to the publication of production statistics that contain a large proportion of the catch reported as ‘mixed’ or ‘unspecified’ sharks. Better identification of species at industry level would lead to more precise catch reporting and allow fishery managers to better understand and conserve stocks. Fishery management also needs improved biological information on chondrichthyans, particularly exploited species. Apart from recent studies into the stock structure and biology of deepwater dogfishes (Daley et al. 2002; Irvine 2004; Graham 2005; Braccini et al. 2006) and shovelnose rays (Kyne & Bennett 2002) and earlier work on carcharhinid sharks by Stevens and McLoughlin (1991), there have been few studies or publications into the basic biology of most species found in the EMR.

Key References and Current Research

Current Research

The seminal work ‘Sharks and Rays of Australia’ by Last and Stevens in 1994 comprehensively described the Australian chondrichthyan fauna for the first time and resulted in a new awareness of the diversity of the fauna. Scientists at the CSIRO Marine and Atmospheric Research (CMAR) laboratories in Hobart, along with taxonomists in other institutions, are currently working towards a revision of ‘Sharks and Rays of Australia’ to be published within two years (P. Last pers. comm.). This will further address the taxonomy of many Australian chondrichthyans, including some commercial species, which are still unresolved. Allied to this is the international Barcode of Life project that aims to DNA barcode all fish species (see www.fishbol.org); many Australian species have already been included in this study but comprehensive collections of samples from the EMR (and other regions) will aid the resolution of taxonomic information gaps.

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Table 12.1 Conservation status of chondrichthyans recorded in catches in the EMR that are listed by the International Union for the Conservation of Nature (IUCN), the Shark Advisory Group (SAR), the Environment Protection and Biodiversity Conservation Act 1999 (EPBC).

Family	Scientific Name	Common Name	IUCN	SAR	EPBC
Centrophoridae	*Centrophorus harrissoni*	Harrisson's Dogfish	CR	C	
Pristidae	*Pristis clavata*	Dwarf Sawfish	CR		
Pristidae	*Pristis zijsron*	Green Sawfish	CR	C	
Myliobatidae	*Myliobatus hamlyni*	Purple Eagle Ray	EN		
Odontaspididae	*Carcharias taurus*	Greynurse Shark**	VU	C	CR
Odontaspidae	*Odontaspis ferox*	Sandtiger Shark*	VU	C	
Lamnidae	*Carcharodon carcharias*	White Shark**	VU	C	VU
Lamnidae	*Isurus oxyrinchus*	Shortfin Mako	VU	C	
Brachaeluridae	*Brachaelurus colcloughi*	Colclough's Shark	VU	C	
Stegastomatidae	*Stegastoma fasciatum*	Zebra Shark	VU		
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny Shark	VU		
Rhincodontidae	*Rhincodon typus*	Whale Shark	VU	C	VU
Carcharhinidae	*Carcharhinus longimanus*	Oceanic Whitetip Shark	VU	C	
Carcharhinidae	*Negaprion acutidens*	Lemon Shark	VU		
Hemigaleidae	*Hemipristis elongata*	Fossil Shark	VU		
Centrophoridae	*Centrophorus squamosus*	Leafscale Gulper Shark	VU	C	
Squatinidae	*Squatina* sp. A	Eastern Angelshark	VU		
Rhinidae	*Rhina ancylostoma*	Shark Ray	VU		
Rhinidae	*Rhynchobatus australiae*	Whitespotted guitarfish	VU	C	
Rhinobatidae	*Rhinobatos typus*	Giant Shovelnose Ray	VU		
Dasyatidae	*Dasyatis fluviorum*	Estuary Stingray	VU		
Dasyatidae	*Taeniura meyeni*	Blotched Fantail Ray	VU		
Dasyatidae	*Urogymnus asperrimus*	Porcupine Ray	VU	C	
Urolophidae	*Urolophus bucculentus*	Sandyback Stingaree	VU		
Urolophidae	*Urolophus sufflavus*	Yellowback Stingaree	VU		
Urolophidae	*Urolophus viridis*	Greenback Stingaree	VU		
Myliobatidae	*Aetomylaeus nichofii*	Banded Eagle Ray	VU		
Pseudocarchariidae	*Pseudocarcharias kamohari*	Crocodile Shark	LR-nt	C	
Triakidae	*Galeorhinus galeus*	School Shark	LR-cd	C	
Triakidae	*Hypogaleus hyugaensis*	Pencil Shark	LR-nt	C	
Triakidae	*Mustelus antarcticus*	Gummy Shark	LR-cd	C	
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus amblyrhynchos*	Grey Reef Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus brevipinna*	Spinner Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus brachyurus*	Bronze Whaler	NT	C	

Family	Scientific Name	Common Name	IUCN	SAR	EPBC
Carcharhinidae	*Carcharhinus leucas*	Bull Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus limbatus*	Common Blacktip Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus melanopterus*	Blacktip Reef Shark	LR-nt	C	
Carcharhinidae	*Carcharhinus obscurus*	Dusky Whaler	LR-nt	C	
Carcharhinidae	*Carcharhinus plumbeus*	Sandbar Shark	LR-nt	C	
Carcharhinidae	*Galeocerdo cuvier*	Tiger Shark	LR-nt	C	
Carcharhinidae	*Prionace glauca*	Blue Shark	LR-nt	C	
Carcharhinidae	*Triaenodon obesus*	Whitetip Reef Shark	LR-nt	C	
Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead	LR-nt	C	
Sphyrnidae	*Sphyrna zygaena*	Smooth Hammerhead	LR-nt	C	
Pristiophoridae	*Pristiophorus* sp. A	Eastern Sawshark	NT	C	
Myliobatidae	*Aetobatus narinari*	Whitespotted Eagle Ray	NT	C	
Chimaeridae	*Hydrolagus ogilbyi*	Ogilby's Ghostshark	NT	C	
Hexanchidae	*Notorynchus cepedianus*	Broadnose shark	DD	C	
Sphyrnidae	*Sphyrna mokarran*	Great Hammerhead	DD	C	
Carcharhinidae	*Carcharhinus amboinensis*	Pigeye Shark	DD	C	
Alopiidae	*Alopias* spp.	Thresher Sharks	DD	C	
Dalatiidae	*Dalatias licha*	Black Shark	DD	C	

CR: critically endangered; DD: data deficient; EN: endangered; LR-nt: Low Risk-near threatened; LR-cd: Low Risk-conservation dependent; C: shark of concern; *: protected in NSW; **: protected in NSW and Queensland.

Table 12.2 Distribution of depth preferences for chondrichthyans found in the EMR.

Habitat	Depth Range (m)	Demersal	Demersal/ Pelagic	Pelagic
Inshore: estuaries, rivers	< 50	2		
Inshore - continental shelf	10–200	63	8	13
Continental shelf - upper continental slope	10–400	3		
Outer continental shelf - upper continental slope	100–700	21	3	
Upper slope	200–700	27		
Continental slope	300–1200	41	3	2
Continental shelf - oceanic	10 – >1000			9
Outer continental shelf - oceanic	100 – >1000			5
Total		157	14	29

Table12. 3 Summary of reproduction information for chondrichthyans in the EMR (Source: SAR, recent publications).

Family	Species	Male mature	Female mature	Max. size	Repro. mode	Litter Size	Gest. Time
Hexanchidae	*Heptranchias perlo*	75	100	137	OVO	9–20	
Hexanchidae	*Hexanchus griseus*	310	420	550	OVO	30–108	
Hexanchidae	*Hexanchus nakamurai*	123	142		OVO	13	
Hexanchidae	*Notorynchus cepedianus*	150	220	300	OVO	82–95	12
Chlamydoselachidae	*Chlamydoselachus anguineus*	~115	145	196	OVO	2–10	
Heterodontidae	*Heterodontus galeatus*	60	70	130	OVI		>5
Heterodontidae	*Heterodontus portusjacksoni*	75	85–90	165	OVI	10–16	9–12
Odontaspididae	*Carcharias taurus*	220	220	318	OPH	2	9–12
Odontaspididae	*Odontaspis ferox*	275	~325	450			
Lamnidae	*Carcharodon carcharias*	350–410	400–500	640	OPH	7–10	>12
Lamnidae	*Isurus oxyrinchus*	195	280	394	OPH	4–16	
Alopiidae	*Alopias superciliosus*	270	300	460	OPH	2–4	
Alopiidae	*Alopias vulpinus*	260–340	350–400	550	OPH	2–4	
Brachaeluridae	*Brachaelurus colcloughi*			>85	OVO	6–8	
Brachaeluridae	*Brachaelurus waddi*			120	OVO	7–8	
Ginglymostomatidae	*Nebrius ferrugineus*	225	230	320	OVO	8	
Hemiscyllidae	*Chiloscyllium punctatum*	70		105	OVI		
Hemiscyllidae	*Hemiscyllium ocellatum*	60		107	OVI	2–50	
Orectolobidae	*Orectolobus halei*	178	174	207	OVO		
Orectolobidae	*Orectolobus maculatus*	128	127	160	OVO	8–31	
Orectolobidae	*Orectolobus ornatus*	81	81	102	OVO	4–18	
Stegastomatidae	*Stegostoma fasciatum*			235	OVI		
Rhincodontodae	*Rhincodon typus*	>900	>900	1200	OVO	300*	
Scyliorhinidae	*Apristurus* sp B	53–57		>67	OVI		
Scyliorhinidae	*Asymbolus analis*	52		>60	OVI		
Scyliorhinidae	*Asymbolus rubiginosus*	37		>53	OVI		
Scyliorhinidae	*Cephaloscyllium laticeps*	82		100	OVI		
Scyliorhinidae	*Cephaloscyllium* sp. A	70		>94	OVI		
Scyliorhinidae	*Galeus boardmani*	40	43	61	OVI		
Triakidae	*Galeorhinus galeus*	120	130	175	OVO	15–43	12
Triakidae	*Hypogaleus hyugaensis*	95	95	>130	VIV	8–11	12
Triakidae	*Mustelus antarcticus*	80	85	175	OVO	1–38	11–12
Carcharinidae	*Carcharhinus albimarginatus*	170	195	275	VIV	1–11	12
Carcharinidae	*Carcharhinus altimus*	190	225	285	VIV	3–15	
Carcharinidae	*Carcharhinus amblyrhynchoides*	110–115	110–115	170	VIV	3	9–10
Carcharinidae	*Carcharhinus amblyrhynchos*	130–140	130–140	255	VIV	1–6	12
Carcharinidae	*Carcharhinus amboinensis*	210	215	280	VIV	6–13	
Carcharinidae	*Carcharhinus brachyurus*	235	245	295	VIV	7–20	
Carcharinidae	*Carcharhinus brevipinna*	190–200	190–200	280	VIV	3–15	
Carcharinidae	*Carcharhinus cautus*	80–85	80–85	150	VIV	1–5	8–10
Carcharinidae	*Carcharhinus dussumieri*	70	70	90	VIV	2	
Carcharinidae	*Carcharhinus falciformis*	200–210	200–210	330	VIV	2–15	
Carcharinidae	*Carcharhinus fitzroyensis*	80	90	135	VIV	1–7	
Carcharinidae	*Carcharhinus leucas*	160–225	180–230	340	VIV	1–13	10–11
Carcharinidae	*Carcharhinus limbatus*	135–180	120–190	250	VIV	4–11	11–12
Carcharinidae	*Carcharhinus longimanus*	175–195	180–200	300	VIV	1–15	12
Carcharinidae	*Carcharhinus macloti*	70–75	70–75	110	VIV	2	12
Carcharinidae	*Carcharhinus melanopterus*	95–110	95–110	140	VIV	3–4	8–9

Family	Species	Male mature	Female mature	Max. size	Repro. mode	Litter Size	Gest. Time
Carcharinidae	*Carcharhinus obscurus*	280	280	365	VIV	3–14	22–24
Carcharinidae	*Carcharhinus plumbeus*	130–180	145–185	240	VIV	1–14	9–12
Carcharinidae	*Carcharhinus sorrah*	90–95	90–95	160	VIV	1–8	10
Carcharinidae	*Carcharhinus tilstoni*	110	115	200	VIV	1–6	10
Carcharinidae	*Galeocerdo cuvier*	300	330	600	OVO	10–80	12
Carcharinidae	*Loxodon macrorhinus*	60	60	90	VIV	2	
Carcharinidae	*Negaprion acutidens*	220	220	300	VV	1–14	10–11
Carcharinidae	*Prionace glauca*	220	220	383	VIV	4–135	9–12
Carcharinidae	*Rhizoprionodon acutus*	75	75	100	VIV	1–8	
Carcharinidae	*Rhizoprionodon taylori*	40	45	81	VIV	1–8	12
Carcharinidae	*Triaenodon obesus*	105	105	170	VIV	1–5	
Hemigaleidae	*Hemigaleus australiensis*	60	65	110	VIV	1–19	6
Hemigaleidae	*Hemipristis elongata*	110	120	230	VIV	2–11	7–8
Sphyrnidae	*Eusphyra blochii*	108	120	186	VIV	6–25	10–11
Sphyrnidae	*Sphyrna lewini*	140–160	200	350	VIV	13–23	9–10
Sphyrnidae	*Sphyrna mokarran*	225	210	600	VIV	6–33	11
Sphyrnidae	*Sphyrna zygaena*	250	265	350	VIV	20–50	10–11
Centrophoridae	*Centrophorus harrissoni*	83	99	112	OVO	1–2	
Centrophoridae	*Centrophorus* cf. *moluccensis*	71	85	95	OVO	2	
Centrophoridae	*Centrophorus squamosus*	100	110	160	OVO	5–9	
Centrophoridae	*Centrophorus* cf. *uyato*	81	98	110	OVO	1	
Centrophoridae	*Deania calcea*	75	97	120	OVO	6–12	
Centrophoridae	*Deania quadrispinosa*	80	94	117	OVO	5–15	
Dalatiidae	*Dalatias licha*	100	120	160	OVO	10–16	
Etmopteridae	*Centroscyllium kamoharai*	41	53	63	OVO	3–22	
Etmopteridae	*Etmopterus lucifer*	30	34	47	OVO		
Etmopteridae	*Etmopterus* cf. *unicolor*	50	59	75	OVO	2–21	
Somniosidae	*Centroscymnus coelolepis*	80	99	120	OVO	13–17	
Somniosidae	*Centroscymnus owstoni*	72	94	120	OVO	13–15	
Somniosidae	*Centroselachus crepidater*	64	82	102	OVO	4–8	
Somniosidae	*Proscymnodon plunketi*	110	130	170	OVO	17–36	
Squalidae	*Squalus chloroculus*	63	81	93	OVO	4–10	<24
Squalidae	*Squalus grahami*	51	63	73	OVO	1–5	
Squalidae	*Squalus megalops*	38	48	61	OVO	1–3	24
Oxynotidae	*Oxynotus bruniensis*	60		>72	OVO	7*	
Pristiophoridae	*Pristiophorus nudipinnis*	90		>99	OVO		9–10
Pristiophoridae	*Pristiophorus* sp A	80	90	125	OVO	4–9	
Squatinidae	*Squatina australis*	80–90	90–100	120	VIV		
Squatinidae	*Squatina* sp A	80–90	100–110	132	VIV		
Rhynchobatidae	*Rhynchobatus australiae*	110		300			
Rhinobatidae	*Aptychotrema rostrata*	64?	58?	120	VIV	4–18	3–5
Rhinobatidae	*Rhinobatos typus*			270			
Rhinobatidae	*Trygonorrhina* sp A						
Gymnuridae	*Gymnura australis*	35–40		>73dw	VIV	2–6	

Size at maturity - maximum: cm; reproductive mode - OVI: oviparous; OVO: ovoviviparous; OPH: oviphagous; VIV: viviparous

Table 12.4 Summary of risk assessments for key commercial sharks and rays in the NSW Ocean Trawl and Ocean Trap and Line Fisheries, and in the Queensland East Coast Inshore Fin Fish Fishery (sources: DPI 2004, DPI 2006, DPI&F 2006).

Family	Species	OTF	OTLF	FIP	Resilience	Risk (NSW)	Risk (Qld)
Orectolobidae	*Orectolobus* spp.	S	K2	Int./High	Mod/Mod-Low	Int./High	
Triakidae	*Mustelus antarcticus*	S	P	Int./High	Mod/Mod-Low	Int./High	
Carcharhinidae	*Carcharhinus* spp.	S	S	Low	Mod-Low	Int.-Low	
Carcharhinidae	*Carcharhinus amblyrhynchos*						Int.
Carcharhinidae	*Carcharhinus dussumieri*						Int.-High
Carcharhinidae	*Carcharhinus sorrah*						Int.-Low
Carcharhinidae	*Carcharhinus tilstoni*						Int.-Low
Carcharhinidae	*Rhizoprionodon acutus*						Int.-Low
Sphyrnidae	*Sphyrna lewini*						Int.-High
Centrophoridae	*Centrophorus* spp.	S	S	High	Mod-Low	High	
Squalidae	*Squalus* spp.	S	S	Int.-High	Mod-Low	High	
Pristiophoridae	*Pristiophorus* sp. A	K2		Int.-High	Mod-Low	High	
Squatinidae	*Squatina* spp.	K2		Int.-High	Mod-Low	High	
Rhinobatidae	*Aptychtrema rostrata*	P		High	Mod-Low	High	
Urolophidae	*Urolophus bucculentus*	S		High	Low-Mod	High	

P: primary; K2: key secondary; S: secondary; FIP: fishery impact profile; Low-Intermediate-High; Resilience: Low-Moderate-High; Risk: Low-Intermediate-High

Table 12.5 Summary of the shark catch in the East Coast Tuna and Billfish Fishery for 2004/05 (data from Lynch, 2005).

Species	Common Name	C (no.)	C/TC (%)	RC (no.)	RC/C (%)	RC/TRC (%)	W (kg)	W/TW (%)
Prionace glauca	Blue Shark	4931	41.8	395	8.0	10.4	14835	11.2
Isurus oxyrinchus	Shortfin Mako	2534	21.5	2035	80.3	53.6	65615	49.3
Carcharhinus brachyurus	Bronze Whaler	1216	10.3	528	43.4	13.9	23746	17.9
Carcharhinus longimanus	Oceanic Whitetip Shark	688	5.8	164	23.8	4.3	5164	3.9
Sphyrna spp.	Hammerhead	679	5.8	270	39.8	7.1	8435	6.3
Galeocerda cuvier	Tiger Shark	401	3.4	169	42.1	4.5	6866	5.2
	Misc	1354	11.5	238	17.6	6.2	8362	6.3
Total for all species		11803 (TC)		3799 (TRC)			133023 (TW)	

C: number of individuals for each species; TC: total number of individuals; RC: number of individuals retained for each species; TRC: total number retained; W: weight of all individuals of each species; TW: total weight for all species combined

Table 12.6 Percentage capture and risk-assessments of key bycatch chondrichthyans on NSW trawl grounds (risk assessments from NSW OTF and OTLF EIS: DPI, 2004 and DPI, 2006). Key bycatch refers to the most commonly caught (present in at least 20% of trawls) species in FRV *Kapala* trawl surveys across various depth strata.

Family	Species	*Inshore (%)	Shelf (%)	Upper slope (%)	Mid-slope (%)	Risk
Hexanchidae	*Heptranchias perlo*	-	2	23	-	High
Heterodontidae	*Heterodontus portusjacksoni*	~41	18	-	-	Intermediate-Low
Parascyllidae	*Parascyllium collare*	~ 9	26	-	-	Low
Scyliorhinidae	*Apristurus* sp. G	-	-	-	58	-
Scyliorhinidae	*Apristurus* sp. A	-	-	-	47	-
Scyliorhinidae	*Apristurus* sp. B	-	-	-	36	-
Scyliorhinidae	*Asymbolus rubiginosus*	~ 1	43	3	-	Low
Scyliorhinidae	*Cephaloscylium* sp. A	-	3	31	-	Low
Scyliorhinidae	*Galeus boardmani*	-	-	27	-	High
Etmopteridae	*Centroscyllium kamoharai*	-	-	-	52	-
Etmopteridae	*Etmopterus lucifer*	-	-	20	34	Intermediate-High
Etmopteridae	*Etmopterus* sp.cf. *unicolor*	-	-	-	61	-
Hypnidae	*Hypnos monoptyerygium*	~30	-	-	-	-
Torpedinidae	*Torpedo macneilli*	-	7	24	5	-
Narcidae	*Narcine tasmaniensis*	-	32	20	-	High
Rajidae	*Dipturus australis*	~11	93	14	-	High
Rajidae	*Dipturus gudgeri*	-	-	24	-	High
Rajidae	*Dipturus* sp. B	-	-	31	-	High
Rajidae	*Dipturus* sp. C	-	-	18	-	High
Rajidae	*Dipturus* sp. I	-	-	-	24	-
Rajidae	*Notoraja* sp. A	-	-	-	55	-
Rajidae	*Pavoraja nitida*	-	15	24	-	High
Urolophidae	*Trygonoptera testacea*	~48	-	-	-	High
Urolophidae	*Trygonoptera* sp. B	~ 15	2	-	-	High
Urolophidae	*Urolophus paucimaculatus*	~20	3	-	-	High
Urolophidae	*Urolophus kapalensis*	~43	-	-	-	High
Urolophidae	*Urolophus sufflavus*	~ 3	53	5	-	High
Urolophidae	*Urolophus viridis*	~ 4	96	17	-	High

Inshore: < 100 m; Shelf: 100–200 m; Upper slope: 200–650 m; Mid-slope: 650–1200 m; * %capture approximated from three inshore surveys

13 Sponges

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Description

Sponges (Porifera) are a predominantly marine phylum living from the intertidal to the abyssal (deepest ocean) zone. Worldwide there are approximately 8,500 described species (Van Soest et al. 2005), with about twice this number, conservatively estimated, remaining to be named (Hooper & Lévi 1994). The Australian fauna, including continental and territorial seas, is comprised of approximately 1,500 described species (Hooper & Wiedenmayer 1994; ABIF-Fauna 2004), although at least 5,000 have so far been recorded (Hooper & Ekins 2005). Most of these have been discovered over the past decade during the search for marine natural products with potentially therapeutic pharmaceutical benefits (Munro et al. 1999; Faulkner 2002). Most of these sponge species were collected from the shallow coastal seabed surrounding the continent and territorial islands, with only a very small proportion sampled from deeper waters off the continental shelf, seamounts, and emergent islands and reefs in the Coral and Tasman Seas along the east coast of Australia.

Sponges occupy most marine habitats, including those found or likely to be found within the vast East Marine Region (EMR), from shallow rocky and coral reefs, algal and seagrass beds, to caves, buried in rubble or binding the interstices within coral reefs, to deeper rubble and sandy slopes, to deep sea habitats including the extremophile (those living in 'extreme' conditions) communities. In all these communities, where sponges are documented in Australia and the Indo-west Pacific, they exhibit very patchy spatial distributions (Fromont 2004; Schlacher et al. 2007), at both small and large scales (Hooper & Kennedy 2002; Hooper et al. 2002; Hooper & Ekins 2005; de Voogd et al. 2006). At times they form the dominant structural benthic component of a community (Wilkinson 1983a), whereas in an adjacent area they may be practically absent (Pitcher & Jackson 2006). Sponge community structure is determined by a number of processes including:

- terrestrial impacts (e.g. freshwater input, turbidity, sedimentation, light penetration, nutrient levels, food particle size availability)

- geomorphology (e.g. microhabitat availability, type of substrate, aspect of the seabed, exposure to waves and currents, depth)

- small scale random events (e.g. patterns and timing of arrival and survival of larvae and asexually produced propagules, effects of severe storm events on fragmentation and dispersal)

- larger scale biogeographic events (e.g. historical changes to physical barriers and current patterns, climate change impacts, presence or absence of carbonate platforms versus other substrata, etc.).

Light intensity and sea temperatures play an important role in structuring a few prominent sponge communities (e.g. shallow subtidal sponge populations with photosynthetic symbiotic bacteria, predominant in coral reefs), but this is not typical for most species which are distributed along large depth gradients.

Unlike some other marine invertebrate phyla, there are no apparent latitudinal gradients of sponge species richness from temperate to tropical waters, with both having patchy mosaics of very rich and poor faunas. The composition of the sponge fauna, however, changes substantially along the east coast of Australia, with several major faunal transitions (or species turnover points) occurring from Tasmania to Cape York (overview in Hooper & Ekins 2005). Within the EMR several studies have examined factors and processes impacting on sponge community structure, particularly in temperate and subtropical waters (Roberts 1996; Roberts & Davis 1996; Wright et al. 1997; Hooper & Kennedy 2002; Davis et al. 2003; Roberts et al. 2006), but our understanding of the relative importance of these processes remains rudimentary.

The most comprehensive ecological inventory of macrobenthic species along the east coast of Australia, including sponges, has recently been completed adjacent to the EMR in the Great Barrier Reef (GBR) Marine Park and Torres Straits regions (Pitcher & Jackson 2006; Pitcher et al. 2006). There are some studies of the effects of trawling on sponge faunas from the GBR (Pitcher et al. 1997; Poiner et al. 1998), but there are very scant data on these or other impacts on the sponge faunas, or indeed the faunal composition, from any of the Provinces within the EMR.

Conservation Status

No sponges are listed or protected under any International, Commonwealth or State legislation (aside from the requirement for permits to access faunas in protected and other special areas). None are listed as confirmed Introduced Marine Pests on the National Introduced Marine Pest (IMPs) Information System (Hewitt et al. 2002), although several widespread species (e.g. *Mycale (Zygomycale) parishii, Tedania anhelans*) found in many ports and harbours around the Indo-west Pacific are suspected IMPs transported by ship bilge water or other vectors. This has not yet been corroborated by genetic or other testing, such as that used to identify the aggressive invasive species of sponge, *Mycale armata* in Hawaiian waters (Coles & Bolick 2006).

Habitat and Distribution

Geographic distributions

Theoretically, sponges potentially occupy all marine habitats at all depths, and are distributed throughout the EMR, however, there is little information for most of provinces of the region, particularly the oceanic ones. Current knowledge of sponge distributions and habitats is summarised below, in decreasing order of data availability. Spatial distribution data from the combined Queensland (QM) and Australian Museum (AM) collections are shown in Figure 13.1.

1. Southeast Shelf Transition, Central Eastern Shelf Province and Central Eastern Shelf Transition: Extensive museum collections of sponges exist from various hard and soft bottom communities within these near-coastal provinces of the EMR. These collections include specimens from the intertidal to deeper trawled areas on the edge of the continental shelf. This near-coast fauna can be further subdivided into two components: northern and southern.

1.1. Central Eastern Shelf Transition: Includes a rich sponge fauna of around 300 collected species (Hooper & Ekins 2005), of which less than a third have been named in the literature (Table 13.1.2), but with some published information on their patterns of richness, geographic distributions and levels of endemism (Davie & Hooper 1998; Hooper et al. 2002; Hooper & Ekins 2005). This area is a significant transition zone with clearly defined species changes at the larger spatial scale. Incursions of temperate and tropical species as well as a suite of other species unique to the region occur at smaller spatial scales (Davie & Hooper 1998).

1.2. Southeast Shelf Transition and Central Eastern Shelf Province: This Province represents some of the best known Australian sponge faunas, consisting of around 850 nominal species names in the literature (ABIF-Fauna 2004), although only about 340 species are now considered to be valid (the remainder being junior synonyms of other species; Van Soest et al. 2005).

2. Northeast Transition and Northeast Province: Knowledge of the sponge faunas from these large oceanic bioregions is restricted to small patchy surveys of some of the coral reef communities in the Coral Sea Territories, with most specimens collected at depths accessible by SCUBA; Northeast Transition (e.g. Osprey, Shark and Bougainville Reefs) and Northeast Province (e.g. Holmes, Saumarez, Herald and Marion Reefs). Approximately 200 species have been identified from this fauna (Table 13.1.4) (Wörheide & Reitner 1996). It is expected that the fauna is orders of magnitude higher than presently known, especially from the deep water surrounding the seamounts and beyond. Various collections of sponges from these Provinces are housed at the Australian Institute of Marine Science (AIMS) and the Museum of Tropical Queensland (MTQ), but very few of these samples have been studied (Hooper & Lévi 1989).

3. Coral Sea Territories: Virtually no documented sponge faunas exist from the other Provinces in the Coral Sea Territories. No sponge collections are known from the Cape Province. Approximately 100 species are known from the Kenn Transition and Kenn Province (Table 13.1.5), primarily from Wreck Reef, Bird

Island and Cato Reef, and are members of the coral reef sponge community not the deep water fauna. Only eight species are known from the Central Eastern Transition (Table 13.1.3) from Saumarez Reef, although additional collections from this region may also reside at AIMS including unpublished species from Lihou and other reefs.

4. Central Eastern Province and Tasman Basin Province: The sponge faunas of the more southern oceanic regions are similarly poorly known in terms of collections, with only 7 and 15 species, respectively, collected from off the coast of NSW out to the Taupo and Brittania Seamounts (Table 13.1.6 and 13.1.7).

5. Lord Howe Province and Norfolk Island Province: Until recently virtually no sponge collections (viz. with any notable taxonomic resolution applied) were known from either of these provinces, aside from some small collections from Elizabeth and Middleton Reefs in the AM (Hutchings 1992), and a few species collected from shallow waters by Neville Coleman in the QM (see also Ponder et al. 2002). In 2003 some extensive deep water surveys were undertaken during the NORFANZ expeditions to both these Provinces, revealing a rich and diverse sponge fauna of approximately 140 and 100 species, respectively (13.1.8 and 13.1.9), most from deeper waters (http://www.environment.gov.au/coasts/discovery/voyages/norfanz/index.html). This collection is only partially identified to Operational Taxonomic Unit (OTU) level (i.e. differentiated to a unique taxon but still unnamed, and hence useless in an international context), but already several new species and genera have been discovered (Schlacher-Hoenlinger et al. 2005), with the expectation that much of this collection will be new to science. A brief analysis of biodiversity patterns amongst the deep sea sampling stations in both provinces, such as comparative species composition, richness and endemism has been published (Schlacher-Hoenlinger 2006).

Taxonomic distributions

Spatial distributions of QM and AM samples combined for the three classes of Porifera: Demospongiae, Calcarea and Hexactinellida, are depicted in Figures 13.2–13.4. Although overwhelmingly numerous in terms of samples and diversity of species, demosponge distributions (Figure 13.2) generally are not good indicators of depths sampled as they are found in virtually all habitats and span a variety of depths. Conversely, calcarean and hexactinellidan sponges are often better indicators of depth profiles, with the former (Figure 13.3) predominant from shallow water, coralline substrates, and the latter (Figure 13.4) indicative of exclusively deeper water faunas. To date very few hexactinellids have been described from any Australian province—mainland, island or oceanic seabed (ABIF-Fauna 2004)—making the NORFANZ collections in particular invaluable as a source of new information on our deep sea fauna.

Life history and reproductive ecology (summarised from Hooper, in press)

Structure

Sponges lack true tissues but have highly mobile and totipotent cells (archaeocytes) capable of differentiating into other cell types to produce various structures and functions as required by the individual to maintain life. Consequently, sponges have a highly adaptable morphology and are highly susceptible to environmental changes. Sponges are composed of an outer layer of cells, the pinacoderm, an inner layer of flagellated cells (cells with a flagellum or hair-like structure) called choanocytes or 'collar cells', and between these a middle layer (or mesohyl). This middle layer includes mobile cells and usually some skeletal material (spongin fibres and filaments, and inorganic spicules made of silicon dioxide or calcium carbonate) that provide some structural support for the individual. Sponges have a highly efficient water exchange system that maintains basic metabolism (breathing, eating, excretion, reproduction, etc.), and contributes significantly to filtration of the surrounding sea water. This system is driven by a system of chambers lined by a single layer of flagellated cells that actively beat to produce a unidirectional water current through the body. These chambers are connected to the external water column by a system of inhalant and exhalant canals with external pores.

Metabolic function

All sponges are filter feeders, although several deep-sea species (belonging to the family Cladorhizidae in particular and a small number of others), have lost this ability and have adopted a carnivorous life-style (Vacelet & Boury-Esnault 1995), including a named species recorded from the EMR (Hooper & Lévi 1989) and several unnamed ones from the NORFANZ expedition (Schlacher-Hoenlinger 2006). Filter feeding is a process by which incoming water is drawn in through a series of sieve-like pores, selectively filtering food particles (such as plankton and bacteria) and finally entrapping them by a collar of cilia at the base of the choanocytes. Entrapped food particles are actively carried across the cell wall, engulfed by archaeocytes, and subsequently transferred throughout the mesohyl to other cells. Filtered water leaves the sponge via the exhalant canal system. Unlike most multicellular animals digestion and excretion of waste products occurs within cells, not within any common body cavity. A sponge is capable of pumping around 10 times its body volume each hour. Some sponges, particularly those growing on the coral reef flats, also have a unique symbiosis with cyanobacteria (previously know incorrectly as 'blue-green algae'), providing the sponge with nutrients derived from photosynthesis (phototrophy or autotrophy) to supplement those obtained by the sponge from normal filter feeding activities. These extra nutrients greatly augment sponge growth rates and competitive ability in coral reef systems. There are also often huge microbial populations (bacteria and Archaea) living within sponge cells and within the mesohyl, with which the cells interact at various levels (from predation to commensalism). In addition to nutrients acquired through filter feeding activities sponges also ingest a myriad of toxic chemicals excreted by other plants and animals from the coral reefs, which they modify and reuse.

Life History

Adult sponges are generally attached to the seabed or other substrates for most of their lives (although some are capable of slow movement; Bond & Harris 1988). Adults may grow as massive individuals, encrusting or burrowing into the substratum, on hard or soft substrata, in sheltered waters or exposed to high currents regimes. Most have mobile larvae that briefly swim or crawl away from their parent. Sponges reproduce both asexually and sexually, using a number of reproductive strategies:

(1) Asexual reproduction involves the production of propagules such as buds and fragments, containing a sufficient number of cells from which complete sponges can develop. Most sponge groups have

considerable means of asexual propagation, such as fragmentation from storm events (an important mechanism for sponge recruitment and dispersal), and extensive regenerative powers that are vital for sustaining local populations.

(2) Sexual reproduction: sponges have sexes that are separate or sequentially hermaphroditic (producing eggs and sperm at different times). Although there are no gonads or reproductive ducts, sexual reproduction involves the production of eggs and sperm by the choanocytes and archaeocytes, with fertilisation often (but not always) internal. Individuals release sperm externally (via the exhalant canals) whereas their eggs remain in the incurrent canals to minimize self fertilisation. In most sponges sperm are engulfed by choanocytes, and transferred to the eggs where fertilisation takes place. Development of embryos is viviparous (i.e. they are brooded internally) and larvae leave the parent for dispersal. Some sponges are oviparous, with females shedding their eggs externally as fertilised eggs or early embryo stages, rarely as unfertilised eggs. Other forms of development are also recorded, such as elimination of free-swimming larvae and embryos brooded in the maternal sponge before being expelled as young adults, but these are exceptional (summary in Maldonado & Bergquist 2002; Maldonado 2006).

Reproductive ecology

Eight different larval types are known but only a few of these have yet been adequately investigated. Most embryos develop into free-swimming or demersal crawling larvae (0.05–5 mm long), ciliated to a greater or lesser extent, with a non-feeding planktonic phase, and short longevity (maximum of 72 hrs recorded; Maldonado 2006). Release of propagules (sperm, fertilised eggs or embryos) is asynchronous in viviparous species but highly synchronous in oviparous sponges, triggered by factors such as temperature and lunar cycle (Fromont & Bergquist 1994).

Molecular studies of individuals in local sponge populations show that most have high levels of genetic variability, not high genetic relatedness as would be expected if asexual recruitment was predominant (Maldonado & Uriz 1999). Larval settlement and metamorphosis is influenced by a variety of environmental stimuli such as light, gravity, physical and chemical features of the substrate (Maldonado 2006).

What little is known about sponge growth rates, regenerative abilities after damage, and longevity of sponges suggests that all these vary considerably across the various groups of sponges and habitats they occupy. For example, some species are known to reproduce and die in less than one year (Ayling 1983), or are highly seasonal in their growth, biomass and ultimately survival (Usher et al. 2004), while some live for only several decades (Ayling 1983), to over 500 years (Wörheide & Reitner 1999).

Predation and defence

Despite a combination of high chemical toxicity and a generally low ratio of soft tissue to mineral skeleton, sponges have many predators, such as molluscs (particularly nudibranchs), echinoderms (e.g. holothurians, asteroids and ophiuroids), fishes (e.g. grazing herbivores), and reptiles (e.g. green and hawksbill turtles). The ability to digest and modify the waste products and chemicals produced by other organisms which live in, on or near sponges may at least partly account for their unusual and frequently novel biochemistry, and commonly high toxicity (Simpson et al. 2000). There is now evidence to show that sponges also use their extensive arsenal of chemicals as both offensive and defensive weapons. This includes repelling predators (Turon et al. 1998), deterring parasites and competing for space (Evans-Illidge et al. 1999). The concentration, toxicity and/or secondary modification of particular compounds may vary seasonally (Henrikson & Pawlik 1998) and in response to predation intensity (Proksch 1994; Hill & Hill 2002).

Significance of Sponges in the East Marine Region

The combination of chemicals produced by normal sponge metabolism, those filtered from the seawater, and those produced by or in combination with the resident microbes makes sponges amongst the most toxic of all life forms and of great interest to the pharmaceutical industry. Indeed, much of our recent knowledge of the eastern Australian sponge fauna is directly attributed to activities of and funding from the 'biodiscovery' (or 'bioprospecting') industry (Quinn et al. 2002). Athough to date no commercial pharmaceutical product has yet eventuated from 'biodiscovery' of the Australian sponge fauna, sponges still have a highly significant potential as sources of new pharmaceutical products (Munro et al. 1999). More recently, a small scale sponge aquaculture has been trialed to grow both 'bath sponges' and other species as sources of bioactive compounds in commercial quantities (Duckworth et al. 1997). This experiment has been confined to Queensland inshore waters and has not yet extended elsewhere within the EMR. Sponges also have economic importance as pests or parasites of aquaculture species, such as edible oysters, pearl shells and giant clams, boring into shell and killing the prey (summary in Hooper 2005), and as undesirable colonisers fouling artificial structures (Henrickson & Pawlik 1998).

Ecologically, sponges are a highly significant component of most benthic ecosystems as they are:

- generally the most efficient seawater filtering recyclers
- the dominant primary producers in some marine systems (Wilkinson 1983b)
- the predominant bioeroders and recyclers of calcium carbonate back into the system in coralline habitats (Schönberg & Wilkinson 2001)
- important refuges for many small invertebrates and microbes (Wilkinson 1984a, 1984b)
- used as protection by fishes and larger invertebrates.

In their role as structural components of the substrate sponges are particularly vulnerable, being adversely affected by trawling through physical damage and as a significant component of bycatch in some fisheries (Australian State of the Environment Committee 2001). There is now some empirical data on their susceptibility, damage incurred and potential for recovery in Australian waters (Pitcher et al. 1997; Poiner et al. 1998), but our understanding of the extent of this damage throughout the EMR is still very rudimentary.

Impacts/Threats

Human impacts on sponge communities are not yet well studied anywhere in the world, including in Australian waters, but there is evidence from various international sources that sponge communities are significantly degraded by pollution from industrial sources (Cebrian et al. 2003), human habitation and sewerage outputs (Roberts 1996; Roberts et al. 1998), eutrophication (excessive input of nutrients into waterways resulting in algal blooms) (Holmes 1997), overfishing of target species (Vacelet 1991), Introduced Marine Pests (Davis et al. 1997), and habitat destruction (Wassenberg et al. 2001), amongst others. Australia's continental shelf and slope consists mainly of soft sediments, some of which have specialised sponge faunas adapted to living in or on soft bottoms. Elsewhere patchy gravel, coralline rubble and pavement rock form substrata for a large variety of invertebrate species, including sponges and bryozoans, and it is these communities that are of critical importance as habitat and food for fish (Australian State of the Environment Committee 2001). But because sponges are generally slow to recruit, slow growing and long lived, they are very vulnerable to anthropogenic and natural disturbances (Roberts et al. 2006). Bottom trawling remains a significant threat to sponges and other sessile invertebrate communities, with some commercially fished areas, such as those based over a soft substrates dominated by organisms like sponges, more susceptible than others. The limited quantitative data currently available shows that each pass of a trawl net along the seabed removes about 5 to 25% of the biota. This effect is cumulative with successive trawls removing an increasingly higher proportion of organisms. Different species have different levels of vulnerability, with especially large sponges particularly susceptible to trawling (Poiner et al. 1998).

In addition to the physical alteration or destruction of the seabed by trawling activities, over-fishing also has a highly significant impact upon bycatch species, including sponges. Wassenberg et al. (2001) suggested that most sponges torn from the seafloor and damaged by trawl nets probably do not survive after being discarded, and that this bycatch is often a significant component of the bottom trawl fisheries in northern Australia. There is no reason why this would be different in trawl fisheries within the EMR. While some species of sponges may withstand some degree of trawl impact (e.g. those with greater flexibility in their growth forms, more tightly cemented to the substratum, with faster growth and recovery rates, etc.), far more detailed studies are required to determine the actual survivorship of sponges after interactions with trawling gear (National Oceans Office 2004).

Similarly, about 50% of Australia's fisheries are supported by rocky reef habitats, and the principal human pressures on rocky reefs come from land-based pollution as well as from fishing. In extensive temperate rocky reefs throughout the EMR macroalgae tend to form the dominant cover on reefs in shallow waters (< 20 m deep), while sessile invertebrates such as sponges cover rocks in deeper water. It is these deeper water reefs that tend to have greater trawling pressure as well as sewerage discharges. For example, discharge of sewerage effluent close to underwater reefs near Sydney was found to have a significant impact on reef fish and encrusting assemblages in the vicinity. When the discharge was relocated, the composition of the encrusting community at the new site changed from one in which algae and sponges were well represented to one dominated by silt and ascidians (Roberts et al. 1998). In the vicinity of the previous cliff face outfall, the reef communities apparently recovered (Underwood & Chapman 1997; Australian State of the Environment Committee 2001).

Reports of sponge disease have increased dramatically in recent years, both internationally and in Australia (Webster 2007), decimating affected sponge populations. These epidemics are reported to have severe impacts on the survival of sponge populations, the ecology of the reef and the fate of associated marine invertebrates. Despite the ecological and commercial importance of sponges, the understanding of sponge disease is still limited. There has generally been a failure to isolate and identify the causative agents of sponge disease, with only one case identifying a novel *Alphaproteobacteria* strain as the primary pathogen. Other potential disease agents include fungi, viruses, cyanobacteria and bacterial strains within the *Bacillus* and *Pseudomonas* genera. There is some evidence for correlations between sponge disease and environmental factors such as climate change and urban/agricultural runoff (Webster 2007).

Information Gaps

Despite increased knowledge of the magnitude and diversity of sponge faunas in regions like the GBR, southern Queensland and central NSW—largely due to surveys of bioactive sponges with pharmaceutical potential —we still have only a very poor sample of the fauna for most of the EMR. The combined QM and AM databases yielded a total count of approximately 1,500 records for the entire region, once the GBR and Torres Strait samples were excluded from the data pool. Within the region only two shallow coastal zones had anything close to adequate representative collections, viz. southeast Queensland (Central Eastern Shelf Transition) and faunas in the vicinity of Sydney (Central Eastern Shelf Province). Moreover, the taxonomic resolution of many of these samples is still largely rudimentary, and our taxonomic capabilities (expertise, human resources) to construct inventories are still grossly inadequate. The current level of understanding of ecological processes in sponge communities at the ecosystem level, their physiological, biochemical and other functions at the species level is poor, and it remains a challenge to even recognise what a sponge species is (Wörheide 1998; Wörheide et al. 2002).

Key References and Current Research

Current Research

Within the EMR the following projects involving sponges are current or planned (a number of other research projects involving sponges, conducted by several marine agencies, are current but these mostly concern the GBR region, which is not part of the EMR):

2007–2008, Hexactinellida from the NORFANZ Expedition are currently in Canada being studied by one of the few hexactinellidan experts, Dr Henry Reiswig (Royal British Columbia Museum), already with indications of new species and genera present in the collections. Similarly, the ‘lithistid’ demosponges (‘rock-sponges’ with desma spicules) from the NORFANZ and other collections are also being currently described and named, and will soon be published (Schlacher et al. in prep.).

2007–2010, 'Deep Downunder': a deep-sea exploration of Australia in collaboration with DeepOceanQuest.com, Australian Research Council, University of Queensland and various museums and universities within Australia and overseas (Coral and Tasman Sea reefs and seamounts). A submersible expedition (aboard the MV 'Alucia') will commence in 2008 to investigate the fauna of the deeper waters of the Coral Sea from which it is hoped our knowledge of Australia's deep water sponge biodiversity will be significantly enhanced (http://ilc00f.facbacs.uq.edu.au/VTHRC/ecovis/deep%20down%20under.htm).

2007–2009, Surveys of bioactive sponges in the Indo-west Pacific (Coral Sea territories, shallow and deep waters). The partners for this project are (or have been): QM, Natural Products Discovery Griffith University, IRD France (CRISP.Project) and University of Utah (US ICBG – NIH projects).

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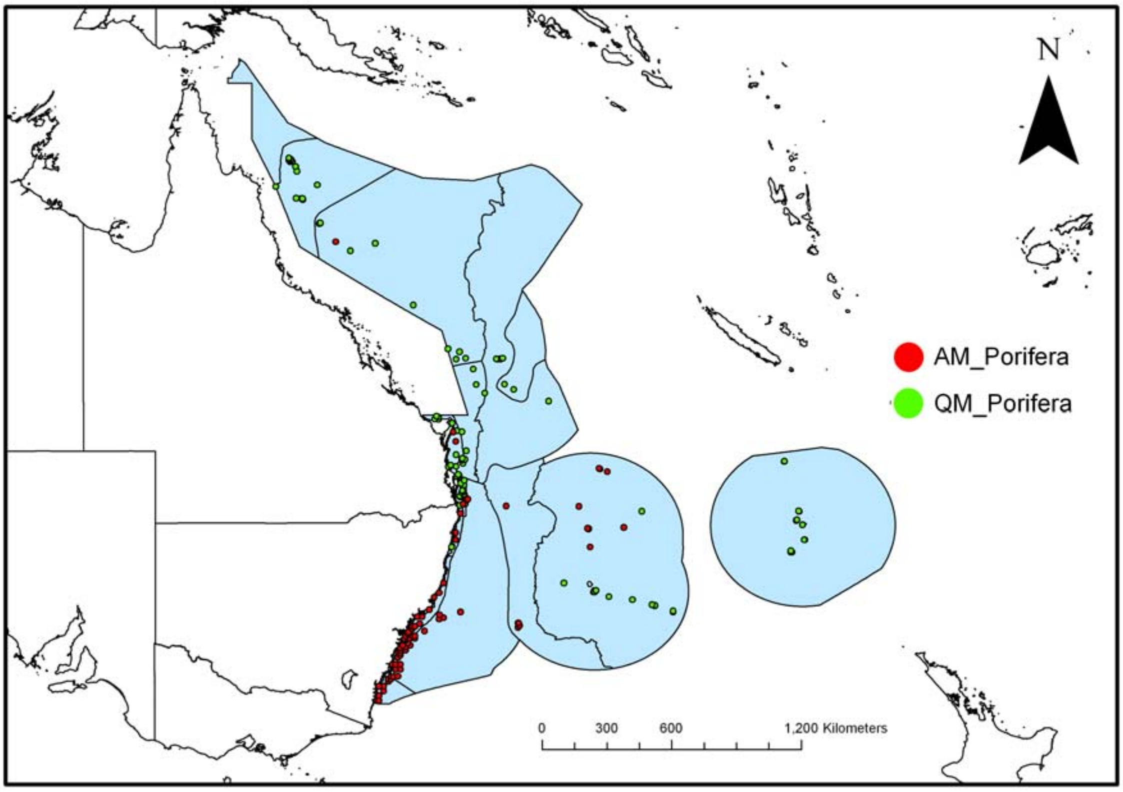

Figure 13.1 Spatial distributions of sponge samples from the collections of the Queensland (QM) and Australian (AM) Museums within the East Marine Region.

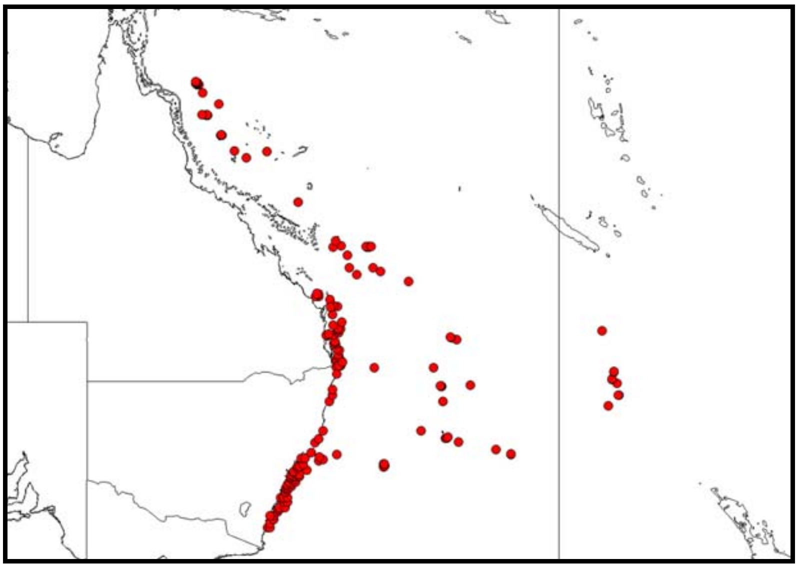

Figure 13.2 Spatial distributions of Demospongiae samples from the combined collections of the QM and AM within the East Marine Region.

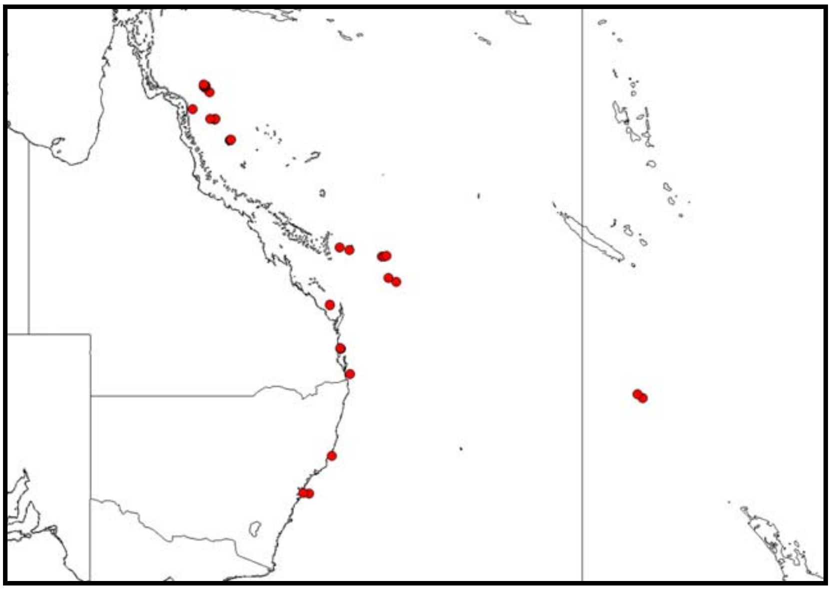

Figure 13.3 Spatial distributions of Calcarea samples from the combined collections of the QM and AM within the East Marine Region.

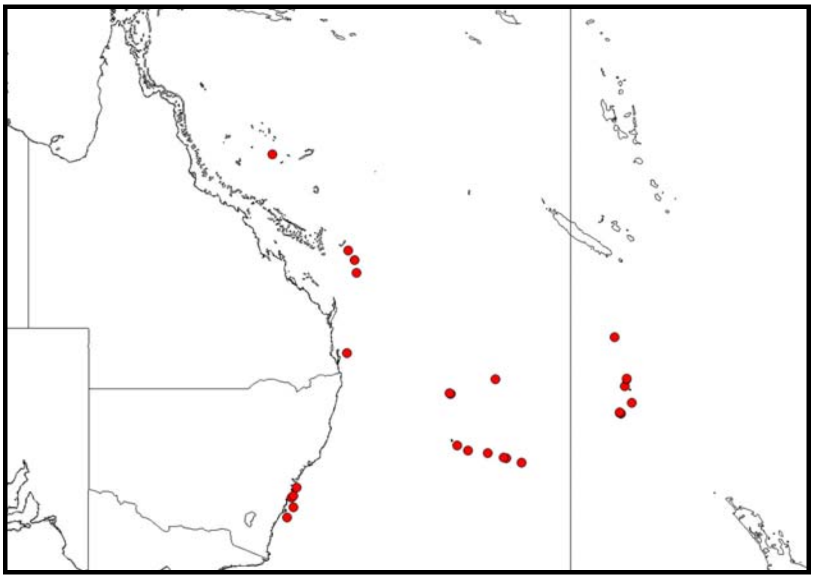

Figure 13.4 Spatial distributions of Hexactinellida samples from the combined collections of the QM and AM within the East Marine Region.

Table 13.2 Species inventories of sponge faunas within the Eastern Marine Region.

Key to nomenclature: 'sp.' and 'spp' denote a taxon (taxa) sorted only to genus level (i.e. not differentiated at OTU level relative to any other species within the Eastern Marine Regional fauna), each counted here as a single taxon. 'sp. x' denotes a taxon differentiated to an OTU level but relative only to a specific (e.g. regional) survey, such as the NORFANZ expedition. A number (e.g. '1234') following a genus name represents an OTU that is a unique taxon relative to the whole Australasian fauna, and likely to represent a new species awaiting formal description

1. Central Eastern Shelf Province & Southeast Shelf Transition (OTU = 172)

Calcarea, Calcarea, Sycettidae
Sycon gelatinosum (Blainville, 1834)
Sycon sp.

Calcarea, Clathrinida, Clathrinidae
Clathrina 1352
Clathrina sp.

Demospongiae. Astrophorida. Ancorinidae
Ancorina sp.
Asteropus simplex (Carter, 1879)
Rhabdastrella sp.
Stelletta spp.
Monosyringia sp.
Jaspis sp.
Scolopes sp.

Demospongiae, Astrophorida, Geodiidae
Erylus spp.
Geodia nitida (Sollas, 1886)
Geodia punctata Hentschel, 1909
Geodia sollasi (Lendenfeld, 1888)
Geodia spp.
Geodia 1329

Demospongiae, Astrophorida, Theneidae
Thenea sp.

Demospongiae, Dendroceratida, Darwinellidae
Dendrilla sp.
Dendrilla nigra (Dendy, 1889)

Demospongiae, Chondrosida, Chondrillidae
Chondrilla australiensis Carter, 1873

Demospongiae, Dedroceratida, Dictyodendrillidae
Dictyodendrilla cavernosa (Lendenfeld, 1886)

Demospongiae, Dictyoceratida, Dysideidae
Dysidea spp.
Dysidea 'menkei'

Demospongiae, Dictyoceratida, Irciniidae
Ircinia jacksoniana Bergquist, 1980
Ircinia rubra Lendenfeld, 1889
Ircinia spp.
Psammocinia rugosa Lendenfeld, 1889
Psammocinia sp.
Sarcotragus arbuscula Lendenfeld

Demospongiae, Dictyoceratida, Spongiidae
Coscinoderma densa Hyatt
Coscinoderma spp.
Leiosella sp.
Spongia canaliculata Lendenfeld, 1885
Spongia spp.

Demospongiae, Dictyoceratida, Thorectidae
Aplysinopsis sp.
Carteriospongia 'australis'
Fasciospongia australis Lendenfeld, 1888
Fasciospongia flabellum (Lendenfeld, 1889)
Fasciospongia rimosa (Lamarck, 1814)
Fasciospongia spp.
Fasciospongia turgida (Lamarck, 1814)
Hyrtios spp.
Luffariella sp.
Phyllospongia spp.
Strepsichordaia caliciformis (Carter, 1885)
Taonura marginalis (Lendenfeld, 1888)
Taonura spp.
Thorecta elegans Lendenfeld, 1889
Thorecta murrayella Lendenfeld, 1889
Thorecta spp.
Thorectandra spp.
Thorectandra typica Carter, 1886

Demospongiae, Hadromerida, Clionaidae
Cliona sp.

Demospongiae, Hadromerida, Polymastiidae
Polymastia sp.

Demospongiae, Hadromerida, Spirastrellidae
Spheciospongia poculoides (Hallman, 1912)
Spheciospongia australis (Lendenfeld, 1888)
Spheciospongia papillosa (Ridley & Dendy, 1886)
Spirastrella spp.

Demospongiae, Hadromerida, Stylocordylidae
Stylocordyla fragilis Bergquist, 1972
Stylocordyla sp.

Demospongiae, Hadromerida, Suberitidae
Suberites sp.
Choanites sp.

Demospongiae, Hadromerida, Tethyidae
Tethya bullae Bergquist & Kelly-Borges, 1991
Oxytethya mirabilis Sara & Sara, 2002
Tethya laevis (Lendenfeld, 1888)

Demospongiae, Hadromerida,Trachycladidae
Trachycladus digitatus (Lendenfeld, 1887)
Trachycladus sp.

Demospongiae, Halichondrida, Axinellidae
Axinella arborescens Ridley & Dendy, 1886
Axinella spp.
Axinella vermiculata Whitelegge, 1907
Cymbastela 521
Cymbastela concentrica (Lendenfeld, 1887)
Homaxinella spp.
Phakellia multiformis Whitelegge, 1907
Phakellia spp.
Phakellia ventilabrum (Ridley & Dendy, 1886)

Demospongiae, Halichondrida, Dictyonellidae
Stylotella sp.
Pararhaphoxya spp.
Rhaphoxya cactiformis (Carter, 1885)
Scopalina sp.

Demospongiae, Halichondrida, Desmoxyidae
Higginsia sp.

Demospongiae, Haplosclerida, Callyspongiidae
Callyspongia frondosa (Lendenfeld, 1887)
Callyspongia ramosa (Gray, 1843)
Callyspongia sp.
Callyspongia truncata (Lendenfeld, 1887)
Chalinissa elegans Lendenfeld, 1887
Chalinissa sp.
Dactylia 'mammifer'
Dactylia spp.

Demospongiae, Haplosclerida ,Chalinidae
Haliclona 'macropora' (Lendenfeld)
Haliclona ramosa (Whitelegge, 1906)
Haliclona spp.

Demospongiae, Haplosclerida, Niphatidae
Amphimedon 'bilamellata' (Carter)
Amphimedon ramosa (Lendenfeld, 1887)
Amphimedon sp.
Cribrochalina dendyi (Whitelegge, 1901)
Gelliodes sp.

Demospongiae, Haplosclerida, Petrosiidae
Petrosia australis Bergquist & Warne, 1980
Petrosia hebes Lendenfeld, 1888
Petrosia sp.
Xestospongia sp.

Demospongiae, Haplosclerida, Phloeodictyidae
Oceanapia ramsayi (Lendenfeld, 1888)
Oceanapia sp.

Demospongiae, Lithistida, Scleritodermidae
Aciculites spp.
Aciculites pulchra Dendy, 1924

Demospongiae Lithistida Azoricidae
Leiodermatium sp.

Demospongiae, Poecilosclerida, Anchinoidae
Phorbas caespitosus (Carter, 1885)

Demospongiae, Poecilosclerida, Cladorhizidae
Chondrocladia clavata Ridley & Dendy, 1886
Cladorhiza moruliformis Ridley & Dendy, 1886
Cladorhiza sp.

Demospongiae, Poecilosclerida, Coelosphaeridae
Coelosphaera globosa Bergquist, 1961
Coelosphaera spp.
Ectyodoryx spp.
Lissodendoryx spp.

Demospongiae, Poecilosclerida, Phellodermidae
Phelloderma polypoides Whitelegge, 1906

Demospongiae, Poecilosclerida, Crellidae
Crella commensalis (Whitelegge, 1906)
Crella incrustans (Lendenfeld, 1888)

Demospongiae, Poecilosclerida, Hymedesmiidae
Pseudohalichondria fibrosa Whitelegge, 1901
Pseudohalichondria spp.

Demospongiae, Poecilosclerida, Microcionidae
Antho chartacea (Whitelegge, 1907)
Antho sp.
Clathria 'typicus'
Clathria arcuophora Whitelegge, 1907

Clathria biclathrata Hooper, 1994
Clathria cactiformis (Lamarck, 1814)
Clathria canaliculata (Whitelegge, 1906)
Clathria cylindrica (Ridley & Dendy, 1886)
Clathria inanchorata Ridley & Dendy, 1886
Clathria macropora Lendenfeld, 1888
Clathria rubra (Lendenfeld, 1888)
Clathria spp.
Clathria striata Whitelegge, 1907
Echinochalina anomala Hallmann, 1912
Echinochalina reticulata Whitelegge, 1907
Echinoclathria confragosa (Hallmann, 1912)
Echinoclathria leporina (Lamarck, 1814)
Holopsamma australis Lendenfeld, 1889
Holopsamma carteri (Ridley & Dendy, 1886)
Holopsamma favus (Carter, 1885)
Holopsamma 'kirkii' Carter
Holopsamma laminaefavosa Carter, 1885
Holopsamma macropora (Lendenfeld, 1888)
Holopsamma ramosa (Hallmann, 1912)
Holopsamma rotunda (Hallmann, 1912)
Holopsamma spp.

Demospongiae, Poecilosclerida, Mycalidae
Esperiopsis sp.
Mycale ancorina (Whitelegge, 1906)
Mycale murrayi (Ridley & Dendy, 1886)
Mycale 'rosetta' Whitelegge
Mycale sp.
Paresperella repens Whitelegge, 1907

Demospongiae, Poecilosclerida, Myxillidae
Desmacidon fruticosa Montagu, 1818
Desmacidon porifera Whitelegge, 1906
Desmacidon spp.
Desmacidon stelligera Whitelegge, 1906
Isodictya spp.
Myxilla mirabilis (Whitelegge, 1907)
Myxilla pumicea (Whitelegge, 1906)
Myxilla spp.

Demospongiae, Poecilosclerida, Phoriospongiidae
Chondropsis kirkii (Bowerbank, 1841)
Phoriospongia lamella Lendenfeld, 1888
Phoriospongia syringiana (Whitelegge, 1906)
Psammascus sp.

Demospongiae, Poecilosclerida, Raspailiidae
Ceratopsion cuneiformis Bergquist, 1970
Echinodictyum sp.
Raspailia echinata Whitelegge, 1907
Raspailia spp.

Demospongiae. Poecilosclerida. Tedaniidae
Tedania anhelans (Lieberkuhn, 1859)
Hemitedania sp.

Demospongiae, Verongida, Ianthellidae
Ianthella quadrangulata Bergquist & Kelly Borges, 1995

Hexactinellida, Lyssacinosida, Euplectellidae
Euplectella spp.

2. Central Eastern Shelf Transition (OTU = 149)

Calcarea, Clathrinida, Leucettidae
Leucetta 1371
Leucetta chagosensis Dendy, 1913
Leucetta microraphis Haeckel, 1872
Pericharax 1187

Calcarea, Leucosolenida, Sycettidae
Sycon gelatinosum Blainville, 1834

Demospongiae, Agelasida, Agelasidae
Agelas mauritiana Carter, 1883
Agelas 2480

Demospongiae, Astrophorida, Ancorinidae
Jaspis sp.
Rhabdastrella globostellata Carter, 1883
Stelletta 1005
Stelletta 1248
Stelletta sp.
Stelletta splendens de Laubenfels, 1954

Demospongiae, Astrophorida, Geodiidae
Erylus amissus Adams and Hooper, 2001

Demospongiae, Astrophorida, Coppatiidae
Paracordyla lignea Hallmann, 1912

Demospongiae, Dendroceratida, Darwinellidae
Acanthodendrilla 2510
Aplysilla sp.
Dendrilla rosea Lendenfeld, 1883
Dendrilla spp.

Demospongiae, Dictyoceratida Dysideidae
Dysidea pallescens Schmidt, 1862
Dysidea sp.

Demospongiae, Dictyoceratida, Irciniidae
Ircinia 1242
Ircinia 1255
Ircinia 2901
Ircinia 3079
Ircinia 3419
Ircinia rugosa Lendenfeld, 1889
Ircinia spp.
Ircinia wistari Wilkinson, 1978
Psammocinia 1407
Psammocinia 3422

Psammocinia halmiformis Lendenfeld, 1889
Psammocinia rugosa Lendenfeld, 1889
Psammocinia sp.

Demospongiae, Dictyoceratida, Spongiidae
Coscinoderma 3423
Hippospongia elastica Lendenfeld, 1889
Hyattella intestinalis (Lamarck, 1813)
Spongia sp.

Demospongiae, Dictyoceratida, Thorectidae
Candidaspongia flabellata Bergquist, Sorokin and Karuso, 1999
Carteriospongia laevis (Laubman)
Dactylospongia 3050
Dactylospongia elegans Thiele, 1899
Fascaplysinopsis 1974
Fascaplysinopsis 2882
Fascaplysinopsis 3056
Fasciospongia spp.
Luffariella sp.
Phyllospongia spp.
Scalarispongia 3591
Scalarispongia sp.

Demospongiae, Hadromerida, Clionaidae
Cliona 1189
Cliona 2527
Cliona 2676
Cliona 2768
Pione hixoni Lendenfeld, 1886
Spheciospongia areolata Dendy, 1897
Spheciospongia papillosa Ridley & Dendy, 1886
Spheciospongia vagabunda Ridley, 1884

Demospongiae, Hadromerida, Polymastiidae
Polymastia craticia Hallmann, 1912

Demospongiae, Hadromerida, Spirastrellidae
Spirastrella montiformis Hallmann, 1912
Spirastrella poculoides Hallmann, 1912

Demospongiae, Hadromerida, Tethyidae
Tethya sp.

Demospongiae, Halichondrida, Axinellidae
Axinella 4115
Axinella sp.
Cymbastela 3767
Cymbastela concentrica Lendenfeld, 1887
Pararhaphoxya sp.
Phycopsis fusiformis Levi, 1967

Demospongiae, Halichondrida, Desmoxyidae
Myrmekioderma granulata Esper, 1830

Demospongiae, Halichondrida, Dictyonellidae
Acanthella 451
Acanthella cavernosa Dendy, 1922
Acanthella klethra Pulitzer-Finali, 1982

Demospongiae, Halichondrida, Halichondriidae
Ciocalypta tyleri Bowerbank, 1873
Halichondria (Halichondria) 3764
Halichondria spp.
Halichondria (Eumastia) 1437
Halichondria (Eumastia) 1451

Demospongiae, Halisarcida,Halisarcidae
Halisarca 2595

Demospongiae, Haplosclerida, Callyspongiidae
Callyspongia (Arenosclera) 1363
Callyspongia (Arenosclera) 2773
Callyspongia (Arenosclera) 2775
Callyspongia (Callyspongia) 1116
Callyspongia (Callyspongia) 1394
Callyspongia (Callyspongia) 2783
Callyspongia (Callyspongia) 3061
Callyspongia (Callyspongia) 3062
Callyspongia (Callyspongia) 3064
Callyspongia (Callyspongia) 3070
Callyspongia (Callyspongia) 456
Callyspongia (Callyspongia) spp.
Callyspongia (Euplacella) 1406
Callyspongia (Euplacella) 2582
Callyspongia (Euplacella) 2675
Callyspongia (Euplacella) 387
Dactylia 833
Siphonochalina 2778
Siphonochalina 3766
Siphonochalina 633
Siphonochalina deficiens Pulitzer-Finali, 1982

Demospongiae, Haplosclerida, Chalinidae
Chalinula 2661
Haliclona (Gellius) 2660
Haliclona (Haliclona) sp.
Haliclona (Haliclona) 1381
Haliclona (Haliclona) 2662
Haliclona (Haliclona) 2843

Demospongiae, Haplosclerida, Niphatidae
Amphimedon 2776
Amphimedon 3420
Niphates 1122
Niphates 2665
Niphates 2774
Niphates 3081
Niphates 586
Niphates sp.

Demospongiae, Haplosclerida, Petrosiidae
Petrosia 3046

Xestospongia 1233
Xestospongia testudinaria Lamarck, 1813

Demospongiae, Haplosclerida, Phloeodictyidae
Oceanapia 716
Oceanapia 2664
Oceanapia ramsayi (Lendenfeld, 1888)

Demospongiae, Homosclerophorida, Plakinidae
Plakinastrella 2677
Plakortis 2674

Demospongiae, Lithistida, Desmanthidae
Petromica (Chaladesma) pacifica List-Armitage & Hooper, 2002

Demospongiae, Lithistida, Theonellidae
Racodiscula spinispirulifera Carter, 1880
Lithistida spp.

Demospongiae, Poecilosclerida, Chondropsidae
Chondropsis 3091
Psammoclema 271

Demospongiae, Poecilosclerida, Microcionidae
Clathria (Clathria) angulifera Dendy, 1896
Clathria (Clathria) biclathrata Hooper, 1994
Clathria (Clathria) kylista Hooper & Levi, 1993
Clathria (Clathria) spp.
Clathria (Thalysias) hirsuta Hooper & Levi, 1993
Clathria (Wilsonella) conectens (Hallmann, 1912)
Echinochalina (Echinochalina) intermedia Whitelegge, 1902
Echinochalina (Protophlitaspongia) 3763
Echinochalina (Protophlitaspon favulosa Hooper, 1996
Holopsamma favus (Carter, 1885)
Holopsamma laminaefavosa Carter, 1885
Holopsamma rotunda Hallmann, 1912

Demospongiae, Poecilosclerida, Mycalidae
Mycale murrayi (Ridley & Dendy, 1886)
Mycale (Zygomycale) parishi (Bowerbank, 1875)
Mycale spp.

Demospongiae, Poecilosclerida, Phoriospongiidae
Psammascus sp.

Demospongiae, Poecilosclerida, Podospongiidae
Diacarnus 2663

Demospongiae, Poecilosclerida, Raspailiidae
Echinodictyum mesenterinum Lamarck, 1814
Raspailia (Raspaxilla) 1696

Demospongiae, Poecilosclerida, Tedaniidae
Tedania 462

Demospongiae, Spirophorida, Tetillidae
Cinachyrella (Raphidotethya) enigmatica (Burton, 1934)
Cinachyrella (Raphidotethya) sp.

3. Central Eastern Transition (OTU = 8)
Demospongiae, Astrophorida, Ancorinidae
Stelletta maxima Thiele, 1898
Stelletta spp.

Demospongiae, Astrophorida, Geodiidae
Geodia 541

Demospongiae, Dictyoceratida, Spongiidae
Spongia sp.

Demospongiae, Haplosclerida, Chalinidae
Haliclona (Haliclona) sp.

Hexactinellid, Amphidiscosida, Hyalonematidae
Hyalonema (Hyalonema) sp.

Hexactinellid, Amphidiscosida, Pheronematidae
Semperella schultzei Semper, 1868
Pheronema sp.

4. Northeast Transition & Northeast Province (OTU = 192)
Calcarea, Clathrinida, Clathrinidae \
Clathrina spp.
Clathrina 519

Calcarea, Clathrinida, Leucaltidae
Leucaltis clathria Haeckel, 1872
Leucetta 2914
Leucetta chagosensis Dendy, 1913
Leucetta microraphis Haeckel, 1872
Leucetta spp.
Pericharax heteroraphis Polejaeff, 1883
Pericharax spp.

Calcarea, Clathrinida, Levinellidae
Levinella sp.

Calcarea, Clathrinida, Soleneiscidae
Soleneiscus radovani Woerheide and Hooper, 1999

Calcarea, Leucosolenida, Grantiidae
Leucandra spp.
Grantia sp.

Calcarea, Leucosolenida, Heteropiidae
Syconessa sp.

Calcarea, Lithonida, Minchinellidae
Plectronina sp.

Minchinella sp.

Calcarea, Murrayonida, Murrayonidae
Murrayona sp.

Calcarea, 'Pharetronida'
'pharetronids' sp.

Demospongiae, Agelasida, Agelasidae
Agelas gracilis Whitelegge, 1897
Agelas 2921
Agelas 3267

Demospongiae, Agelasida, Astroscleridae
Astrosclera sp.
Astrosclera willeyana Lister, 1900

Demospongiae, Astrophorida, Ancorinidae
Jaspis 1995
Melophlus 2131
Melophlus 3246
Rhabdastrella globostellata Carter, 1883
Stelletta 1005
Stelletta 1739
Stelletta 3412
Stelletta clavosa Sollas, 1888
Stelletta pachydermata Sollas, 1886
Stelletta splendens de Laubenfels, 1954

Demospongiae, Astrophorida, Geodiidae
Erylus citrus Adams and Hooper, 2001

Demospongiae, Astrophorida, Pachastrellidae
Characella 3411

Demospongiae, Chondrosida, Chondrillidae
Chondrosia 1994
Chondrosia 3283

Demospongiae, Dendroceratida, Darwinellidae
Aplysilla sulfurea Schulze, 1878

Demospongiae, Dendroceratida, Dictyodendrillidae
Acanthodendrilla 1948
Acanthodendrilla 2923
Dictyodendrilla 1737
Dictyodendrilla 1740

Demospongiae, Dictyoceratida, Dysideidae
Citronia astra Hooper, Schlacher & Carroll, 2007
Dysidea 1214
Dysidea 1547
Dysidea 2916
Dysidea 2920
Dysidea 2927
Dysidea 3276
Dysidea 3277
Dysidea arenaria (Keller, 1889)
Dysidea avara Schmidt, 1862
Dysidea granulosa Bergquist, 1965
Dysidea lizardensis Hooper, Schlacher & Carroll, 2007
Dysidea pallescens Schmidt, 1862
Euryspongia 2157
Lamellodysidea herbacea (Keller, 1889)

Demospongiae, Dictyoceratida, Irciniidae
Ircinia 1242
Ircinia 1876
Ircinia 1944
Ircinia 3173
Psammocinia 1727

Demospongiae, Dictyoceratida, Spongiidae
Coscinoderma mathewsi Lendenfeld, 1886
Hippospongia 2240
Spongia 1812
Spongia 3278
Spongia spp.

Demospongiae, Dictyoceratida, Thorectidae
Aplysinopsis 2911
Cacospongia 3183
Candidaspongia flabellata Bergquist, Sorokin and Karuso, 1999
Dactylospongia 2994
Dactylospongia elegans Thiele, 1899
Fascaplysinopsis 1590
Fascaplysinopsis 2314
Fenestraspongia 3275
Hyrtios 2918
Hyrtios 2924
Hyrtios 3271
Hyrtios 3272
Hyrtios 3273
Hyrtios erecta Keller, 1889
Hyrtios reticulata Thiele, 1899
Luffariella 2031
Luffariella 2302
Phyllospongia lamellosa Esper, 1794
Phyllospongia papyracea Esper, 1806
Strepsichordaia lendenfeldi Bergquist, Ayling & Wilkinson, 1988
Thorecta 3232
Thorectoxia 3279

Demospongiae, Hadromerida, Acanthochaetetida
Acanthochaetetes wellsi Hartman & Goreau, 1975
Acanthochaetetes spp.

Demospongiae, Hadromerida, Clionaidae
Cliona 2515
Cliona 2676

Demospongiae, Hadromerida, Tethyidae
Tethya 3415

Demospongiae, Hadromerida, Timeidae
Timea 1389

Demospongiae, Halichondrida, Axinellidae
Auletta 3256
Cymbastela concentrica Lendenfeld, 1887
Cymbastela coralliophila Hooper & Bergquist, 1992
Phakellia stipitata Carter, 1881
Phycopsis fusiformis Levi, 1967

Demospongiae, Halichondrida, Desmoxyidae
Myrmekioderma granulata Esper, 1830

Demospongiae, Halichondrida, Dictyonellidae
Acanthella cavernosa Dendy, 1922
Acanthella costata Kieschnick, 1900
Liosina 2129
Liosina paradoxa Theile, 1899
Rhaphoxya 3249
Stylissa 1741
Stylissa flabellata Ridley & Dendy, 1886
Stylissa massa Carter, 1887

Demospongiae, Halichondrida, Halichondriidae
Axinyssa 2929
Axinyssa 2930
Axinyssa 3250
Axinyssa 3251
Axinyssa 3252
Ciocalypta 3413
Halichondria (Halichondria) 1984
Halichondria (Halichondria) 2922
Halichondria (Halichondria) 3253
Hymeniacidon 1066

Demospongiae, Haplosclerida, Callyspongiidae
Callyspongia (Euplacella) 1559

Demospongiae, Haplosclerida, Chalinidae
Haliclona (Haliclona) 1515
Haliclona (Haliclona) 1581
Haliclona (Haliclona) 1734
Haliclona (Haliclona) 1735
Haliclona (Haliclona) 1954
Haliclona (Haliclona) 2685
Haliclona (Haliclona) 3263
Haliclona (Haliclona) aculeata Pulitzer-Finali, 1982
Haliclona (Reniera) 1733
Haliclona (Reniera) 2926
Haliclona (Reniera) osiris de Laubenfels, 1954

Demospongiae, Haplosclerida, Niphatidae
Cribrochalina 3260
Niphates 2190
Niphates 2526
Niphates 2913
Niphates 2917
Niphates 3258

Demospongiae, Haplosclerida,
Petrosiidae
Neopetrosia exigua Kirkpatrick, 1900
Neopetrosia pacifica Kelly-Borges &
Bergquist, 1988
Petrosia 2928
Petrosia 3367
Xestospongia 1230
Xestospongia 3257

Demospongiae, Haplosclerida,
Phloeodictyidae
Aka 1373
Aka 1636
Aka 1736
Aka 1738
Pachypellina 2919

Demospongiae, Homosclerophorida,
Plakinidae
Plakinastrella 3269
Plakortis nigra Levi, 1959

Demospongiae, Lithistida, Azoricidae
Leiodermatium 3399

Demospongiae, Lithistida, Corallistidae
Corallistes sp

Demospongiae, Poecilosclerida,
Chondropsidae
Batzella 2734
Psammoclema 2980
Psammoclema 3268

Demospongiae, Poecilosclerida,
Crellidae
Crella (Crella) 1525

Demospongiae, Poecilosclerida,
Desmacididae
Desmapsamma 1732

Demospongiae, Poecilosclerida,
Esperiopsidae
Ulosa 2925
Ulosa spongia de Laubenfels, 1954

Demospongiae, Poecilosclerida,
Iotrochotidae
Iotrochota 2818

Demospongiae, Poecilosclerida,
Microcionidae
Clathria (Microciona) mima de
Laubenfels, 1954

Clathria (Thalysias) craspedia Hooper, 1996
Echinochalina (Protophlitaspongia) 1991
Echinochalina (Protophlitaspongia) 3333
Echinochalina (Protophlitaspongia) isaaci Hooper, 1996

Demospongiae, Poecilosclerida, Mycalidae
Mycale 1730

Demospongiae, Poecilosclerida, Podospongiidae
Diacarnus 3247
Diacarnus 3248

Demospongiae, Poecilosclerida, Raspailiidae
Aulospongus 2349
Thrinacophora 1993

Demospongiae, Spirophorida, Tetillidae
Cinachyrella (Raphidotethya) enigmatica (Burton, 1934)
Cinachyrella 1729
Cinachyrella 1731
Cinachyrella 1870
Cinachyrella 3410
Cinachyrella australiensis Carter, 1886

Demospongiae, Verongida, Aplysinellidae
Aplysinella rhax de Laubenfels, 1954
Suberea 2912

Demospongiae, Verongida, Aplysinidae
Aplysina ianthelliformis Lendenfeld, 1888

Demospongiae, Verongida, Ianthellidae
Ianthella 1843
Ianthella 3280

Demospongiae, Verongida, Pseudoceratinidae
Pseudoceratina 1565
Pseudoceratina 1871
Pseudoceratina 2915
Pseudoceratina 3176
Pseudoceratina clavata Pulitzer-Finali, 1982

Demospongiae, Verticillitida, Verticillitidae
Vaceletia 1723
Vaceletia crypta Vacelet, 1979
Vaceletia spp.

Hexactinellid, Amphidiscosida, Hyalonematidae
Hyalonema (Pteronema) 3414

Hexactinellid, Amphidiscosida, Pheronematidae
Semperella schultzei Semper, 1868
Pheronema sp.

5. Kenn Transition & Kenn Province (OTU = 98)
Calcarea, Clathrinida, Clathrinidae
Clathrina helveola Woerheide and Hooper, 1999
Clathrina 1352

Calcarea, Clathrinida, Leucaltidae
Leucaltis clathria Haeckel, 1872

Calcarea, Clathrinida, Leucettidae
Leucetta 1978
Leucetta microraphis Haeckel, 1872
Pericharax heteroraphis Polejaeff, 1883

Calcarea, Clathrinida, Levinellidae
Levinella prolifera Dendy, 1913

Calcarea, Leucosolenida, Lelapiidae
Grantiopsis 1582

Calcarea, Leucosolenida, Sycettidae
Sycon gelatinosum Blainville, 1834
Sycetta 1558
Sycetta 1720

Demospongiae, Agelasida, Astroscleridae
Astrosclera willeyana Lister, 1900

Demospongiae, Astrophorida, Ancorinidae
Ancorina 1963
Jaspis 1955
Jaspis 1964
Melophlus 1982
Stelletta 1005
Stelletta maxima Thiele, 1898

Demospongiae, Astrophorida, Geodiidae
Erylus amissus Adams and Hooper, 2001
Erylus circus ,Adams and Hooper, 2001
Erylus citrus Adams and Hooper, 2001
Geodia 2461

Demospongiae, Dendroceratida, Darwinellidae
Darwinella 1030
Dendrilla rosea Lendenfeld, 1883

Demospongiae, Dendroceratida, Dictyodendrillida
Acanthodendrilla 1945
Dictyodendrilla 1942

Demospongiae, Dictyoceratida, Dysideidae
Dysidea 1959
Dysidea 1961
Dysidea arenaria (Keller, 1889)
Lamellodysidea chlorea (de Laubenfels, 1954)
Lamellodysidea herbacea Keller, 1889

Demospongiae, Dictyoceratida, Irciniidae
Ircinia 1876

Ircinia 1944
Ircinia 1950
Ircinia 1969
Psammocinia 1951

Demospongiae, Dictyoceratida, Spongiidae
Coscinoderma mathewsi Lendenfeld, 1886
Spongia 1983
Spongia 1990

Demospongiae, Dictyoceratida, Thorectidae
Candidaspongia flabellata Bergquist, Sorokin and Karuso, 1999
Carteriospongia flabellifera Bowerbank, 1877
Dactylospongia elegans Thiele, 1899
Fascaplysinopsis 1549
Fascaplysinopsis 1962
Fascaplysinopsis 1974
Fascaplysinopsis reticulata Hentschel, 1912
Hyrtios 1891
Luffariella 1975
Smenospongia 3284

Demospongiae, Hadromerida, Acanthochaetetida
Acanthochaetetes wellsi Hartman & Goreau, 1975

Demospongiae, Hadromerida, Alectonidae
Neamphius huxleyi Sollas, 1888

Demospongiae, Halichondrida, Axinellidae
Cymbastela coralliophila Hooper & Bergquist, 1992

Demospongiae, Halichondrida, Desmoxyidae
Myrmekioderma granulata Esper, 1830

Demospongiae, Halichondrida, Dictyonellidae
Acanthella costata Kieschnick, 1900
Acanthella klethra Pulitzer-Finali, 1982

Demospongiae, Halichondrida, Halichondriidae
Axinyssa 1878
Axinyssa 1953
Halichondria (Halichondria) 1227
Halichondria (Halichondria) 1984
Hymeniacidon 1066

Demospongiae, Halisarcida, Halisarcidae
Halisarca 1965

Demospongiae, Haplosclerida, Callyspongiidae
Callyspongia (Callyspongia) 1946
Callyspongia (Callyspongia) 1956
Callyspongia (Callyspongia) australis Lendenfeld, 1887
Callyspongia (Euplacella) 1949
Callyspongia (Euplacella) 1952
Dactylia 1941
Dactylia 1981

Demospongiae, Haplosclerida, Chalinidae
Haliclona (Haliclona) 1954
Haliclona (Haliclona) 1734
Haliclona (Haliclona) 1971

Demospongiae, Haplosclerida, Niphatidae
Amphimedon 1869
Amphimedon 1985
Niphates 1821
Niphates 1943
Niphates 1980
Niphates 1989

Demospongiae, Haplosclerida, Petrosiidae
Neopetrosia pacifica Kelly-Borges & Bergquist, 1988
Petrosia 1976
Xestospongia testudinaria Lamarck, 1813

Demospongiae, Haplosclerida, Phloeodictyidae
Oceanapia 1988

Demospongiae, Poecilosclerida, Chondropsidae
Psammoclema & algae complex 1123

Demospongiae, Poecilosclerida, Coelosphaeridae
Coelosphaera 1979

Demospongiae, Poecilosclerida, Desmacellidae
Biemna 1977
Desmapsamma 1967
Neofibularia 1972
Neofibularia hartmani Hooper & Levi, 1993
Neofibularia irata Wilkinson, 1978

Demospongiae, Poecilosclerida, Microcionidae
Clathria (Microciona) 1957
Clathria (Clathria) kylista Hooper & Levi, 1993
Clathria (Microciona) 1957

Demospongiae, Poecilosclerida, Podospongiidae
Diacarnus levii Kelly-Borges & Vacelet, 1995

Demospongiae, Verongida, Aplysinellidae
Porphyria flintae Bergquist, 1995

Demospongiae, Verongida, Aplysinidae
Aplysina ianthelliformis Lendenfeld, 1888

Demospongiae, Verongida, Ianthellidae
Ianthella basta (Pallas, 1776)

Demospongiae, Verongida, Pseudoceratinidae
Pseudoceratina 1835
Pseudoceratina 1871
Pseudoceratina 1947
Pseudoceratina 1973

6. Central Eastern Province (OTU = 7)
Demospongiae, Astrophorida, Ancorinidae
Ancorina spp.

Demospongiae, Dictyoceratida, Irciniidae
Ircinia sp.

Demospongiae, Hadromerida, Spirastrellidae
Spheciospongia poculoides (Hallmann, 1912)

Demospongiae, Halichondrida, Axinellidae
Axinella spp.

Demospongiae, Poecilosclerida, Cladorhizidae
Cladorhiza sp.

Demospongiae, Poecilosclerida, Microcionidae
Holopsamma rotunda (Hallmann, 1912)

Demospongiae, Poecilosclerida, Phellodermidae
Phelloderma polypoides Whitelegge, 1906

7. Tasman Basin Province (OTU = 15)
Demospongiae, Astrophorida, Ancorinidae
Stelletta sp.

Demospongiae, Astrophorida, Geodiidae
Erylus sp.
Geodia spp.

Demospongiae, Astrophorida, Pachastrellidae
Pachastrella spp.

Demospongiae, Dictyoceratida, Irciniidae
Ircinia 'aligera' (Burton)

Demospongiae, Dictyoceratida, Thorectidae
Aplysinopsis digitata Lendenfeld, 1888
Thorecta spp.

Demospongiae, Hadromerida, Tethyidae
Tethya magna Kirkpatrick, 1903

Demospongiae, Halichondrida, Axinellidae
Homaxinella sp.

Demospongiae, Halichondrida, Halichondriidae
Epipolasis novaezelandiae Bergquist, 1970

Demospongiae, Haplosclerida, Chalinidae
Orina sp.

Demospongiae, Haplosclerida, Petrosiidae
Petrosia australis Bergquist & Warne, 1980
Xestospongia sp.

Demospongiae, Spirophorida, Scleritodermatidae
Scleritoderma camusi Levi & Levi, 1983

Demospongiae, Spirophorida, Tetillidae
Tetilla spp.

8. Lord Howe Province (OTU = 135)
Demospongiae, Astrophorida, Ancorinidae
Asteropus sp1_NORFANZ
Ecionemia sp1_NORFANZ
Jaspis sp.
Melophlus sp1_NORFANZ
Melophlus sp2_NORFANZ
Stelletta sp1_NORFANZ
Stelletta sp2_NORFANZ
Stelletta sp3_NORFANZ
Stelletta sp4_NORFANZ
Stelletta sp5_NORFANZ

Demospongiae, Astrophorida, Geodiidae
Caminus sp1_NORFANZ
Geodia sp1_NORFANZ
Isops sp1_NORFANZ

Demospongiae, Astrophorida, Pachastrellidae
Characella 3886_NORFANZ
Poecillastra 3884_NORFANZ
Stoeba 3908_NORFANZ
Thenea 3904_NORFANZ

Demospongiae, Astrophorida, Theneidae
Thenea grayi Sollas, 1886

Demospongiae, Chondrosida,Chondrillidae
Chondrilla sp1_NORFANZ

Demospongiae, Dendroceratida, Darwinellidae
Chelonaplysilla sp1_NORFANZ

Demospongiae, Dendroceratida, Dictyodendrillida
Acanthodendrilla 3241

Demospongiae, Dictyoceratida, Dysideidae
Lamellodysidea sp1_NORFANZ

Demospongiae, Dictyoceratida, Irciniidae
Ircinia sp1_NORFANZ

Demospongiae, Dictyoceratida, Spongiidae
Coscinoderma sp1_NORFANZ
Coscinoderma sp2_NORFANZ
Coscinoderma sp3_NORFANZ
Spongia sp1_NORFANZ
Spongia sp2_NORFANZ
Spongia sp3_NORFANZ

Demospongiae, Dictyoceratida, Thorectidae
Carteriospongia foliascens (Pallas, 1766)
Dactylospongia sp2_NORFANZ
Luffariella sp1_NORFANZ
Phyllospongia lamellosa (Esper, 1799)

Demospongiae, Hadromerida, Clionaidae
Cliona 2956

Demospongiae, Hadromerida, Polymastiidae
*Spinularia australis*_NORFANZ L?vi, 1993

Demospongiae, Hadromerida, Spirastrellidae
Spirastrella sp2_NORFANZ
Spirastrella 3895_NORFANZ

Demospongiae, Hadromerida, Suberitidae
Suberites 3909_NORFANZ

Demospongiae, Hadromerida, Tethyidae
Tethya 3911_NORFANZ

Demospongiae, Halichondrida, Axinellidae
Axinella sp1_NORFANZ
Axinella sp2_NORFANZ
Phakellia 3345_NORFANZ
Phakellia sp3_NORFANZ
Phakellia sp5_NORFANZ

Demospongiae, Halichondrida, Dictyonellidae
Acanthella sp1_NORFANZ
Dictyonella sp1_NORFANZ
Rhaphoxya sp1_NORFANZ

Demospongiae, Halichondrida, Halichondriidae
Axinyssa sp1_NORFANZ
Axinyssa sp3_NORFANZ
Halichondria (Halichondria) sp5_NORFANZ
Topsentia sp1_NORFANZ

Demospongiae, Haplosclerida, Callyspongiidae
Callyspongia (Arenosclera) sp1_NORFANZ

Demospongiae, Haplosclerida, Chalinidae
Haliclona (Reniera) sp3_NORFANZ

Demospongiae, Haplosclerida, Niphatidae
Amphimedon sp1_NORFANZ
Amphimedon sp2_NORFANZ
Amphimedon sp3_NORFANZ
Niphates 3242
Niphates 3243
Niphates sp1_NORFANZ

Demospongiae, Haplosclerida, Petrosiidae
Petrosia (Strongylophora) sp1_NORFANZ
*Petrosia punctata*_NORFANZ L?vi & L?vi, 1983
Petrosia sp3_NORFANZ
Petrosia sp4_NORFANZ
Petrosia sp5_NORFANZ
Xestospongia sp5_NORFANZ

Demospongiae, Haplosclerida, Phloeodictyidae
Oceanapia sp6_NORFANZ

Demospongiae, Homosclerophorida, Plakinidae
Corticium 3876_NORFANZ

Demospongiae, Lithistida, Azoricidae
Leiodermatium sp2_NORFANZ

Demospongiae, Lithistida, Corallistidae
Neophrissospongia sp1_NORFANZ
Neoschrammeniella sp1_NORFANZ

Demospongiae, Lithistida, Isoraphiniidae
Costifer sp1_NORFANZ

Demospongiae, Lithistida, Scleritodermidae
*Microscleroderma herdmani*_NORFANZ Dendy, 1905
Scleritoderma sp1_NORFANZ
Scleritoderma sp2_NORFANZ
Scleritoderma sp3_NORFANZ

Demospongiae, Lithistida, Theonellidae
Discodermia sp1_NORFANZ
Discodermia sp2_NORFANZ
Theonella sp1_NORFANZ

Demospongiae, Poecilosclerida, Chondropsidae
Chondropsis 3921_NORFANZ

Demospongiae, Poecilosclerida, Cladorhizidae
Chondrocladia 3939_NORFANZ

Demospongiae, Poecilosclerida, Coelosphaeridae
Lissodendoryx (Lissodendoryx) 3927_NORFANZ

Lissodendoryx (Lissodendoryx) sp3_NORFANZ

Demospongiae, Poecilosclerida, Crellidae
Crella_(Yvesia) sp1_NORFANZ

Demospongiae, Poecilosclerida, Desmacellidae
Desmacella 3943_NORFANZ

Demospongiae, Poecilosclerida, Hamacanthidae
Hamacantha (Vomerula) 3944_NORFANZ

Demospongiae, Poecilosclerida, Microcionidae
Clathria (Axosuberites) 3916_NORFANZ

Demospongiae, Poecilosclerida, Mycalidae
Mycale (Oxymycale) 3319_NORFANZ
Mycale (Oxymycale) sp2_NORFANZ

Demospongiae, Spirophorida, Tetillidae
Cinachyrella 2048_NORFANZ
Cinachyrella 3877_NORFANZ
Tetilla simplex (Sollas, 1886)

Demospongiae, Verongida, Aplysinidae
Aplysina sp1_NORFANZ
Aplysina sp78_NORFANZ

Demospongiae, Verticillitida, Verticillitidae
Vaceletia sp1_NORFANZ

Hexactinellida, Amphidiscosida, Hyalonematidae
Hyalonema_(Hyalonema) sp1_NORFANZ

Hexactinellida, Amphidiscosida, Pheronematidae
Pheronema sp1_NORFANZ
Pheronema sp2_NORFANZ
Pheronema sp3_NORFANZ
Pheronema sp5_NORFANZ

Hexactinellida, Hexactinosida, Farreidae
*Farrea occa*_NORFANZ

Hexactinellida, Unsorted, Unsorted
Unidentified sp105_NORFANZ
Unidentified sp109_NORFANZ
Unidentified sp11_NORFANZ
Unidentified sp111_NORFANZ
Unidentified sp112_NORFANZ
Unidentified SP118_NORFANZ
Unidentified SP119_NORFANZ
Unidentified sp12_NORFANZ
Unidentified SP120_NORFANZ
Unidentified SP123_NORFANZ
Unidentified sp135_NORFANZ
Unidentified sp138_NORFANZ
Unidentified sp143_NORFANZ
Unidentified sp21_NORFANZ
Unidentified sp38_NORFANZ
Unidentified sp42_NORFANZ
Unidentified sp46_NORFANZ
Unidentified sp48_NORFANZ
Unidentified sp49_NORFANZ
Unidentified sp58_NORFANZ
Unidentified sp60_NORFANZ
Unidentified sp62_NORFANZ
Unidentified sp70_NORFANZ
Unidentified sp71_NORFANZ
Unidentified sp74_NORFANZ
Unidentified sp80_NORFANZ
Unidentified sp81_NORFANZ
Unidentified sp82_NORFANZ
Unidentified sp84_NORFANZ
Unidentified sp85_NORFANZ
Unidentified sp86_NORFANZ
Unidentified sp88_NORFANZ
Unidentified sp96_NORFANZ
Unidentified sp98_NORFANZ
Unidentified sp99_NORFANZ

9. Norfolk Island Province (OTU = 94)
Calcarea, Clathrinida, Soleneiscidae
Dendya poterium Haeckel, 1872

Calcarea, Leucosolenida, Leucosoleniidae
Leucosolenia botryoides Ellis and Solander, 1786

Calcarea,Unsorted,
Unidentified sp66_NORFANZ
Unidentified sp83_NORFANZ
Unidentified sp87_NORFANZ

Demospongiae, Astrophorida, Ancorinidae
Stelletta sp1_NORFANZ
Stelletta sp7_NORFANZ

Demospongiae, Astrophorida, Pachastrellidae
Poecillastra 3885_NORFANZ
Pachastrella 3889_NORFANZ

Demospongiae, Dictyoceratida, Irciniidae
Psammocinia sp2_NORFANZ

Demospongiae, Dictyoceratida, Spongiidae
Spongia sp1_NORFANZ
Spongia sp2_NORFANZ

Demospongiae, Hadromerida, Polymastiidae
*Spinularia australis*_NORFANZ L?vi, 1993

Demospongiae, Hadromerida, Spirastrellidae
Spirastrella 3896_NORFANZ

Demospongiae, Hadromerida, Suberitidae
Suberites 634

Demospongiae, Halichondrida, Desmoxyidae
*Parahigginsia phakellioides*_NORFANZ Dendy, 1924

Demospongiae, Halichondrida, Halichondriidae
Axinyssa sp2_NORFANZ
Halichondria (Halichondria) 1429
Halichondria (Halichondria) sp2_NORFANZ
Halichondria (Halichondria) sp4_NORFANZ
Topsentia sp1_NORFANZ

Demospongiae, Halisarcida, Halisarcidae
Halisarca dujardini_magellanica Topsent, 1901

Demospongiae, Haplosclerida, Chalinidae
Cladocroce sp1_NORFANZ
Haliclona (Reniera) sp2_NORFANZ

Demospongiae, Haplosclerida, Niphatidae
Niphates sp2_NORFANZ

Demospongiae, Haplosclerida, Petrosiidae
Petrosia sp2_NORFANZ
Petrosia sp6_NORFANZ
Xestospongia sp1_NORFANZ
Xestospongia sp4_NORFANZ
Xestospongia sp6_NORFANZ
Xestospongia sp7_NORFANZ

Demospongiae, Haplosclerida, Phloeodictyidae
Aka sp1_NORFANZ
Oceanapia sp10_NORFANZ
Oceanapia sp12_NORFANZ
Oceanapia sp13_NORFANZ
Oceanapia sp15_NORFANZ
Oceanapia sp16_NORFANZ
Oceanapia sp17_NORFANZ
Oceanapia sp2_NORFANZ
Oceanapia sp3_NORFANZ
Oceanapia sp7_NORFANZ
Oceanapia sp8_NORFANZ
Oceanapia sp9_NORFANZ
Pachypellina sp1_NORFANZ
Pachypellina sp3_NORFANZ

Demospongiae, Homosclerophorida, Plakinidae
Plakortis sp1_NORFANZ

Demospongiae, Lithistida, Azoricidae
Leiodermatium sp1_NORFANZ

Demospongiae, Lithistida, Neopeltidae
Homophymia sp1_NORFANZ

Demospongiae, Lithistida, Pleromidae
*Pleroma menoui*_NORFANZ Levi & Levi, 1983

Demospongiae, Poecilosclerida,
Acarnidae
Zyzzya 3912_NORFANZ

Demospongiae, Poecilosclerida,
Chondropsidae
Psammoclema densum Marshall, 1880

Demospongiae, Poecilosclerida,
Cladorhizidae
*Chondrocladia pulvinata*_NORFANZ

Demospongiae, Poecilosclerida,
Coelosphaeridae
Lissodendoryx (Acanthodoryx)
3924_NORFANZ

Demospongiae, Poecilosclerida,
Crambeidae
Monanchora 3435_NORFANZ
Monanchora 3928_NORFANZ

Demospongiae, Poecilosclerida,
Crellidae
Crella_(Yvesia) 3929_NORFANZ

Demospongiae, Poecilosclerida,
Dendoricellidae
Pyloderma 3930_NORFANZ

Demospongiae, Poecilosclerida,
Microcionidae
Clathria (Clathria) 3913_NORFANZ
Clathria (Clathria) 3917_NORFANZ

Demospongiae, Poecilosclerida,
Mycalidae
Mycale (Mycale) sp1_NORFANZ
Phlyctaenophora_(Barbozia)
3945_NORFANZ

Demospongiae, Poecilosclerida,
Phellodermidae
Echinostylinos 3933_NORFANZ
Echinostylinos 3935_NORFANZ

Demospongiae, Poecilosclerida,
Podospongiidae
Podospongia 3897_NORFANZ

Demospongiae, Poecilosclerida,
Raspailiidae
Aulospongus 3918_NORFANZ

Demospongiae, Spirophorida, Tetillidae
Craniella 3879_NORFANZ

Hexactinellida, Amphidiscosida,
Hyalonematidae

Hyalonema_(Hyalonema) sp1_NORFANZ

Hexactinellida, Hexactinosid,a Aphrocallistidae
Aphrocallistes beatrix_beatrix Gray, 1858

Hexactinellida, Hexactinosida, Farreidae
*Farrea occa*_NORFANZ
Farrea sp2_NORFANZ

Hexactinellida, Lyssacinosida, Rossellidae
Aulosaccus sp.

Hexactinellida, Unsorted, Unsorted
Unidentified sp102_NORFANZ
Unidentified sp103_NORFANZ
Unidentified sp107_NORFANZ
Unidentified SP114-NORFANZ
Unidentified SP117_NORFANZ
Unidentified SP121_NORFANZ
Unidentified SP124_NORFANZ
Unidentified SP126_NORFANZ
Unidentified sp136_NORFANZ
Unidentified sp141_NORFANZ
Unidentified sp142_NORFANZ
Unidentified sp144_NORFANZ
Unidentified sp17_NORFANZ
Unidentified sp20_NORFANZ
Unidentified sp23_NORFANZ
Unidentified sp26_NORFANZ
Unidentified sp27_NORFANZ
Unidentified sp31_NORFANZ
Unidentified sp32_NORFANZ
Unidentified sp36_NORFANZ
Unidentified sp6_NORFANZ
Unidentified sp7_NORFANZ
Unidentified sp75_NORFANZ

14 Syngnathids

Author: Vicky Tzioumis





Description

The family Syngnathidae is a group of bony fishes which include seahorses, pipefishes, pipehorses and sea dragons. A total of about 330 species have been described worldwide. Australia has the highest recorded diversity of syngnathids with an estimated 25–37% of the world's species (Pogonoski et al. 2002). Approximately 25% of syngnathid genera and 20% of species are endemic to Australian waters (Kuiter 2000; Pogonoski et al. 2002; Martin-Smith &Vincent 2006). Syngnathid fauna from New South Wales (NSW) represent a transition zone between temperate and tropical species (Kuiter 2000).

Syngnathids are characterised by having thick, external armour encasing the body and a tubular snout with a small mouth at the tip. There are currently four recognised syngnathid subfamilies: a) the Syngnathinae, the largest group, includes the pipefishes. These are generally long and pencil-like in shape, with a straight, tapering tail. There are approximately 200 species of pipefishes in 35 genera and they have a much wider latitudinal distribution than seahorses and also occur in freshwater. b) Seahorses belong to the Hippocampinae, and are characterised by a prehensile tail and a thickened body. Adult seahorses range in size from a centimetre to about 28 cm in height. c) The Solegnathinae includes the pipehorses and the sea dragons. Pipehorses have a typical pipefish-like head and body and the prehensile tail of a seahorse. They are the largest fishes in the family with one species growing to 50 cm in length (Kuiter 2000). Pipehorses of the genus *Solegnathus* are the most valuable syngnathid in Traditional Chinese Medicine (TCM) (Vincent 1996; Martin-Smith et al. 2003). Two genera of sea dragons each including one species are endemic to Australian waters. The leafy sea dragon (*Phycodurus eques*) and the weedy or common sea dragon

(*Phyllopteryx taeniolatus*) may reach up to 45 cm in length. They have elaborate, permanent leaf-like appendages which help to camouflage them among seaweed. d) The Doryrhamphinae are free-swimming pipefishes that have a large flag-like tail (Kuiter 2000).

A number of syngnathid species are caught incidentally in fisheries operating in the East Marine Region (EMR), (see Impacts/Threats). Pipehorses are caught incidentally (but are permitted to be harvested) in the Queensland East Coast Trawl Fishery (ECTF) and are a target species in the Marine Aquarium Fish Fishery (MAFF) which operates almost exclusively within the Great Barrier Reef Marine Park. Syngnathids are a small component of the bycatch for trawl fisheries operating off the NSW coast. They are valuable as curios and aquarium fish, and dried specimens are highly sought after in the Traditional Chinese Medicine trade where they are used as treatments for a number of conditions including skin health, asthma and as aphrodisiacs (Vincent 1996; Martin-Smith & Vincent 2006).

Conservation Status

An increase in the TCM trade and the paucity of data on the biology or ecology of most syngnathids has resulted in worldwide conservation concern. Forty-seven species are currently listed on the IUCN Red List of Threatened Species (IUCN 2006). The status of 38 species of syngnathids occurring in Australian waters has been recently assessed along the lines of the IUCN listings (Pogonoski et al. 2002).

In addition, all seahorses (*Hippocampus* spp.) were listed in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in 2002. This means that all member countries of CITES agreed that the international trade in seahorses will have to be regulated to ensure it is not harmful to the survival of wild populations (CITES 2007; Project Seahorse 2007).

All syngnathids are protected species in Australian Commonwealth waters and in NSW, Tasmanian, and Victorian waters. In Queensland, syngnathids are currently permitted to be harvested and exported from both the ECTF and the MAFF. Both these fisheries are managed by the Queensland Department of Primary Industries and Fisheries (DPI&F) (Pogonoski et al. 2002; Dodt 2005). A number of syngnathid species found in the EMR are included on the IUCN Red List of Threatened Species and are listed in Table 14.1.

Table 14.1 Syngnathids found in the EMR that are included on the IUCN Red List of Threatened Species and/or are were assigned conservation status in Australian waters by Pogonoski et al. 2002. (Sources: IUCN 2006; Martin-Smith & Vincent 2006, Kuiter 2000, 2001, CAAB list).

Species[1]	Common names	IUCN Red List status[2]	Australian Conservation Status[3]
Hippocampus abdominalis	Big-belly/pot-bellied seahorse	DD	[LR:cd]
Hippocampus fisheri – (H. jugumus)	Fisher's (or collar) seahorse	DD	[DD]
Hippocampus kelloggi – (H. queenslandicus)	Great, Kellogg's, or offshore (or Queensland) seahorse	DD	[DD]
Hippocampus kuda – (H. taeniopterus)	Estuary, spotted, yellow (or common) seahorse	VU A4cd	[DD]
*Hippocampus minotaur**	Bullneck seahorse	DD	DD
Hippocampus spinosissimus – (H. queenslandicus)	Hedgehog (or Queensland) seahorse	VU A4cd	[LR:nt]
Hippocampus trimaculatus –(H. dahli)	Flat-faced, three-spot (or low-crown) seahorse	VU A4cd	[LR:nt]
Hippocampus tristis	Sad seahorse	No listing	DD
*Hippocampus whitei**	New Holland, Sydney or White's seahorse	DD	DD
*Hippocampus zebra**	Zebra seahorse	DD	DD
*Phyllopteryx taeniolatus**	Weedy or common seadragon	NT	LR:cd
*Solegnathus dunckeri**	Duncker's pipehorse	DD	DD
Solegnathus hardwickii	Hardwick's pipehorse	DD	DD
Solegnathus spinosissimus	Spiny pipehorse/spiny seadragon	VU A1d+2d	DD

[1] Using taxonomy adapted by the IUCN, i.e. Lourie et al. 1999; synonymous species are given in parentheses. *endemic to Australia
[2]DD=Data Deficient, VU=Vulnerable. For an explanation of criteria see IUCN (2006).
[3]From Pogonoski et al. (2002); the taxonomy used by Pogonoski et al. (2002) was not the same as that used by the IUCN (2006); assessments of synonymous species are given in parentheses LR:cd=Lower Risk: conservation dependent; LR:nt =Lower Risk: near threatened; NT= Near Threatened (IUCN, 1994).

Habitat and Distribution

The majority of syngnathids are found in shallow (<30 m) inshore habitats such as macroalgal reefs, rocky reefs, seagrass and soft-bottom estuarine habitats. Only a few species are found in deeper offshore areas including the commercially important *Solegnathus* spp. which are taken as bycatch, dried and sold for use in the TCM trade. Syngnathids are generally found in low abundance in most habitats, although some pipefishes reach high densities in seagrass beds, where they are often the dominant taxa (Martin-Smith, unpublished manuscript and refs. therein).

Life history and reproductive ecology

The majority of syngnathid research has focussed on their characteristic and unusual breeding biology. All syngnathids have highly specialized modes of reproduction with males providing sole parental care through incubation of eggs in or on the body. Eggs are embedded in the skin under the tail of pipehorses and sea dragons, while pipefishes and seahorses have specialized brooding structures ranging from ventral flaps to fully enclosed pouches (Kuiter 2000; Moreau & Vincent 2004; Sanchez-Camara et al. 2005).

Syngnathids have limited reproductive potential, with the numbers of eggs in a single batch typically in the hundreds. The number of young in each brood will generally be lower in the smaller sized species (Vincent 1996; Kuiter 2000; Foster & Vincent 2004). Sea dragon and pipehorse males may incubate up to 300 eggs at a time on their tails and brood size in male pipefishes ranges from a few hundred to about 1000 eggs depending on species and age (Kuiter 2000).

Some species of syngnathids have pelagic larvae and a few adults may drift in kelp rafts but most are bottom dwelling with restricted home ranges making them extremely vulnerable to habitat loss or degradation (Kuiter 2000; Martin-Smith unpublished manuscript).

Available growth and longevity studies for syngnathids suggest rapid growth and short lifespans (Kuiter 2000; Martin-Smith unpublished manuscript; Sanchez-Camara et al. 2005).

Most syngnathids are more active during daylight hours (diurnal) and feed almost exclusively on small crustaceans, such as mysid shrimps, that are sucked up whole. Each species has a favoured habitat and is usually well camouflaged to mimic its environment. Despite their excellent camouflage the adults are preyed upon by benthic fishes and pelagic young have high mortality rates (Kuiter 2000).

Significance of Syngnathids in the East Marine Region

Syngnathids are clearly important in the context of coastal biodiversity with a considerable number of species and a high degree of endemism in Australian waters. Pipehorses of the genus *Solegnathus* which are caught as bycatch in trawl fisheries operating in the EMR (see Impacts/Threats) are an important source for the TCM trade and SE Australia is the only source of sea dragons for the live aquarium trade supplying specimens for the European, American and Japanese markets. In terms of abundance syngnathids do not appear to be a major ecosystem component except in seagrass habitats and most available evidence suggests their contribution to energy flow will be low in most areas (Martin-Smith unpublished manuscript).

Impacts/Threats

There are three key threats to syngnathids in Australian waters (including those of the EMR):

- loss or degradation of habitat, particularly in coastal areas
- collecting of wild specimens for the marine aquarium fish trade
- harvesting for the TCM trade.

The highly specialized biology of syngnathids including a restricted diet, specific habitat requirements, low mobility and low reproductive output with obligate male brooding render them more susceptible to these threats (Kuiter 2000; Pogonoski et al. 2002; Martin-Smith & Vincent 2006; Martin-Smith, unpublished manuscript).

Many syngnathids inhabit relatively shallow inshore areas which makes them vulnerable to human disturbance. Increasing coastal development has the potential to impact on important habitats such as seagrass, reef and soft bottom habitats through pollution, urban run-off and dredging (Vincent 1996; Kuiter 2000; Pogonoski et al. 2002; Martin-Smith unpublished manuscript).

Australia is the sole supplier of two sea dragon species, *Phycodorus eques* and *Phyllopteryx taeniolatus,* to the live aquarium trade. In a review of exports of syngnathids from Australia Martin-Smith and Vincent (2006) conclude that trade volume is relatively low (although lucrative) and probably poses a low risk compared to habitat loss as traders tend to capture a few brooding males and rear the young for later sale. There is no evidence of population declines for either species (Pogonoski et al. 2002).

Seahorses are often collected for use in home aquaria but require particular care in captivity as they usually only consume live food. Without special care many seahorses taken from the wild do not survive for very long (Kuiter 2000). A number of aquaculture organizations in Australia have developed techniques for breeding and keeping seahorses and they are largely sold to the live aquarium markets in Australia, North America, Europe and Asia (Martin-Smith & Vincent 2006). Cultured specimens are not accepted in the TCM trade (Anna Murray pers. comm.).

More than 98% of Australia's exports of dried syngnathids for use in the TCM trade are the pipehorses *Solegnathus dunckeri* and *S. hardwickii* sourced largely from the bycatch component of the ECTF. They represent Australia's largest syngnathid export both by volume and value (Martin-Smith et al. 2003; Martin-Smith & Vincent 2006). Because *S.dunckeri* is an endemic species Australia is the sole supplier of this pipehorse to the TCM trade (Martin-Smith & Vincent 2006).

In a recent assessment of the Queensland ECTF it was reported that over 90% of the total syngnathid catch was made up of the pipehorses, *Solegnathus dunckeri* and *S. hardwickii* (Dodt, 2005; Connolly et al. 2001). *Solegnathus* spp. have also been reported as bycatch in the NSW Ocean Trawl Fishery (OTF) and in trawl fishing operations off Victoria which are managed by the Australian Fisheries Management Authority (Bowles & Martin-Smith 2003). A survey of bycatch in the demersal trawl fisheries in south-eastern Australia also showed that *Solegnathus* spp. were the major component of the syngnathid bycatch with *Solegnathus spinosissimus* the most commonly caught species on the south coast of NSW and eastern Victoria and *S. dunckeri* the most commonly caught species from the central to the far north coast of NSW

(Bowles & Martin-Smith 2003). The volumes traded from these fisheries are largely unknown and not regulated as in the ECTF.

In an assessment of risk to bycatch species caught in the NSW OTF (DPI 2004) four species of syngnathids were identified as being at medium to high risk from fishing operations. These were: the pipehorses *Solegnathus dunckeri*; *S. spinosissimus*; *S. sp.1* and the seahorse *Hippocampus tristis.* Many of the other species of syngnathids found along the NSW coast are restricted to shallow, estuarine habitats and are considered at low risk from trawling operations (DPI 2004).

Pogonoski et al. (2002) concluded that marine protected areas and no-take zones situated in critical habitats (see Habitat and Distribution) are probably the most effective means for protecting individual species in Australian waters.

Information Gaps

Despite the high profile of syngnathids and their conservation status little is known of the biology and ecology of most species (Pogonoski et al. 2002; Vincent 2006; Martin-Smith unpublished manuscript).

In an unpublished review of the ecological role of syngnathids in the coastal ecosystems of south-eastern Australia Martin-Smith (unpublished manuscript) concluded that our understanding of this role is limited and that priority areas of research for syngnathids should include:

- validated estimates of population density over large spatial scales
- direct measurements of growth and age
- estimates of food uptake and energy conversion
- dispersal over small and medium spatial scales
- investigation of factors driving the population dynamics of syngnathids.

Further research on the basic biological and population dynamics of the *Solegnathus* spp. that make up the bulk of exports for TCM use is required. Accurate distributional and depth data are required to identify key habitats. The designation of suitable non-trawl protected areas in the northern NSW and southern Queensland areas may be crucial to survival. Species specific data on distribution and biology could be obtained by monitoring the catches of the species taken by trawl fishers on Queensland and NSW coastlines (Pogonoski et al. 2002; Dodt 2005).

Key References and Current Research

Current Research

An observer program has been developed by the Queensland Department of Primary Industries and Fisheries to provide an independent validation of bycatch species (including syngnathids) caught in the East Coast Trawl Fishery (ECTF) (Dodt 2005). Further research is currently underway to investigate the basic biology of syngnathids collected in scientific surveys and to examine the relationship between syngnathid distribution and abundance and habitat characteristics (Dodt 2005). Observer programs are planned for all NSW fisheries and the need for further research to examine syngnathid preferred habitats overlapping with the commercial trawl sector of the Southern and Eastern Scalefish Shark Fishery (SESSF) is highlighted in the Draft Bycatch Action Plan (2005) at:
www.afma.gov.au/fisheries/sess/sess_commonwealth/mac/2005/setmac89/item09.pdf

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Web references: Project Seahorse: www.projectseahorse.net/

15 Trawl Bycatch

Author: Ken Graham












Description

Bycatch, as defined in The Commonwealth Policy on Fisheries Bycatch, encompasses the part of the commercial fishing catch not targeted by the fisher. It includes byproduct, discards and ‘catch’ not landed but affected by interaction with the fishing gear (DAFF 2007). Byproduct is a retained (commercial) component of catches and, along with fishery target species, is subject to fishery-specific management plans. The discarded bycatch is the non-commercial portion of the fisher's catch which is returned to the sea either because it has no value or because regulations preclude it being retained (collectively known as discards).

The East Marine Region (EMR) supports a variety of coastal and offshore fisheries based in southern Queensland and New South Wales (NSW). All these fisheries generate bycatch but, of all the fishing methods, demersal (bottom) trawling is the most indiscriminate and produces by far the greatest quantity and diversity of discards. This report focuses on the non-commercial teleosts (bony fish) and invertebrates (crustaceans and molluscs) discarded by the trawl fisheries of NSW and Queensland. Bycatch issues relating to other taxa such as sharks and rays, seabirds, seals, turtles and marine snakes are discussed in the relevant chapters.

The Queensland trawl fisheries target principally scallops, prawns and stout whiting, and operate mostly in the inshore (< 100 m) and shelf (100–200 m) zones. The NSW Ocean Trawl Fishery (OTF) extends from the Queensland border in the north to the Victorian border in the south. North of Barrenjoey Point (Sydney) the boundaries extend from the coast to the 4000 m depth contour. South of Barrenjoey Point, the NSW jurisdiction extends to three nautical miles seawards of the coast; trawling outside this boundary is managed by the Commonwealth as part of the Southern and Eastern Scalefish and Shark Fishery (SESSF). Prawn-trawlers off the northern half of NSW target mainly prawns, cephalopods and whiting while fish-trawlers operate off central and southern NSW for fish and squid. Prawn-trawlers (excluding those targeting royal-red prawns) mainly operate in depths between 10 and 100 m whereas fish and royal-red prawn trawlers utilize grounds across the shelf and on the upper slope to depths of about 600 m; occasionally, trawlers will fish to about 1000 m.

In the 1990s, discarded bycatch from Queensland prawn trawl fisheries was estimated to exceed 25 000 t per annum (Robins & Courtney 1998) resulting in the progressive introduction of regulations that required all otter trawl vessels to fit a turtle excluder device (TED) and an additional bycatch reduction device (BRD) to every trawl net. More recently, the Queensland Department of Primary Industries and Fisheries completed several studies that assessed bycatch and evaluated BRDs in the Queensland trawl fisheries (Courtney et al. 2007).

During the same period, several studies quantified (by weight) overall discard rates on NSW grounds fished by trawlers operating in the OTF and SESSF through commercial-trawler onboard-observer studies (Liggins 1996; Kennelly et al. 1998) and fishery-independent surveys by FRV *Kapala* (Graham et al. 1995, 1996, 1997; Graham & Wood 1997). Discard rates of non-commercial species ranged between 30% of the total catch weight by offshore fish-trawlers (Liggins 1996) to more than 60% of catch weight by prawn-trawlers (Kennelly et al. 1998); *Kapala* survey discard rates were within this range. Subsequently, bycatch reduction devices (BRDs) were introduced into the NSW Offshore Prawn Trawl (OPT) fishery to reduce discarding rates.

Published *Kapala* survey data includes species lists of fishes, molluscs and crustaceans (stomatopods and decapods), each with their frequency of capture, but catch weights of individual non-commercial species were not collected. Quantitative data (by number) for individual bycatch species were, however, collected and recorded in the *Kapala* Survey Databases held by the NSW Department of Primary Industries (DPI) at the Cronulla Fisheries Research Centre of Excellence. These data were used in the risk analysis of non-commercial bycatch species in the NSW OTF Environmental Impact Statement (DPI 2004). Data presented here for NSW trawling grounds were derived from the same databases and, along with Queensland data from Courtney et al. (2007), have been summarised to meet the criteria for this report i.e. into four depth zones: inshore, <100 m; shelf, 100–200 m; upper slope, 200–650 m and mid-slope, 650–1200 m; in addition, taxonomic names have been updated where required (see CAAB 2007).

Conservation Status

All members of the families Solenostomidae (ghost pipefishes), Syngnathidae (seahorses and pipehorses) and Pegasidae (seamoths), and a small number of essentially shallow water or reef dwelling teleosts that occur in NSW waters are protected under the NSW Fisheries Management Act (DPI 2004). In addition, all syngnathids and solenostomids are listed marine species under the *Environment Protection and Biodiversity* (EPBC) *Act*. It is an offence to kill, injure, take, trade, keep or move any member of a listed marine species in Commonwealth waters without a permit. Limited landings of pipehorses (*Solegnathus* spp.) are allowed in Queensland (see chapter 14). All seahorses (*Hippocampus*) were listed in Appendix II of CITES (Convention on International Trade in Endangered Species of Wild fauna and Flora) in 2002 (see chapter on Syngnathids).

Table 15.1 lists nine protected species recorded in low numbers from NSW trawl grounds during RV *Kapala* surveys, including a single specimen of the Ballina Angelfish which is known only from northern NSW and Lord Howe Island; three species of syngnathids were reported from southern Queensland trawl grounds (Courtney et al. 2007).

Table 15.1 Bycatch teleosts recorded from trawl catches in EMR waters that are on the IUCN Redlist or are protected in NSW and Queensland.

Family	Scientific Name	Common Name	IUCN	NSW	Qld
Solenostomidae	*Solenostoma cynopterus*	Robust Ghostpipefish		P	
Syngnathidae	*Filicampus tigris*	Tiger Pipefish		P	
Syngnathidae	*Hippocampus abdominalis*	Bigbelly Seahorse	DD	P	
Syngnathidae	*Hippocampus queenslandicus*	Queensland Seahorse			R
Syngnathidae	*Hippocampus tristis*	Sad Seahorse		P	
Syngnathidae	*Solegnathus dunckeri*	Duncker's Pipehorse	DD	P	R
Syngnathidae	*Solegnathus* cf. *hardwickii*	Hardwick's Pipehorse	DD		R
Syngnathidae	*Solegnathus spinosissimus*	Spiny Pipehorse	VU	P	
Syngnathidae	*Trachyrhamphus bicoarctatus*	Bentstick Pipefish		P	
Pegasidae	*Pegasus volitans*	Slender Seamoth		P	
Pomacanthidae	*Chaetodontoplus ballinae*	Ballina Angelfish		P	

DD=data deficient; VU: vulnerable; P: protected; R: recorded

Habitat and Distribution

Queensland and NSW trawl fishery surveys and studies have documented very diverse demersal faunas in coastal areas of the EMR. A total of 690 species (235 families) comprising 484 (149) teleosts, 103 (49) molluscs, and 101 (37) crustaceans were identified from catches on NSW trawl grounds during stratified surveys in 1989–1997. Non-commercial bycatch species (366 teleosts, 79 molluscs and 78 crustaceans) contributed 25–40% of total catch (by number) on inshore grounds, and more than 50% of total catch on the deeper shelf and slope grounds (see Appendix A, B, C). Courtney et al. (2007) list 406 bycatch taxa from the shallow water (< 91 m) king prawn trawl fishery grounds, and 346 taxa from the deepwater (> 91 m) trawl grounds off southern Queensland. These lists include all organisms encountered during their gear trials but a subset of the data (teleosts, crustaceans and molluscs) is comparable with the available NSW data. Approximately 215 teleost, 70 crustacean and 50 mollusc species were classed as bycatch on the inshore grounds, while on the trawl grounds deeper than 91 m, around 160 teleost, 65 crustacean and 50 mollusc species were recorded. Overall, 280 species of teleosts and 171 species of crustaceans and molluscs were listed across all depths.

Despite the high diversity, a relatively small number of species contributed a large proportion of total catch by number in all depth zones. A total of 23 species and 12 families of teleosts were assessed as key components of bycatch on Queensland and NSW trawl grounds; collectively, they contributed between 75% and 95% of the total teleost bycatch numbers (Table 15.2). Most abundant on inshore and shelf grounds were butterfly gurnards (Triglidae), longspine flathead (*Platycephalus longispinus*), dragonets (Callionymidae), small soles and flounders (Soleidae, Bothidae) and boxfishes (Ostraciidae). Butterfly gurnards also dominated the deeper shelf catches along with bellowsfishes (Macroramphosidae) and three-spined cardinalfish (*Apogonops anomalus*). Whiptails and rattails (Macrouridae and Bathygadidae) were the most speciose group of bycatch teleosts on the continental slope with 60 species recorded from NSW alone (Iwamoto & Graham 2001). Collectively, whiptails were about 10% of total-catch weights (Graham 1990; Andrew et al. 1997) and about 50% of total teleost-bycatch numbers on both the upper and mid slopes (Table 15.2). On the upper slope, a further 30% of the bycatch was comprised of cucumberfish (*Paraulopus nigripinnis*) and deep sea flathead (*Hoplichthys haswelli*) while basketwork eels (Synaphobranchidae), slickheads (Aleopocephalidae) and morid cods (Moridae) were the other commonly caught groups on the mid-slope (Table 15.2).

Demersal trawling is generally done on relatively smooth, sandy or mud substrates and it can therefore be inferred that species that are abundant in trawl catches favour such habitats. It is also likely that species rarely caught by trawl may be more abundant in non-trawlable habitats such as areas of reef or foul ground, or they live mostly in the water column clear of the seabed and are unlikely to be caught by demersal trawls. Non-trawlable areas in the EMR may be fished by traps and lines but little bycatch is reported (DPI 2006) and faunal assemblages in such habitats are largely unknown.

Analyses of the trawl data for teleosts showed that species diversity and assemblages varied geographically and with depth, and that most species were depth-dependent. Of the 306 species of non-commercial bycatch teleosts recorded in survey trawls off central and southern NSW (K. Graham, unpublished data), almost 27% were caught exclusively on the inshore grounds (< 90 m) and nearly 30% were endemic to the mid-slope zone (650–1200 m); less than 25% of the total number of species was caught in two or more of the depth zones and only a single species (*Apogonops anomalus*) was recorded in all depths (Table 15.3a). Data for the Queensland trawl grounds (Courtney et al. 2007) showed that about 40% of bycatch teleosts were confined to the inshore depths, 25% were caught only in depths greater than 90 m and the remainder spanned both depth zones.

Geographically, teleost diversity on inshore and shelf depths decreased with increasing latitude. Almost twice as many teleost species were recorded on the Queensland grounds compared to southern NSW (Table 15.3b). On the inshore grounds, more than 30% of the Queensland species were not found in NSW and, for both depth zones, only about 20% of the species were distributed between Queensland and southern NSW. There were no comparable data for continental slope depths.

Data on invertebrate bycatch numbers on NSW grounds were available for inshore, shelf and upper slope depth zones. Of the 101 species of molluscs (Appendix B), 76 were non-commercial species but these contributed less than 1% of the total bycatch number; this reflects the relative inefficiency of trawl gear in capturing benthic molluscs. Ten species, mainly cephalopods, each contributed more than 5% of bycatch-mollusc numbers on any ground (Table 15.4).

There were 99 species of crustaceans recorded during surveys on the NSW grounds with 77 classed as bycatch (Appendix C). On inshore prawn grounds, crustacean bycatch was 4–6% of total catch numbers (of all taxa) and consisted mainly of mantis shrimps (Stomatopoda), small prawns, and several species of swimmer crabs (Portunidae); on the upper slope, the swimmer crab *Ovalipes molleri* was about 22% of the total catch number and 90% of crustacean bycatch (Table 15.4). Crustacean bycatch on the Queensland grounds was dominated by the small hardback prawn (*Trachypenaeus curvirostris*) and a number of swimmer crab species (Table 15.4; Courtney et al. 2007).

Table 15.2 Key bycatch teleost families and species on Queensland and NSW trawl grounds. Queensland data are number/hectare (Courtney et al. 2007); NSW data are % no. of total bycatch teleosts in each depth zone; risk assessment from OTF EIS (DPI 2004).

		Queensland		New South Wales					
Family	**Species**	**Inshore <91m**	**Shelf >91m**	**Inshore (north)**	**Inshore (south)**	**shelf**	**upper slope**	**mid-slope**	**Risk**
Triglidae	(8 species)			17.9	15.1	41.1	2.3	-	
Triglidae	*Lepidotrigla argus*	81.4	7.0	17.1	12.0	<0.1	-	-	H
Triglidae	*Lepidotrigla umbrosa*	13.8	-	0.4	-	-	-	-	
Triglidae	*Lepidotrigla modesta*	-	-	-	-	21.8	-	-	H
Triglidae	*Lepidotrigla mulhalli*	-	-	<0.1	1.4	19.0	1.8	-	H
Platycephalidae	(3 species)			19.0	18.7	<0.1	-	-	
Platycephalidae	*Platycephalus longispinis*	11.2	<0.1	18.4	18.7	-	-	-	H
Nemipteridae	*Nemipterus theodorei*	12.3	<0.1	0.3	-	-	-	-	

		Queensland		New South Wales					
Family	**Species**	**Inshore <91m**	**Shelf >91m**	**Inshore (north)**	**Inshore (south)**	**shelf**	**upper slope**	**mid-slope**	**Risk**
Sparidae	*Dentex tumifrons*	<0.1	1.5	-	-	-	-	-	
Bothidae	(8 species)			16.3	0.5	0.6	-		
Bothidae	*Lophonectes gallus*	-	-	15.6	0.5	0.6	-	-	H
Bothidae	*Engyprosopon grandisquama*	11.3	<0.1	0.5	-	-	-	-	
Soleidae	(6 species)			8.5	-	-	-	-	
Callionymidae	(6 species)			7.4	5.9	<0.1	-	-	
Callionymidae	*Bathycallionymus moretonensis*	0.1	2.8	<0.1	-	0.7	-	-	
Callionymidae	*Repomucenus calcaratus*	11.5	-	5.5	5.8	-	-	-	H
Callionymidae	*Repomucenus limiceps*	13.3	-	<0.1	-	-	-	-	
Neosebastidae	*Maxillicosta whitleyi*	15.2	<0.1	5.0	3.3	<0.1	-	-	H
Acropomatidae	*Apogonops anomalus*	-	5.5	6.1	0.7	17.9	4.8	<0.1	I-H
Ostraciidae	(6 species)			3.5	10.4	<0.1	-	-	
Macroramphosidae	(3 species)			0.2	36.5	14.6	6.0	-	
Macroramphosidae	*Macroramphosus scolopax*	<0.1	1.1	0.2	26.5	10.4	-	-	I-H
Macroramphosidae	*Macroramphosus gracilis*	<0.1	2.9	<0.1	10.0	4.2	-	-	I-H
Paraulopidae	*Paraulopus nigripinnis*	-	-	-	-	18.7	13.8	-	I-H
Hoplichthyidae	*Hoplichthys haswelli*	-	-	-	-	-	15.3	-	H
Macrouridae	(41 species)	-	-	-	-	-	51.8	49.9	
Macrouridae	*Lepidorhynchus denticulatus*	-	-	-	-	-	20.2	5.0	H
Macrouridae	*Caelorinchus mirus*	-	-	-	-	-	16.2	-	H
Macrouridae	*Caelorinchus parvifasciatus*	-	-	-	-	-	9.7	-	H
Macrouridae	*Coryphaenoides serrulatus*	-	-	-	-	-	-	15.1	
Macrouridae	*Caelorhinchus innotabilis*	-	-	-	-	-	0.3	10.3	
Synaphobranchidae	(5 species)	-	-	-	-	-	-	12.2	
Synaphobranchidae	*Diastabranchus capensis*	-	-	-	-	-	-	9.2	
Moridae	(10 species)	-	-	0.7	<0.1	<0.1	0.1	5.3	
Alepocephalidae	(10 species)	-	-	-	-	-	-	4.5	
Bathygadidae	(5 species)	-	-	-	-	-	-	4.5	

Inshore (<100 m) north-central, southern NSW; shelf (100-200 m); upper slope (200-650 m); mid-slope 650-1200 m; Risk I: intermediate, H: high. Selection criteria: Queensland inshore >10/ha, shelf >1/ha; NSW >10% total bycatch number

Table 15.3a Depth distributions of bycatch teleosts on NSW and Queensland trawl grounds.

	NSW			Queensland		
Depth zone(s)	**T**	**N**	**% of total**	**T**	**N**	**%**
Inshore (0-90 m)	126	82	26.8	182	103	42.1
Shelf (90-200 m)	74	23	7.5	142	63	25.7
Upper slope (200-650 m)	77	36	11.8			
Mid-slope (650-1200 m)	116	91	29.7			
Inshore – shelf		33	10.8		79	32.2
Inshore - shelf - upper slope		10	3.3			
Inshore - shelf - upper slope - mid-slope		1	0.3			
Shelf - upper slope		6	2.0			
Shelf - upper slope - mid-slope		1	0.3			
Upper slope - mid-slope		23	7.5			
Total number of species		306			245	

T: total no. of species in each depth zone; N: no. of species exclusive to depth zone or across two or more zones;
Sources NSW: K. Graham, unpublished data; Qld: Courtney et al. (2007)

Table 15.3b Geographic distributions of bycatch teleosts (No. of species) on NSW and Queensland trawl grounds.

Depth zone	**Inshore (0–90 m)**			**Shelf (90–200 m)**		
	T	**No.**	**%**	**T**	**No.**	**%**
Queensland	182	92	34.2	142	108	59.3
Qld - NSW(north)		37	13.8			
Qld - NSW(north) - NSW(south)		52	19.3			
Qld - NSW(south)		1	0.4		34	18.7
NSW(north)	148	34	12.6			
NSW(north) - NSW(south)		25	9.3			
NSW(south)	106	28	10.4	74	40	22.0
Total number of species		269			182	

T: total no. of species in each area; No.: no. of species within each area or areas;
%: percentage of total species.
Sources NSW: K. Graham, unpublished data; Qld: Courtney et al. (2007)]

Table 15.4 Key bycatch invertebrate species on Queensland and NSW trawl grounds. Queensland data are no./ha (Courtney et al. 2007); NSW data are % no. of total bycatch molluscs or crustaceans in each depth zone.

		Queensland		New South Wales			
Family	**Species**	**Inshore <91m**	**Shelf >91m**	**Inshore (north)**	**Inshore (south)**	**Shelf**	**Upper slope**
Molluscs							
Sepiidae	*Sepia limata*	0.1	0.2	7.2	-	-	-
Sepiolidae	*Austrorossia australis*	-	-	-	-	-	14.7
Sepioloididae	*Sepioloidea lineolata*	0.1	0.1	38.3	#	-	-
Enoploteuthidae	*Enoploteuthis galaxias*	-	-	-	-	-	8.2
Histioteuthidae	*Histioteuthis miranda*	-	-	-	-	-	6.8
Opisthoteuthidae	*Opisthoteuthis persephone*	-	-	-	-	-	6.8
Ranellidae	*Fusitriton retiolus*	-	-	-	-	-	32.8
Buccinidae	*Penion mandarinus*	-	-	-	-	-	14.7
Olividae	*Ancillista velesiana*	<0.1	-	7.6	#	-	-
Glycymerididae	*Glycymeris holosericus*	-	-	18.9	-	-	-
Crustaceans							
Squillidae	*Belosquilla laevis*	0.5	-	6.3	-	-	-
Squillidae	*Anchisquilloides mcneilli*	-	-	7.0	-	3.4	-
Penaeidae	*Trachypenaeus curvirostris*	22.7	0.3	31.5	1.0	-	-
Solenoceridae	*Solenocera australiana*	-	-	5.6	-	-	-
Pandalidae	*Plesionika laurentae*	0.4	4.2	-	-	-	-
Latriellidae	*Latriella philargium*	-	-	-	-	10.5	-
Majidae	*Leptomithrax waitei*	<0.1	0.1		-	59.1	-
Portunidae	*Charybdis bimaculata*	0.1	3.2	18.7	2.8	11.5	-
Portunidae	*Charybdis miles*	<0.1	0.4	5.9	-	-	-
Portunidae	*Ovalipes australiensis*	-	-	-	90.7	-	-
Portunidae	*Ovalipes molleri*	-	-	-	-	0.3	89.5
Portunidae	*Portunus argentatus*	21.2	0.3	2.0	-	-	-
Portunidae	*Portunus rubromarginatus*	15.4	<0.1	7.1	-	-	-

Inshore (<100 m) north, central, southern NSW; shelf (100-200 m); upper slope (200-650 m); # recorded.
Selection criteria: Queensland inshore >10/ha, shelf >1/ha; NSW >5% total bycatch number

Life history and reproductive ecology

Most teleosts and invertebrates are relatively fast growing and produce large numbers of pelagic eggs and larvae. The early larval and post-larval life stages of several bycatch teleosts were delineated by Neira et al. (1998) but the biology of non-commercial species is seldom investigated. However, current studies by NSW DPI into the age, growth and reproduction of key species in NSW fisheries include the longspine flathead (*Platycephalus longispinus*) and eye gurnard (*Lepidotrigla argus*), the two most abundant bycatch species on inshore trawl grounds (see Table 15.2).

Migration/movement

Although several species of large commercial teleosts undertake winter spawning migrations along the NSW upper slope, none of the non-commercial teleosts are known to have similar or other migratory behaviour. Similarly, commercial invertebrates such as king prawns (*Melicertus plebejus*) and smooth bugs (*Ibacus chacei*) migrate northwards as they mature. There is no information on such movements by non-commercial invertebrates.

Significance of Bycatch in the East Marine Region

There is the general perception that bycatch fish and invertebrates have low economic importance although some bycatch species such as the toothed whiptail (*Lepidorhynchus denticulatus*) are occasionally retained for use as bait in the tuna-longline fishery. However, the advent of a more ecosystem-based approach to fishery management has resulted in a greater recognition of the importance of many small bycatch species in marine food chains. In general, most bycatch teleosts are small, lower-order carnivores feeding on smaller fish and invertebrates while, in turn, being prey for the larger carnivorous fish.

Impacts/Threats

Fishing

By definition, the main threat to trawl bycatch species is the trawling process itself. While changes in catch rates and stock structure are routinely monitored for commercial species, little or no data are collected for discarded bycatch. However, the main impacts to bycatch species are trawl-induced mortality, habitat modification and environmental change. The long-term impacts of trawling on bycatch species are unknown, but depletion of bycatch biomass may be a contributing factor in concurrent reductions in commercial fish stocks such as gemfish (*Rexea solandri*). Conversely, the greater abundances of some deepwater crabs such as *Ovalipes molleri* and *Dagnaudus petterdi* on NSW upper slope trawl grounds in recent years may have resulted from an increased supply of food through the discarding of bycatch by trawlers (Andrew et al. 1997).

Continued fishing pressure is likely to have the greatest impact on bycatch species and the high levels of discarding in trawl fisheries has generated worldwide and local concern (e.g. Andrew & Pepperell 1992;

Buxton & Eayrs 1998; Kennelly et al. 1998). Studies of shallow water trawling showed that 80–90% of teleosts do not survive when discarded (Hill & Wassenberg 1990; Wassenberg & Hill 1989), and this mortality figure is probably closer to 100% for deepwater trawl bycatch which are exposed to severe barotrauma and water temperature changes during capture. The Environmental Impact Assessment for the NSW OTF concluded that 95% of bycatch species (fish and invertebrates) on NSW trawl grounds were at a high or moderately-high level of risk (DPI 2004).

All jurisdictions covering EMR waters have responded to trawl-bycatch issues. The Australian Fisheries Management Authority (AFMA) has developed fishery-specific bycatch action plans for Commonwealth managed fisheries e.g. the SESSF Bycatch Action Plan 2006-2008 (AFMA 2007). At the State level, a number of BRDs have been developed to reduce bycatch mortality in Queensland and NSW managed prawn-trawl fisheries (Eayrs et al. 1997; Broadhurst 2000; Broadhurst et al. 2002; Courtney et al. 2007) and various devices have become mandatory. These include TEDs which, in addition to excluding turtles, effectively exclude most sharks, rays and large teleosts, square-mesh codends that are designed to better select appropriate harvest sizes of targeted species, and BRDs such as square-mesh panels which reduce the numbers of unwanted small teleosts.

Habitat Loss

Because trawling is conducted on relatively smooth areas of seabed, the process does not cause major modification to the seafloor profile. However, continual trawling on substrates that support sessile organisms such as sponges and gorgonians can destroy such assemblages in a relatively short period (Sainsbury 1988). The loss of these organisms can reduce habitat diversity and consequently lower species diversity (see DPI 2004 for discussion). Fish trawls can be rigged with groundropes fitted with heavy and large diameter bobbins (or rollers) so as to avoid gear damage when trawling across areas of relatively hard substrate that often support rich assemblages of sessile organisms; the fishing areas and allowable size of bobbin-rigged groundropes is regulated in waters under NSW jurisdiction.

Information Gaps

There is continuing research by the NSW DPI into ways to improve the selectivity of trawl gear with investigations into the efficacy of square-mesh codends and general codend arrangement and construction (DPI 2007).While improved gear selectivity should decrease undersized commercial bycatch its effect on non-commercial bycatch is unknown., Bycatch reduction devices (as used in prawn trawls) are unsuitable for fish trawling as their design would necessarily exclude many primary and secondary target species and there is no one gear size or arrangement that would minimise bycatch across all species. While better selectivity of fish-trawl codends would help reduce unwanted commercial and non-commercial bycatch species, a better understanding of the variability in the composition and quantity of bycatch in fish trawls may enable specific methods or gear modifications to be developed.

Key References and Current Research

Current Research

The Wildfisheries section of the NSW DPI is currently collaborating in long-term research with the University of British Columbia, Canada, where ecosystem models are being developed to investigate multispecies management strategies for capture fisheries; the diversity and abundance of bycatch on NSW trawl grounds is being factored into some of these models (DPI 2007). With the proposal to have all ocean prawn-trawls used in NSW fitted with square-mesh codends by 2008, an onboard observer program is currently quantifying and comparing the retained and discarded catches from the standard diamond-mesh and proposed square-meshed codends.

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16 Summary of Impacts and Threats

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Impacts are those events currently happening and known to have an effect on key species and threats are those events that may happen to key species groups (e.g. have happened in the past and may happen again, or are likely in the future as a result of anticipated changes) (National Oceans Office, 2004).

There is a combination of factors which suggest that the impacts and threats accrued by the Key Species Groups of the East Marine Region (EMR) are greater than in other bioregions recognised by the Integrated Marine and Coastal Regionalisation of Australia (IMCRA) plan. These factors include:

- the EMR is adjacent to the east coast of the mainland, the most heavily populated part of Australia, increasing the potential for anthropogenic impacts and threats to occur
- the EMR includes remote areas which are difficult to study and monitor, and for which there is little existing baseline data, increasing the potential for threats and impacts to go undetected
- the EMR is vast and covers an enormous diversity of geographic, climatic, bathymetric, geological and biological diversity, increasing the variety of threats and impacts which need to be considered.

A summary of impacts and threats noted for each of the Key Species Groups documented in this report is presented in Table 16.1.

Several of these impacts and threats are common to a number of the Key Species Groups and these are further summarised in Table 16.2. It is important that these common threats are not interpreted without consulting Table 16.1 as additional threats not indicated in Table 16.2 are listed there.

As in other Australian marine planning areas it is particularly important that the accumulation of combined threats and impacts be considered when evaluating the risk to the Key Species Groups of the EMR and determining appropriate abatement and conservation measures in response.

Table 16.1 Summary of Impacts and Threats identified for Key Species Groups of the EMR arranged by the Species Group.

KEY SPECIES GROUP	IMPACTS/THREATS
Corals	• global climate change leading to increased incidence of coral bleaching • runoff from coastal development and agriculture leading to poor water quality • anchor damage • fishing • cyclones • coral feeding organisms • disease
Crustaceans	• contamination by chemicals or heavy metals, either by accumulation along the food chain or locally by spills • habitat loss/modification through global climate change • habitat loss/modification through commercial fishing activities, particularly trawling • overfishing of target species by commercial fisheries • mortality as bycatch of commercial fisheries, particularly trawl fisheries
Demersal Fish	• overfishing of commercial species • mortality as bycatch of commercial fisheries, particularly trawl fisheries • habitat loss/modification through commercial fishing activities, particularly trawling
Echinoderms	• mortality as bycatch of commercial fisheries, particularly trawl fisheries • habitat loss/modification through commercial fishing activities, particularly trawling • habitat loss/modification through global climate change • lowered survivorship of pelagic and benthic life stages due to impaired skeletogenesis resulting from ocean acidification caused by global warming • storms and cyclones • freshwater run-off from coastal development • overfishing of commercial bêche-de-mer and sea urchin species • changes in community ecology and biodiversity due to overfishing of commercial bêche-de-mer and sea urchin species
Marine Snakes	• habitat loss, particularly by degradation of reefal systems through siltation, eutrophication or pollution from agricultural run-off • degradation of reefal systems associated with the impacts of projected climatic shifts • mortality as bycatch of commercial trawl fisheries • damage to feeding grounds by commercial trawl fisheries
Marine Turtles	• habitat loss, especially seagrass and algal pastures, through increased sediment

KEY SPECIES GROUP	IMPACTS/THREATS
	discharge associated with land clearing • accumulation of chemical pollutants such as chlorinated hydrocarbons through the food chain and subsequent transfer to succeeding generations • changes to light horizons at nesting beaches associated with building developments resulting in lower nesting densities • mortality as bycatch of commercial trawl fisheries prior to the mandatory use of turtle exclusion devices • entanglement in gear from commercial and recreational fisheries, particularly commercial longline and trap fisheries • boatstrike and propeller cuts • Ingestion of synthetic debris, particularly plastics and fishing line, resulting in gut blockages • traditional hunting at unsustainable levels
Molluscs	• habitat loss/modification through commercial fishing activities, particularly trawling • mortality as bycatch of commercial fisheries, particularly trawl fisheries • impaired calcium deposition in shells, particularly of planktonic larvae and pelagic adults, resulting from ocean acidification caused by global warming • overfishing of commercial species (currently limited in the EMR to Ballot's saucer scallop which has a managed fishery designed to protect stocks)

Plankton	• eutrophication of coastal waters resulting from increased sewerage disposal and sea temperatures
	• introduction of exotic species via the ballast water of commercial vessels
	• global climate change
	  • shifts in the distribution and abundance of particular species due to changes in seawater temperature and chemistry
	  • alteration of the production peak of phytoplankton and the resulting secondary productivity of zooplankton
	  • impaired calcium deposition in shells of some groups resulting from ocean acidification
	  • disruption of food chains

Seabirds	• mortality as bycatch of commercial fisheries, particularly longline and trawl fisheries
	• disturbance to nesting sites, particularly by humans (e.g. boats and planes)
	• predation by feral and introduced predators
	• pollution
	  • oil spills
	  • accumulation of heavy metals and organic compounds through the food chain
	  • discarded marine debris particularly plastic which may entangle birds or lead to gut blockages if ingested
	• loss of food stock

KEY SPECIES GROUP	IMPACTS/THREATS
	• global climate change • shifts in food availability • variations to life history patterns associated with changes in temperature • alteration to breeding sites as a result of changes in weather patterns
Seals	• interaction with commercial fishing operations resulting in entanglement in fishing gear • entanglement in marine debris • reduction in food supply • human disturbance, including tourism, aircraft and vessels • oil spills and chemical contaminants • diseases
Sharks and Rays	• overfishing by commercial and recreational fisheries • mortality as bycatch of commercial fisheries, particularly trawl fisheries
Sponges	• pollution, particularly from industrial sources, sewerage and coastal development • eutrophication • mortality as bycatch of commercial fisheries, particularly trawl fisheries • habitat loss, particularly as a result of trawling by commercial fisheries • disease, possibly exacerbated by environmental factors such as climate change and urban/agricultural runoff
Syngnathids	• loss or degradation of habitat, particularly in coastal areas through pollution, urban run-off and dredging associated with increased coastal development • collecting of wild specimens for the marine aquarium fish trade • unsustainable harvesting for the Traditional Chinese Medicine trade • mortality as bycatch of commercial trawl fisheries (in the EMR this is primarily restricted to four species of *Solegnathus* and *Hippocampus tristis*)
Trawl Bycatch	• trawl-induced mortality particularly for deepwater species • habitat modification leading to lowered habitat diversity and species diversity • environmental change

Table 16.2 Summary of common Impacts and Threats identified for Key Species Groups of the EMR arranged by the Threat/Impact.

Threat	Impact	Key Species Group affected
Global climate change	Increased incidence of disease (e.g. coral bleaching; sponge disease)	Corals; Sponges
	Habitat loss/modification	Crustaceans; Echinoderms; Marine Snakes; Seabirds
	Impaired calcium deposition due to ocean acidification	Echinoderms; Molluscs; Plankton
	Shifts in abundance and distribution of particular species	Plankton
	Disruption of food chains	Plankton; Seabirds
	Variation to life history patterns	Seabirds
Coastal development	Reduced water quality and associated habitat loss	Corals; Echinoderms; Marine Snakes; Plankton; Sponges; Syngnathids; Turtles
	Changes to light horizons	Turtles
Fishing	Mortality as bycatch	Corals; Crustaceans; Demersal fish; Echinoderms; Marine snakes; Molluscs; Seabirds; Seals; Sharks and rays; Sponges; Syngnathids; Turtles
	Habitat/loss modification	Corals; Crustaceans; Demersal fish; Echinoderms; Marine snakes; Molluscs; Sponges
	Unsustainable harvesting	Corals; Crustaceans; Demersal fish; Echinoderms; Molluscs; Sharks and rays; Sponges; Syngnathids; Turtles
	Changes in community ecology and biodiversity due to overfishing	Echinoderms
Severe weather events (e.g. cyclones)	Direct damage	Corals
	Habitat damage	Echinoderms
Pollution	Direct chemical contamination	Crustaceans; Seabirds; Seals; Sponges
	Chemical contamination through accumulation via food chains	Crustaceans; Seabirds; Seals; Turtles
	Entanglement	Seabirds; Seals
	Gut blockages from ingestion	Seabirds; Turtles

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17 Summary of information gaps

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The vast size of the East Marine Region (EMR), covering considerable ecological and geographic diversity, and the relatively recent recognition of the region as a management unit, are significant factors contributing to gaps in available information for this region. These factors are also barriers to determining the gaps that exist in available information as data is spread through numerous sources. The EMR is not unique in this regard and many of the information gaps, and solutions, that have been identified in other planning regions (National Oceans Office 2004) are applicable, for example:

- research and monitoring effort has tended to be concentrated in areas which are more readily accessible
- information is needed to create a baseline from which future impacts and changes can be monitored
- the degree to which key species groups within the EMR also occur outside this region needs to be considered and conservation strategies devised which account for the management of these organisms in other jurisdictions
- past research and monitoring of key species groups has, to a significant extent, relied on the activities of commercial fishing operations and occurred in areas where these fisheries operate; a greater reliance on independent research and monitoring, particularly in areas where fisheries do not operate, is needed
- cooperation and coordinated effort between research and management agencies are required to build a knowledge base across the region and to maximise the benefits of research conducted.

A summary of the information gaps documented for the Key Species Groups in this report is presented in Table 17.1.

Table 17.1 Summary of information requirements noted for Key Species Groups of the EMR.

KEY SPECIES GROUP	INFORMATION REQUIREMENTS
Corals	• data from offshore regions • data from subtropical coastal regions • data on the effect of high temperature bleaching on the reefs of the Coral Sea • a means of monitoring bleaching events and consequent losses in diversity in remote areas
Crustaceans	• knowledge of the basic taxonomy, biodiversity, ecology and community structure • publications providing an overview of the fauna from the EMR • baseline data to monitor impacts and change • effective programs to sample poorly known areas, and key ecosystems such as seamounts, and to make data accumulated available • data on the impacts of fisheries on non target species
Demersal fish	• comprehensive collections to provide accurate stock identification and up-to-date taxonomy of the exploited species • improved resource assessments of primary and key secondary species • data on the impact of trawling on ocean ecosystems
Echinoderms	• data from benthic communities of the shelf and deep water • understanding of the species diversity comprising the EMR bêche-de-mer fisheries • knowledge of the ecological impacts of the EMR bêche-de-mer fisheries • a database with which to follow the anticipated changes that climate change will bring to diversity and communities in the EMR • understanding of the larval life and early benthic stage of most species • knowledge of the recruitment dynamics and the locations of sources and sinks of propagules
Marine Snakes	• data on distribution and natural history through direct observation
Marine Turtles	• quantification of mortality from human related impacts • data on the impact of climate change on the distribution and abundance of suitable foraging habitat for each species • identification of shifts in distributions in response to changing climate and habitat availability • data on population age structure to aid management decisions • data on the pelagic life history phase to aid understanding of population dynamics
Molluscs	• taxonomic descriptions and identification tools for some species taken in commercial fisheries in order to assist in stock management • field programs to ensure adequate sampling of the full range of diversity, and provide a taxonomic basis to establish baseline data on distributions,

	abundances and habitat preferences • understanding distributions and life history of cephalopod species, particularly those encountered in commercial fishing operations
Plankton	• a key to classification and identification • monitoring of potentially harmful phytoplankton species • a means to monitor populations and place short term fluctuations into a longer term context • data concerning communities at the shelf break (200 m isobath) and seamounts
Seabirds	• information regarding seabird mortality in the EMR, particularly away from breeding sites and in relation to fishing activities • the impacts of pollution and marine debris • assessment of conservation status and threatening processes for numerous species • data on foraging range, dietary preference, availability of food, and the variability in these for numerous species • data on migratory behaviour
Seals	• improved estimates of the abundance of pups in breeding colonies • trends in abundance at selected seal colonies • further data on feeding ecology and foraging behaviour • data on diet in order to assess possible ecological interactions with the fishing industry • data on operational interactions with fishers • data on movements and feeding areas
Sharks and Rays	• improved identification of exploited species at industry level permitting better catch reporting and management of stocks • improved biological data, particularly for exploited species
Sponges	• improved sampling intensity to provide representative data for the region • greater taxonomic resolution for existing samples • identification tools • expertise to determine diversity and distributions • data on ecological processes in communities at the ecosystem level • data on physiological, biochemical and other functions at the species level
Syngnathids	• details of the biology and ecology of most species • validated estimates of population density over large spatial scales • direct measurements of growth and age • estimates of food uptake and energy conversion • data on dispersal over small and medium spatial scales • an investigation of factors driving the population dynamics • accurate distributional and depth data to identify key habitats

	• monitoring of conservation strategies
Trawl Bycatch	• improved understanding of variability in the composition and quantity of bycatch in fish trawls to enable specific methods or gear modifications to be developed • data on the effect of gear selectivity on non-commercial bycatch

Additionally, a summary of apparent sampling gaps based on specimens recorded in faunal collections of the Australian Museum, Queensland Museum and those available to the public from other institutions is presented below.

Point data from specimen collections in State and Commonwealth institutions has been found to be informative in 'gap analyses' of taxon distribution and sampling effort in order to define poorly known faunal regions (Last et al. 2005). This information can be used to determine the priorities for research and identify locations for targeted surveys to fill these gaps. It can also be used to identify and define major changes in species diversity or test existing biogeographic concepts (O'Hara et al. 2002; Hooper & Ekins 2004). Past analyses of this nature have concentrated on fish distributions, however, invertebrate groups are likely to be equally biogeographically informative (Last et al. 2005) and can indicate different patterns (Hooper & Ekins 2004; O'Hara 2007). To date these analyses have not concentrated specifically on the EMR and/or have used restricted datasets relative to this area.

The Australian and Queensland Museum databases represent the most comprehensive collections across a range of taxa for this region; additional relevant datasets are available through Online Zoological Collections of Australian Museums (OZCAM, see http://www.ozcam.gov.au/about.php) and the Australian Biodiversity Information Facility (ABIF, see http://www.abif.org/). For this report these datasets were utilised for the following Key Species Groups: corals, crustaceans, echinoderms, molluscs and sponges (see relevant chapters). Additionally, sampling points from these databases for fish, a classification including three Key Species Groups identified in the EMR (demersal fish, sharks and rays, and syngnathids), are indicated in Figure 17.1. Each of these taxa (corals, crustaceans, echinoderms, fish, molluscs and sponges) represent organisms with wide distributions, collected using a range of sampling methods, and consequently relatively well represented in faunal collections. They are, therefore, considered suitable surrogates to identify comparatively poorly known provincial bioregions within the EMR. The combined sampling sites for these taxa are shown in Figure 17.2. The number of data points for each taxon and provincial bioregion is summarised in Table 17.1.

Comprehensive analyses of these datasets, such as those of O'Hara et al. (2002), Hooper & Ekins (2004), Last et al. (2005), O'Hara (2006) and O'Hara (2007) are outside the scope of this report, but some general observations regarding sampling gaps can be made.

Intensity of sampling declines sharply as distance from the mainland coast increases (Figure 17.2). The highest frequency of sampling usually occurs within 150 km of the coast although immediately to the north and south of Sydney this is increased to a radius of approximately 300 km. Similarly, the sampling intensity near Brisbane is maintained further offshore than elsewhere along the coast. Provinces remote from the mainland such as the Lord Howe Province and the Norfolk Island Province show a corresponding pattern with samples tending to cluster within 150 km of the main islands within these provinces. Because these islands are located centrally, within these provinces, few samples have been collected from the margins of these areas. Sampling intensity is also low along the eastern margins of the provinces on the eastern boundary of the EMR such as the Kenn Transition and Kenn Province. Similarly, there are relatively few samples from the eastern margin of the Tasman Basin Province located between the Central Eastern Province and the Lord Howe Province.

Of the 14 provinces comprising the EMR (see Figure 1.1) the lowest number of samples have been collected in the Kenn Province, followed by the Tasman Basin Province and the Kenn Transition (Table 17.2). The latter two of these provinces are 2.7 and 6.5 times as large as the Kenn Province, respectively. The Southeast Transition and the Southeast Shelf Transition appear to be areas where relatively few samples have been collected. This however, is misleading, as these provinces are well sampled but only partially occur in the EMR as they are bisected by the southern boundary of the region. The highest number of samples collected in the EMR is in the Central Eastern Province (31% of total samples collected). These are heavily concentrated on the western margin of this province and information for the central and eastern sections is scarce. The Central Eastern Shelf Transition has the next highest number of samples from the region (18% of total samples collected).

The highest number of samples for four of the six groups considered (Crustacea, Echinodermata, Mollusca and Fish) comes from the Central Eastern Province (Table 17.2). For three of these taxa (Crustacea, Molluscs and Fish) the next highest number of samples is from the Central Eastern Shelf Transition. This is also the province with the second highest number of samples recorded, in the data from the EMR examined here. The highest number of coral samples is from the Northeast Province, followed by the Lord Howe Province. This pattern undoubtedly reflects the typically tropical distribution of this group and the influence of the East Australian Current in inducing dispersal to the Lord Howe Island area.

Fish account for the highest number of samples taken from the region (39%) followed by molluscs (35%). The high number of samples of molluscs indicates they may be particularly useful for further bioregionalisation studies as suggested by Reid et al. (2007), particularly in the EMR. Sponges are represented by the lowest number of samples corresponding to point data examined for this report. This may reflect the taxonomic difficulties of this group, as they are ubiquitous in distribution. The absence of records from the Cape Province is a clear information gap as sponges are undoubtedly numerous and diverse in this province.

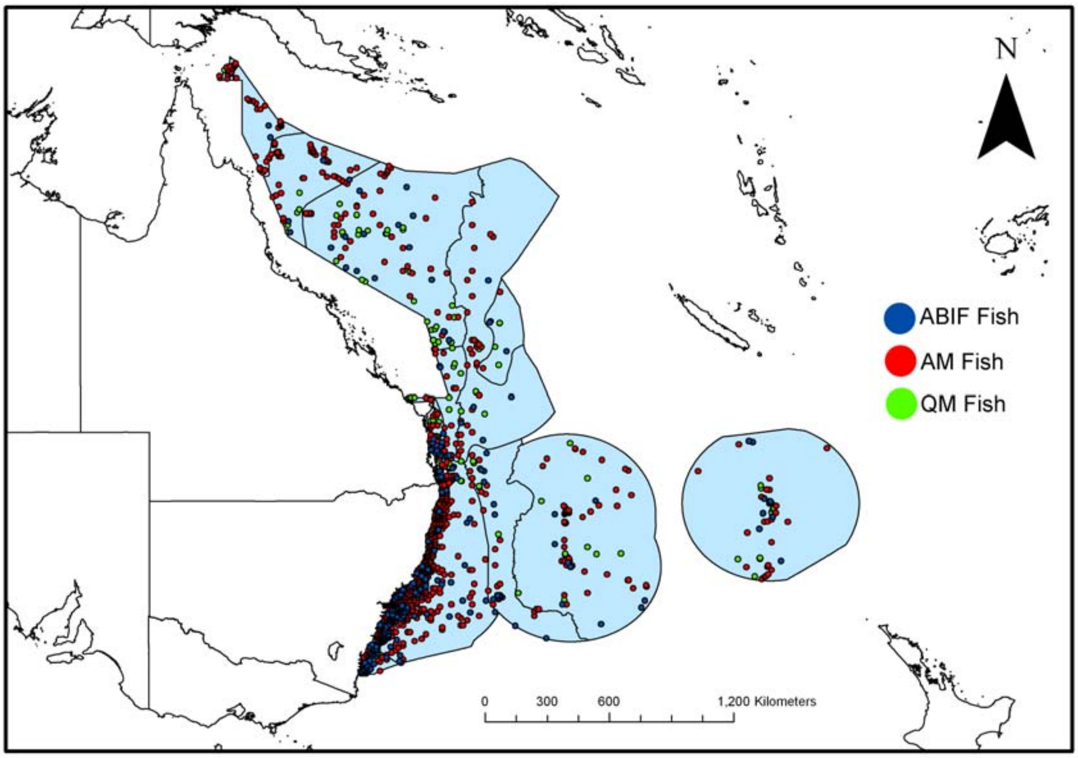

Figure 17.1 Fish records from the EMR based on Australian (AM) and Queensland (QM) Museum, and Australian Biodiversity Information Facility (ABIF) datasets.

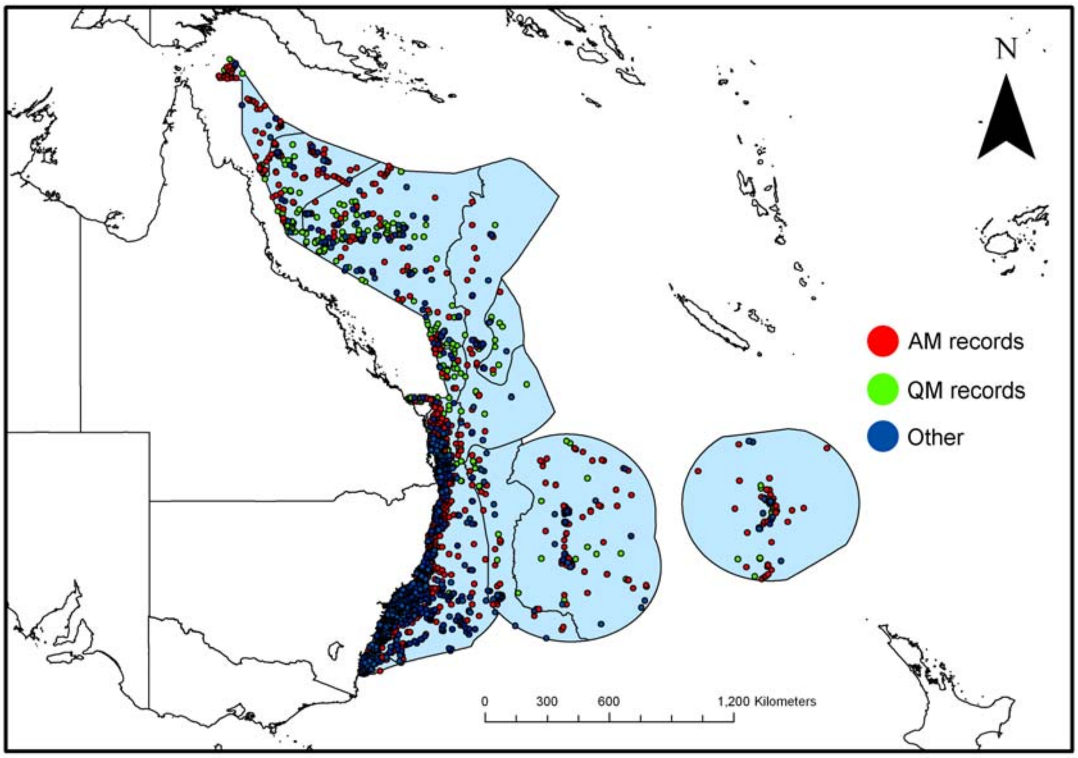

Figure 17.2 Combined records from the EMR for corals, crustaceans, echinoderms, fish, molluscs and sponges based on Australian (AM) and Queensland (QM) Museum, and Australian Biodiversity Information Facility (ABIF) datasets.

Table 17.2 Number of samples collected for each species group in each Province

KEY SPECIES GROUP/ PROVINCE	Corals	Crustacea	Echinodermata	Mollusca	Sponges	Fish	Total
Cape Province	12	133	120	77	0	1886	**2228**
Central Eastern Shelf Province	43	1331	325	4083	285	4504	**10571**
Central Eastern Shelf Transition	14	979	187	1926	238	2238	**5582**
Central Eastern Province	234	3591	1236	5477	42	7728	**18308**
Central Eastern Transition	26	708	118	2127	39	722	**3740**
Kenn Province	17	28	12	146	22	34	**259**
Kenn transition	218	25	22	364	145	198	**972**
Lord Howe Province	533	854	556	1106	195	1113	**4357**
Norfolk Island Province	27	203	47	732	23	627	**1659**

KEY SPECIES GROUP/ PROVINCE	Corals	Crustacea	Echinodermata	Mollusca	Sponges	Fish	Total
Northeast Province	682	541	39	2996	105	1408	**5771**
Northeast Transition	45	27	39	378	238	1364	**2091**
Southeast Shelf Transition	9	185	70	872	97	644	**1877**
Southeast Transition	7	174	169	487	6	461	**1304**
Tasman Basin Province	24	65	33	123	25	197	**467**
Total	**1891**	**8844**	**2973**	**20894**	**1460**	**23124**	**59186**

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Appendices

Appendix A. Teleosts recorded from trawl surveys off NSW on northern, central and southern inshore grounds (<100 m), central and southern shelf gounds (100–200 m), upper slope (200–650 m) and mid slope (650–1200 m) grounds.

CAAB: CAAB no.; C: commercial

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 060006	Muraenidae	*Gymnothorax prasinus*	Green Moray		*					
37 063003	Muraenesocidae	*Muraenesox bagio*	Common Pike Eel	C		*				
37 063001	Muraenesocidae	*Oxyconger leptognathus*	Bigeye Pike Eel		*	*	*			
37 065001	Nettastomatidae	*Nettastoma parviceps*	Smallhead Duckbill Eel							*
37 067034	Colocongridae	*Coloconger scholesi*	Short-tail Conger							*
37 067012	Congridae	*Bassanago bulbiceps*	Swollenhead Conger						*	
37 067013	Congridae	*Bassanago hirsutus*	Deepsea Conger						*	*
37 067032	Congridae	*Bathycongrus odontostomus*	Toothy Conger							*
37 067033	Congridae	*Bathyuroconger vicinus*	Largetooth Conger							*
37 067007	Congridae	*Conger verreauxi*	Southern Conger	C		*	*	*	*	
37 067001	Congridae	*Conger wilsoni*	Eastern Conger		*					
37 067028	Congridae	*Gnathophis grahami*	Graham's Conger		*	*		*		
37 067002	Congridae	*Gnathophis longicaudus*	Little Conger		*	*	*			
37 067016	Congridae	*Gnathophis umbrellabius*	Umbrella Conger			*	*	*		
37 067018	Congridae	*Macrocephenchelys brevirostris*	Rubbernose Conger					*		
37 067019	Congridae	*Poeciloconger kapala*	Mottled Conger		*	*	*			
37 067011	Congridae	*Rhynchoconger ectenurus*	Longnose Conger					*		
37 067020	Congridae	*Scalanago lateralis*	Ladder Eel				*			
37 067021	Congridae	*Uroconger lepturus*	Slender Conger			*				
37 068041	Ophichthidae	*Echelus uropterus*	Finned Snake Eel					*		
37 068039	Ophichthidae	*Muraenichthys australis*	Thompson's Snake Eel					*		
37 068047	Ophichthidae	*Ophichthus urolophus*	Manetail Snake Eel					*		
37 068001	Ophichthidae	*Ophisurus serpens*	Serpent Eel			*	*	*		
37 070001	Synaphobranchidae	*Diastobranchus capensis*	Basketwork Eel							*
37 070007	Synaphobranchidae	*Histiobranchus bruuni*	Bruun's Cut-throat Eel							*
37 070005	Synaphobranchidae	*Simenchelys parasitica*	Snubnose Eel							*
37 070003	Synaphobranchidae	*Synaphobranchus affinis*	Grey Cut-throat Eel							*

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 070008	Synaphobranchidae	*Synaphobranchus kaupii*	Kaup's Cut-throat Eel							*
37 081004	Halosauridae	*Aldrovandia affinis*	Allied Halosaur							*
37 081003	Halosauridae	*Halosauropsis macrochir*	Black Halosaur							*
37 081002	Halosauridae	*Halosaurus pectoralis*	Australian Halosaur							*
37 082001	Lipogenyidae	*Lipogenys gillii*	Spiny Sucker Eel							*
37 083002	Notacanthidae	*Notacanthus chemnitzii*	Cosmopolitan Spineback							*
37 083001	Notacanthidae	*Notacanthus sexspinis*	Southern Spineback							*
37 085001	Clupeidae	*Etrumeus teres*	Maray		*	*				
37 085005	Clupeidae	*Hyperlophus vittatus*	Sandy Sprat		*	*	*			
37 085794	Clupeidae	*Sardinops sagax*	Australian Pilchard	C	*	*	*			
37 086001	Engraulidae	*Engraulis australis*	Australian Anchovy		*	*	*	*		
37 097001	Argentinidae	*Argentina australiae*	Silverside			*		*	*	
37 106003	Gonostomatidae	*Gonostoma atlanticum*	Atlantic Fangjaw						*	
37 106002	Phosichthyidae	*Phosichthys argenteus*	Silver Lightfish						*	
37 111001	Chauliodontidae	*Chauliodus sloani*	Sloane's Viperfish						*	
37 114014	Alepocephalidae	*Alepocephalus* australis	Smallscale slickhead							*
37 114013	Alepocephalidae	*Alepocephalus* cf. *antipodianus*	Antipodean Slickhead							*
37 114029	Alepocephalidae	*Alepocephalus longiceps*	Longfin Slickhead							*
37 114004	Alepocephalidae	*Asquamiceps hjorti*	Barethroat Slickhead							*
37 114033	Alepocephalidae	*Conocara kreffti*	Wrinkled Slickhead							*
37 114008	Alepocephalidae	*Rouleina attrita*	Softskin Slickhead							*
37 114023	Alepocephalidae	*Rouleina eucla*	Eucla Slickhead							*
37 114024	Alepocephalidae	*Rouleina guentheri*	Bordello Slickhead							*
37 114009	Alepocephalidae	*Talismania antillarum*	Antillean Slickhead							*
37 114012	Alepocephalidae	*Talismania longifilis*	Longtail Slickhead							*
37 114002	Alepocephalidae	*Xenodermichthys copei*	Bluntsnout Slickhead							*
37 117001	Aulopidae	*Aulopus purpurissatus*	Sergeant Baker	C	*	*	*	*		
37 117003	Aulopidae	*Hime curtirostris*	Shortsnout Threadsail					*	*	
37 118019	Bathysauridae	*Bathysaurus ferox*	Deepsea Lizardfish							*
37 118006	Synodontidae	*Saurida filamentosa*	Threadfin Saury		*	*		*		
37 118001	Synodontidae	*Saurida undosquamis*	Largescale Saury		*	*	*			
37 118002	Synodontidae	*Trachinocephalus myops*	Painted Grinner		*	*	*	*		
37 120002	Chlorophthalmidae	*Chlorophthalmus* cf. *agassizi*	Shortnose Greeneye						*	
37 120001	Paraulopidae	*Paraulopus nigripinnis*	Blacktip Cucumberfish			*	*	*	*	
37 121001	Neoscopelidae	*Neoscopelus macrolepidotus*	Largescale Neoscopelid						*	*

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 121002	Neoscopelidae	*Neoscopelus microchir*	Shortfin Neoscopelid						*	*
37 123002	Ipnopidae	*Bathypterois longifilis*	Longray Spiderfish							*
37 123003	Ipnopidae	*Bathypterois longipes*	Abyssal Spiderfish							*
37 123008	Ipnopidae	*Bathytyphlops marionae*	Marion's Spiderfish							*
37 126002	Paralepididae	*Lestidium nudum*	Naked Barracudina						*	*
37 126011	Paralepididae	*Stemonosudis rothschildi*	Rothschild's Barracudina						*	
37 136000	Ateleopodidae	*Ateleopus japonicus*	Pacific Jellynose Fish					*		
37 141001	Gonorynchidae	*Gonorynchus greyi*	Beaked Salmon		*	*	*	*		
37 192001	Plotosidae	*Cnidoglanis macrocephalus*	Estuary Cobbler	C	*	*				
37 192004	Plotosidae	*Euristhmus lepturus*	Longtail Catfish		*					
37 192002	Plotosidae	*Plotosus lineatus*	Striped Catfish		*	*				
37 205008	Batrachoididae	*Batrachomoeus dubius*	Eastern Frogfish		*	*				
37 208003	Lophiidae	*Lophiodes mutilus*	Smooth Goosefish						*	*
37 208004	Lophiidae	*Lophiodes naresi*	Goosefish						*	
37 208001	Lophiidae	*Lophiomus setigerus*	Broadhead Goosefish			*		*	*	
37 210011	Antennariidae	*Antennarius nummifer*	Spotfin Anglerfish		*					
37 210009	Antennariidae	*Antennarius striatus*	Striate Anglerfish		*	*	*			
37 210014	Antennariidae	*Kuiterichthys furcipilis*	Rough Anglerfish			*	*	*		
37 211003	Chaunacidae	*Chaunax endeavouri*	Furry Coffinfish					*	*	
37 211004	Chaunacidae	*Chaunax penicillatus*	Pencil Coffinfish						*	
37 212010	Ogcocephalidae	*Coelophrys brevipes*	Balloon Seabat							*
37 212007	Ogcocephalidae	*Dibranchus japonicus*	Japanese Seabat							*
37 212000	Ogcocephalidae	*Halicmetus reticulatus*	Marbled Seabat						*	*
37 212001	Ogcocephalidae	*Halieutaea brevicauda*	Shortfin Seabat		*	*		*	*	
37 220002	Ceratiidae	*Ceratias holboelli*	Longray Seadevil						*	
37 222001	Linophrynidae	*Haplophryne mollis*	Soft Leafvent Angler							*
37 224015	Melanonidae	*Melanonus gracilis*	Pelagic Cod							*
37 224016	Melanonidae	*Melanonus zugmayeri*	Arrowtail Cod							*
37 224008	Moridae	*Antimora rostrata*	Violet Cod							*
37 224028	Moridae	*Gadella macrura*	Longtail Cod							*
37 224009	Moridae	*Halargyreus johnsonii*	Slender Cod	C						*
37 224018	Moridae	*Lepidion inosimae*	Giant Cod	C						*
37 224010	Moridae	*Lepidion microcephalus*	Smallhead Cod							*
37 224017	Moridae	*Lepidion schmidti*	Schmidt's Cod	C						*
37 224023	Moridae	*Lotella phycis*	Slender Beardie					*		

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 224005	Moridae	*Lotella rhacina*	Largetooth Beardie			*				
37 224002	Moridae	*Mora moro*	Ribaldo	C					*	*
37 224007	Moridae	*Notophycis marginata*	Forkbeard Cod						*	*
37 224021	Moridae	*Physiculus therosideros*	Scalyfin Cod					*		
37 224003	Moridae	*Pseudophycis barbata*	Bearded Rock Cod	C				*		
37 224011	Moridae	*Pseudophycis breviuscula*	Bastard Red Cod		*	*	*	*		
37 224004	Moridae	*Tripterophycis gilchristi*	Chiseltooth Grenadier Cod						*	*
37 224029	Moridae	*Tripterophycis svetovidovi*	Brown Grenadier Cod							*
37 227001	Macruronidae	*Macruronus novaezelandiae*	Blue Grenadier	C					*	*
37 228014	Aphyonidae	*Aphyonus gelatinosus*	Gelatinous Blindfish							*
37 228015	Aphyonidae	*Barathronus maculatus*	Spotted Gelatinous Cusk							*
37 228018	Bythitidae	*Cataetyx niki*	Brown Brotula							*
37 228064	Bythitidae	*Diplacanthopoma kreffti*	Deepbody Cusk							*
37 228047	Bythitidae	*Hastatobythites arafurensis*	Spinyhead Cusk							*
37 228002	Ophidiidae	*Genypterus blacodes*	Pink Ling	C				*	*	*
37 228031	Ophidiidae	*Monomitopus* sp.	cusk eel						*	*
37 228048	Ophidiidae	*Ophidion genyopus*	Ravenous Cusk		*	*	*	*		
37 232030	Bathygadidae	*Bathygadus cottoides*	Codhead Rat Tail							*
37 232098	Bathygadidae	*Bathygadus furvescens*	Blackfin Rat Tail							*
37 232077	Bathygadidae	*Bathygadus spongiceps*	Spongy Rat Tail							*
37 232119	Bathygadidae	*Gadomus aoteanus*	Filamentous Rat Tail							*
37 232078	Bathygadidae	*Gadomus* sp. cf. *colletti*								*
37 232042	Macrouridae	*Caelorinchus acanthiger*	Spottyface Whiptail							*
37 232002	Macrouridae	*Caelorinchus fasciatus*	Banded Whiptail							*
37 232014	Macrouridae	*Caelorinchus innotabilis*	Notable Whiptail						*	*
37 232031	Macrouridae	*Caelorinchus kaiyomaru*	Kaiyomaru Whiptail							*
37 232040	Macrouridae	*Caelorinchus kermadecus*	Kermadec Whiptail							*
37 232110	Macrouridae	*Caelorinchus macrorhynchus*	Bigsnout Whiptail							*
37 232017	Macrouridae	*Caelorinchus matamua*	Blueband Whiptail							*
37 232045	Macrouridae	*Caelorinchus maurofasciatus*	Falseband Whiptail						*	*
37 232003	Macrouridae	*Caelorinchus mirus*	Gargoyle Fish						*	
37 232112	Macrouridae	*Caelorinchus mycterismus*	Pinocchio Whiptail							*
37 232047	Macrouridae	*Caelorinchus parvifasciatus*	Little Whiptail						*	
37 232029	Macrouridae	*Cetonurus globiceps*	Globehead Whiptail							*
37 232039	Macrouridae	*Coryphaenoides dossenus*	Humpback Whiptail							*

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 232050	Macrouridae	*Coryphaenoides grahami*	Graham's Whiptail							*
37 232019	Macrouridae	*Coryphaenoides rudis*	Bighead Whiptail							*
37 232015	Macrouridae	*Coryphaenoides serrulatus*	Serrulate Whiptail							*
37 232053	Macrouridae	*Coryphaenoides striaturus*	Striate Whiptail							*
37 232016	Macrouridae	*Coryphaenoides subserrulatus*	Longray Whiptail							*
37 232055	Macrouridae	*Haplomacrourus nudirostris*	Nakedsnout Whiptail							*
37 232099	Macrouridae	*Hymenocephalus aterrimus*	Blackest Whiptail							*
37 232058	Macrouridae	*Hymenocephalus longibarbis*	Longbarb Whiptail						*	*
37 232082	Macrouridae	*Hymenocephalus nascens*	Origin Whiptail							*
37 232061	Macrouridae	*Kuronezumia bubonis*	Bulbous Whiptail							*
37 232062	Macrouridae	*Kuronezumia leonis*	Snubnose Whiptail							*
37 232004	Macrouridae	*Lepidorhynchus denticulatus*	Toothed Whiptail						*	*
37 232005	Macrouridae	*Lucigadus nigromaculatus*	Blackspot Whiptail						*	*
37 232007	Macrouridae	*Malacocephalus laevis*	Smooth Whiptail						*	*
37 232086	Macrouridae	*Mataeocephalus acipenserinus*	Sturgeon Whiptail							*
37 232087	Macrouridae	*Mataeocephalus kotlyari*	Kotlyar's Whiptail							*
37 232035	Macrouridae	*Mesobius antipodum*	Black Whiptail							*
37 232102	Macrouridae	*Nezumia coheni*	Cohen's Whiptail							*
37 232075	Macrouridae	*Nezumia kapala*	Kapala Whiptail							*
37 232066	Macrouridae	*Nezumia namatahi*	Namatahi Whiptail							*
37 232067	Macrouridae	*Nezumia propinqua*	Aloha Whiptail							*
37 232103	Macrouridae	*Sphagemacrurus richardi*	Richard's Whiptail							*
37 232076	Macrouridae	*Trachonurus gagates*	Velvet Whiptail							*
37 232092	Macrouridae	*Trachonurus sentipellis*	Shaggy Whiptail							*
37 232028	Macrouridae	*Trachyrincus longirostris*	Unicorn Whiptail							*
37 232073	Macrouridae	*Ventrifossa johnboborum*	Snoutscale Whiptail							*
37 232074	Macrouridae	*Ventrifossa nigrodorsalis*	Spinnaker Whiptail						*	*
37 232096	Macrouridae	*Ventrifossa paxtoni*	Thinbarbel Whiptail							*
37 234014	Hemiramphidae	*Hyporhamphus australis*	Eastern Sea Garfish	C	*	*				
37 235001	Belonidae	*Ablennes hians*	Barred Longtom		*					
37 253000	Polymixiidae	*Polymixia* sp.	Beardfish						*	*
37 254001	Diretmidae	*Diretmichthys parini*	Black Spinyfin							*
37 254002	Diretmidae	*Diretmus argenteus*	Discfish							*
37 255011	Trachichthyidae	*Aulotrachichthys novaezelandicus*	New Zealand Roughy		*			*		

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 255009	Trachichthyidae	*Hoplostethus atlanticus*	Orange Roughy	C						*
37 255001	Trachichthyidae	*Hoplostethus intermedius*	Blacktip Sawbelly						*	*
37 255013	Trachichthyidae	*Hoplostethus melanopus*	Smallscale Sawbelly							*
37 255007	Trachichthyidae	*Optivus agastos*	Violet Roughy		*	*	*			
37 255003	Trachichthyidae	*Paratrachichthys macleayi*	Sandpaper Fish					*		
37 255015	Trachichthyidae	*Trachichthys australis*	Southern Roughy			*				
37 257001	Anoplogastridae	*Anoplogaster cornuta*	Fangtooth							*
37 258001	Berycidae	*Beryx decadactylus*	Imperador	C					*	
37 258002	Berycidae	*Beryx splendens*	Alfonsino	C					*	
37 258003	Berycidae	*Centroberyx affinis*	Redfish	C	*	*	*	*	*	
37 259001	Monocentrididae	*Cleidopus gloriamaris*	Australian Pineapplefish		*	*	*			
37 261003	Holocentridae	*Ostichthys japonicus*	Giant Squirrelfish		*	*		*		
37 263001	Zeniontidae	*Zenion japonicum*	Japanese Dory						*	
37 264002	Cyttidae	*Cyttus australis*	Silver Dory	C		*	*	*	*	
37 264005	Cyttidae	*Cyttus novaezealandiae*	New Zealand Dory					*	*	
37 264001	Cyttidae	*Cyttus traversi*	King Dory	C					*	*
37 264010	Zeidae	*Cyttopsis rosea*	Rosy Dory						*	
37 264003	Zeidae	*Zenopsis nebulosus*	Mirror Dory	C		*	*	*	*	
37 264004	Zeidae	*Zeus faber*	John Dory	C	*	*	*	*		
37 265001	Grammicolepididae	*Grammicolepis brachiusculus*	Thorny Tinselfish						*	
37 265003	Grammicolepididae	*Xenolepidichthys dalgleishi*	Spotted Tinselfish						*	*
37 266004	Oreosomatidae	*Allocyttus verrucosus*	Warty Oreodory	C						*
37 266001	Oreosomatidae	*Neocyttus rhomboidalis*	Spiky Oreodory	C						*
37 266002	Oreosomatidae	*Oreosoma atlanticum*	Oxeye Oreodory							*
37 266003	Oreosomatidae	*Pseudocyttus maculatus*	Smooth Oreodory	C						*
37 267006	Caproidae	*Antigonia rhomboidea*	Rhomboid Deepsea Boarfish		*	*		*		
37 267007	Caproidae	*Antigonia rubicunda*	Rosy Deepsea Boarfish		*	*		*		
37 269001	Veliferidae	*Metavelifer multiradiatus*	Common Veilfin			*	*			
37 271001	Trachipteridae	*Trachipterus arawatae*	Southern Ribbonfish						*	
37 278001	Fistulariidae	*Fistularia commersonii*	Smooth Flutemouth		*	*	*			
37 278002	Fistulariidae	*Fistularia petimba*	Rough Flutemouth	C	*	*	*	*	*	
37 279001	Macroramphosidae	*Centriscops humerosus*	Banded Bellowsfish						*	
37 279007	Macroramphosidae	*Macroramphosus gracilis*	Little Bellowsfish		*	*	*	*		
37 279002	Macroramphosidae	*Macroramphosus scolopax*	Common Bellowsfish		*	*	*	*	*	
37 282064	Syngnathidae	*Filicampus tigris*	Tiger Pipefish			*				

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 282120	Syngnathidae	*Hippocampus abdominalis*	Bigbelly Seahorse			*				
37 282117	Syngnathidae	*Hippocampus tristis*	Sad Seahorse		*					
37 282029	Syngnathidae	*Solegnathus spinosissimus*	Spiny Pipehorse				*	*		
37 282006	Syngnathidae	*Trachyrhamphus bicoarctatus*	Bentstick Pipefish		*					
37 287011	Apistidae	*Apistus carinatus*	Longfin Waspfish		*					
37 287045	Neosebastidae	*Maxillicosta whitleyi*	Whitley's Gurnard Perch		*	*	*	*		
37 287019	Neosebastidae	*Neosebastes incisipinnis*	Incised Gurnard Perch		*	*	*	*		
37 287006	Neosebastidae	*Neosebastes thetidis*	Thetis Fish					*		
37 287010	Pteroidae	*Dendrochirus brachypterus*	Dwarf Lionfish		*	*				
37 287026	Pteroidae	*Dendrochirus zebra*	Zebra Lionfish		*	*				
37 287040	Pteroidae	*Pterois volitans*	Common Lionfish		*	*				
37 287066	Scorpaenidae	*Scorpaena cardinalis*	Eastern Red Scorpionfish	C	*	*				
37 287008	Scorpaenidae	*Scorpaena papillosa*	Southern Red Scorpionfish					*		
37 287093	Sebastidae	*Helicolenus barathri*	Bigeye Ocean Perch	C					*	*
37 287001	Sebastidae	*Helicolenus percoides*	Reef Ocean Perch	C		*	*	*	*	
37 287046	Sebastidae	*Trachyscorpia eschmeyeri*	Deepsea Ocean Perch	C						*
37 287022	Synanceiidae	*Erosa erosa*	Pacific Monkeyfish		*					
37 287021	Synanceiidae	*Minous versicolor*	Plumbstriped Stingfish		*					
37 287048	Tetrarogidae	*Centropogon australis*	Eastern Fortescue		*	*	*			
37 287034	Tetrarogidae	*Neocentrpogon aeglefinis*	Onespot waspfish			*				
37 287058	Tetrarogidae	*Notesthes robusta*	Bullrout		*	*	*			
37 288004	Peristediidae	*Peristedion picturatum*	Robust Amour Gurnard						*	
37 288062	Peristediidae	*Satyrichthys* sp. cf. *welchi*	Robust Armour Gurnard					*		
37 288001	Triglidae	*Chelidonichthys kumu*	Red Gurnard	C	*	*	*	*		
37 288032	Triglidae	*Lepidotrigla argus*	Eye Gurnard		*	*	*	*		
37 288033	Triglidae	*Lepidotrigla grandis*	Little Red Gurnard				*	*		
37 288007	Triglidae	*Lepidotrigla modesta*	Cocky Gurnard					*	*	
37 288008	Triglidae	*Lepidotrigla mulhalli*	Roundsnout Gurnard			*	*	*	*	
37 288002	Triglidae	*Lepidotrigla papilio*	Spiny Gurnard		*	*	*			
37 288000	Triglidae	*Lepidotrigla* sp.	Spinynose Gurnard					*		
37 288029	Triglidae	*Lepidotrigla umbrosa*	Blackspot Gurnard		*	*				
37 288003	Triglidae	*Lepidotrigla vanessa*	Butterfly Gurnard				*			
37 288005	Triglidae	*Pterygotrigla andertoni*	Painted Latchet	C					*	
37 288006	Triglidae	*Pterygotrigla polyommata*	Latchet	C		*	*	*	*	
37 290005	Aploactinidae	*Aploactis aspera*	Dusky Velvetfish		*					

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 292001	Pataecidae	*Pataecus fronto*	Red Indian Fish			*	*			
37 296048	Bembridae	*Bembras macrolepis*	Bigscale Flathead					*		
37 296041	Platycephalidae	*Ambiserrula jugosa*	Mud Flathead		*	*	*			
37 296001	Platycephalidae	*Neoplatycephalus richardsoni*	Tiger Flathead	C	*	*	*	*	*	
37 296021	Platycephalidae	*Platycephalus arenarius*	Northern Sand Flathead		*	*	*			
37 296007	Platycephalidae	*Platycephalus caeruleopunctatus*	Bluespotted Flathead	C	*	*	*	*		
37 296004	Platycephalidae	*Platycephalus fuscus*	Dusky Flathead	C	*	*	*			
37 296036	Platycephalidae	*Platycephalus longispinis*	Longspine Flathead		*	*	*			
37 296038	Platycephalidae	*Platycephalus marmoratus*	Marbled Flathead	C	*	*	*			
37 296011	Platycephalidae	*Ratabulus diversidens*	Freespine Flathead	C	*	*	*	*		
37 297002	Hoplichthyidae	*Hoplichthys citrinus*	Lemon Ghost Flathead						*	
37 297001	Hoplichthyidae	*Hoplichthys haswelli*	Deepsea Flathead						*	
37 297006	Hoplichthyidae	*Hoplichthys ogilbyi*	Ogilby's Ghost Flathead					*		
37 305001	Psychrolutidae	*Psychrolutes marcidus*	Smooth-head Blobfish						*	*
37 307002	Liparidae	*Careproctus paxtoni*	Blunt-tooth Snailfish							*
37 307003	Liparidae	*Psednos balushkini*	Palemouth Snailfish							*
37 308004	Dactylopteridae	*Dactyloptena orientalis*	Purple Flying Gurnard		*					
37 308001	Dactylopteridae	*Dactyloptena papilio*	Largespot Flying Gurnard		*	*	*			
37 309002	Pegasidae	*Pegasus volitans*	Slender Seamoth		*					
37 311053	Acropomatidae	*Apogonops anomalus*	Threespine Cardinalfish		*	*	*	*	*	*
37 311054	Acropomatidae	*Synagrops japonicus*	Glowbelly Seabass					*	*	*
37 311055	Callanthidae	*Callanthias australis*	Splendid Perch	C				*		
37 311034	Percichthyidae	*Macquaria novemaculeata*	Australian Bass	C		*				
37 311002	Serranidae	*Caesioperca lepidoptera*	Butterfly Perch	C		*				
37 311095	Serranidae	*Caprodon longimanus*	Longfin Perch	C				*		
37 311147	Serranidae	*Epinephelus ergastularius*	Banded Rockcod	C	*	*	*	*		
37 311086	Serranidae	*Epinephelus undulatostriatus*	Maori Rockcod	C	*					
37 311036	Serranidae	*Hypoplectrodes maccullochi*	Halfbanded Seaperch		*					
37 311102	Serranidae	*Lepidoperca brochata*	Fangtooth Perch					*	*	
37 311001	Serranidae	*Lepidoperca pulchella*	Eastern Orange Perch	C		*		*	*	
37 311161	Serranidae	*Ostracoberyx paxtoni*	Spinycheek Seabass						*	
37 311000	Serranidae	*Tosana niwae*	Pink perchlet					*		
37 311165	Serranidae	*Triso dermopterus*	Oval Rockcod		*					
37 320003	Glaucosomatidae	*Glaucosoma scapulare*	Pearl Perch	C	*					
37 321005	Terapontidae	*Pelates sexlineatus*	Eastern Striped Grunter		*	*	*			

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CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 321002	Terapontidae	*Terapon jarbua*	Crescent Grunter		*					
37 326002	Priacanthidae	*Cookeolus japonicus*	Longfin Bigeye	C			*	*		
37 326011	Priacanthidae	*Priacanthus fitchi*	Deepsea Bigeye					*		
37 326001	Priacanthidae	*Priacanthus macracanthus*	Spotted Bigeye		*	*	*	*		
37 326006	Priacanthidae	*Pristigenys niphonia*	Whiteband Bigeye		*	*				
37 327158	Apogonidae	*Apogon fasciatus*	Striped Cardinalfish		*					
37 327009	Apogonidae	*Apogon nigripinnis*	Two-eye Cardinalfish		*					
37 327013	Apogonidae	*Apogon truncatus*	Flagfin Cardinalfish		*					
37 327002	Dinolestidae	*Dinolestes lewini*	Longfin Pike	C		*	*			
37 327010	Epogonidae	*Epigonus denticulatus*	White Deepsea Cardinalfish						*	*
37 327018	Epogonidae	*Epigonus robustus*	Robust Deepsea Cardinalfish							*
37 327035	Epogonidae	*Epigonus telescopus*	Black Deepsea Cardinalfish							*
37 330010	Sillaginidae	*Sillago ciliata*	Sand Whiting	C		*	*			
37 330014	Sillaginidae	*Sillago flindersi*	Eastern School Whiting	C	*	*	*	*		
37 330015	Sillaginidae	*Sillago maculata*	Trumpeter Whiting	C	*	*				
37 330005	Sillaginidae	*Sillago robusta*	Stout Whiting	C	*	*	*			
37 331005	Malacanthidae	*Branchiostegus serratus*	Australian Barred Tilefish	C		*		*		
37 331006	Malacanthidae	*Branchiostegus wardi*	Pink Tilefish	C		*		*		
37 334002	Pomatomidae	*Pomatomus saltatrix*	Tailor	C	*	*	*			
37 335001	Rachycentridae	*Rachycentron canadum*	Cobia	C	*					
37 336002	Echeneidae	*Remora remora*	Remora		*					
37 337038	Carangidae	*Alectis indica*	Diamond Trevally				*			
37 337010	Carangidae	*Alepes apercna*	Smallmouth Scad		*					
37 337024	Carangidae	*Atule mate*	Barred Yellowtail Scad		*					
37 337021	Carangidae	*Carangoides caeruleopinnatus*	Onion Trevally		*					
37 337011	Carangidae	*Carangoides chrysophrys*	Longnose Trevally		*					
37 337013	Carangidae	*Carangoides equula*	Whitefin Trevally		*			*		
37 337005	Carangidae	*Carangoides malabaricus*	Malabar Trevally		*					
37 337055	Carangidae	*Decapterus macarellus*	Mackerel Scad					*		
37 337017	Carangidae	*Decapterus macrosoma*	Slender Scad		*		*	*		
37 337062	Carangidae	*Pseudocaranx georgianus*	Silver Trevally	C	*	*	*	*		
37 337007	Carangidae	*Seriola hippos*	Samson Fish	C			*			
37 337014	Carangidae	*Seriolina nigrofasciata*	Blackbanded Amberjack	C	*					
37 337002	Carangidae	*Trachurus declivis*	Common Jack Mackerel	C	*	*	*	*	*	
37 337077	Carangidae	*Trachurus murphyi*	Peruvian Jack Mackerel	C					*	

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CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 337003	Carangidae	*Trachurus novaezelandiae*	Yellowtail Scad	C	*	*	*	*		
37 337020	Carangidae	*Uraspis uraspis*	Whitemouth Trevally				*			
37 338001	Coryphaenidae	*Coryphaena hippurus*	Mahi Mahi	C		*				
37 341012	Leiognathidae	*Leiognathus moretoniensis*	Zigzag Ponyfish		*					
37 344002	Arripidae	*Arripis trutta*	Eastern Australian Salmon	C			*			
37 345001	Emmelichthyidae	*Emmelichthys nitidus*	Redbait					*		
37 347025	Nemipteridae	*Nemipterus aurifilum*	Yellowlip Threadfin Bream		*					
37 347036	Nemipteridae	*Nemipterus theodorei*	Theodore's Threadfin Bream		*					
37 349005	Gerreidae	*Gerres subfasciatus*	Common Silverbiddy	C	*	*	*			
37 350003	Haemulidae	*Diagramma labiosum*	Painted Sweetlips		*					
37 353004	Sparidae	*Acanthopagrus australis*	Yellowfin Bream	C		*	*			
37 353002	Sparidae	*Dentex tumifrons*	Yellowback Bream	C	*	*		*		
37 353001	Sparidae	*Pagrus auratus*	Snapper	C	*	*	*	*		
37 353013	Sparidae	*Rhabdosargus sarba*	Tarwhine	C	*	*	*			
37 354001	Sciaenidae	*Argyrosomus hololepidotus*	Mulloway	C		*	*			
37 354020	Sciaenidae	*Atractoscion aequidens*	Teraglin	C	*	*	*	*		
37 355015	Mullidae	*Parupeneus spilurus*	Blacksaddle Goatfish	C	*	*				
37 355001	Mullidae	*Upeneichthys lineatus*	Bluestriped Goatfish	C	*	*	*	*		
37 355033	Mullidae	*Upeneus filifer*	Pennant Goatfish		*					
37 355003	Mullidae	*Upeneus moluccensis*	Goldband Goatfish		*	*				
37 355014	Mullidae	*Upeneus tragula*	Bartail Goatfish	C	*	*	*			
37 356001	Monodactylidae	*Schuettea scalaripinnis*	Eastern Pomfred		*					
37 357005	Pempheridae	*Pempheris affinis*	Blacktip Bullseye		*	*				
37 357006	Pempheridae	*Pempheris analis*	Bronze Bullseye		*	*	*			
37 357008	Pempheridae	*Pempheris compressa*	Smallscale Bullseye		*	*	*			
37 357001	Pempheridae	*Pempheris multiradiata*	Bigscale Bullseye			*	*			
37 358001	Bathyclupeidae	*Bathyclupea gracilis*	Slender Deepsea Herring							*
37 361001	Kyphosidae	*Kyphosus sydneyanus*	Silver Drummer	C		*				
37 361010	Scorpididae	*Atypichthys strigatus*	Mado		*	*	*			
37 361005	Scorpididae	*Microcanthus strigatus*	Stripey		*	*	*			
37 361009	Scorpididae	*Scorpis lineolata*	Silver Sweep	C	*		*			
37 365020	Chaetodontidae	*Amphichaetodon howensis*	Lord Howe Butterflyfish					*		
37 365039	Chaetodontidae	*Chaetodon guentheri*	Gunther's Butterflyfish		*					
37 365005	Chaetodontidae	*Heniochus diphreutes*	Schooling Bannerfish		*		*			
37 366001	Enoplosidae	*Enoplosus armatus*	Old Wife		*	*	*			

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CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 367002	Pentacerotidae	*Paristiopterus labiosus*	Giant Boarfish	C	*	*	*	*		
37 367003	Pentacerotidae	*Pentaceropsis recurvirostris*	Longsnout Boarfish	C			*			
37 367004	Pentacerotidae	*Pentaceros decacanthus*	Bigspine Boarfish						*	
37 367005	Pentacerotidae	*Zanclistius elevatus*	Blackspot Boarfish				*	*	*	
37 372001	Pomacentridae	*Pristotis obtusirostris*	Gulf Damsel		*					
37 376002	Aplodactylidae	*Aplodactylus lophodon*	Rock Cale	C	*	*				
37 377009	Cheilodactylidae	*Cheilodactylus fuscus*	Red Morwong	C	*					
37 377008	Cheilodactylidae	*Cheilodactylus vestitus*	Crested Morwong	C	*					
37 377002	Cheilodactylidae	*Nemadactylus douglasii*	Grey Morwong	C		*	*	*		
37 377003	Cheilodactylidae	*Nemadactylus macropterus*	Jackass Morwong	C				*	*	
37 378002	Latridae	*Latridopsis forsteri*	Bastard Trumpeter	C		*	*	*		
37 380001	Cepolidae	*Cepola australis*	Australian Bandfish		*	*				
37 381004	Mugilidae	*Liza argentea*	Goldspot Mullet	C		*				
37 382003	Sphyraenidae	*Sphyraena acutipinnis*	Sharpfin Barracuda		*	*	*	*		
37 384035	Labridae	*Bodianus flavipinnis*	Yellowfin Pigfish	C				*		
37 384061	Labridae	*Bodianus unimaculatus*	Eastern Blackspot Pigfish	C				*		
37 384074	Labridae	*Choerodon frenatus*	Bridled Tuskfish		*					
37 384041	Labridae	*Notolabrus gymnogenis*	Crimsonband Wrasse	C	*					
37 384195	Labridae	*Suezichthys devisi*	Australian Rainbow Wrasse		*					
37 388005	Opistognathidae	*Opistognathus jacksoniensis*	Southern Smiler		*					
37 390001	Pinguipedidae	*Parapercis allporti*	Barred Grubfish			*		*	*	
37 390012	Pinguipedidae	*Parapercis binivirgata*	Redbanded Grubfish			*		*		
37 390009	Pinguipedidae	*Parapercis* cf. *macrophthalma*	Narrowbarred Grubfish					*		
37 390005	Pinguipedidae	*Parapercis nebulosa*	Pinkbanded Grubfish		*					
37 390000	Pinguipedidae	*Simipercis trispinosa*	Pink grubfish			*				
37 393008	Percophidae	*Enigmapercis reducta*	Broad Duckbill			*				
37 400002	Uranoscopidae	*Ichthyscopus barbatus*	Fringe Stargazer			*	*			
37 400026	Uranoscopidae	*Ichthyscopus nigripinnis*	Blackfin Stargazer		*					
37 400022	Uranoscopidae	*Ichthyscopus sannio*	Spotted Stargazer			*				
37 400018	Uranoscopidae	*Kathetostoma canaster*	Speckled Stargazer	C					*	
37 400003	Uranoscopidae	*Kathetostoma laeve*	Common Stargazer	C		*	*			
37 400005	Uranoscopidae	*Pleuroscopus pseudodorsalis*	Scaled Stargazer	C						*
37 400023	Uranoscopidae	*Uranoscopus terraereginae*	Queensland Stargazer		*	*				
37 400001	Uranoscopidae	*Xenocephalus armatus*	Bulldog Stargazer	C		*	*	*	*	
37 400020	Uranoscopidae	*Xenocephalus australiensis*	Australian Stargazer						*	

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CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 401007	Champsodontidae	*Champsodon machaeratus*	Knife Gaper						*	
37 401000	Champsodontidae	*Champsodon* sp.	Knife Gaper		*	*		*		
37 408073	Blenniidae	*Petroscirtes lupus*	Brown Sabretooth Blenny		*					
37 408001	Blenniidae	*Xiphasia setifer*	Hairtail Blenny		*	*	*			
37 416017	Clinidae	*Cristiceps aurantiacus*	Yellow Crested Weedfish			*				
37 416007	Clinidae	*Cristiceps australis*	Southern Crested Weedfish				*			
37 427038	Callionymidae	*Bathycallionymus moretonensis*	Ocellate Dragonet		*			*		
37 427050	Callionymidae	*Calliurichthys scaber*	Japanese Stinkfish		*					
37 427001	Callionymidae	*Foetorepus calauropomus*	Common Stinkfish		*	*	*	*		
37 427015	Callionymidae	*Repomucenus calcaratus*	Spotted Dragonet		*	*	*			
37 427012	Callionymidae	*Repomucenus limiceps*	Rough-head Dragonet		*					
37 427023	Callionymidae	*Repomucenus macdonaldi*	Greyspotted Dragonet			*				
37 438001	Siganidae	*Siganus nebulosus*	Black Rabbitfish	C	*					
37 439012	Gempylidae	*Nesiarchus nasutus*	Black Gemfish							*
37 439009	Gempylidae	*Rexea antefurcata*	Longfin Gemfish	C					*	
37 439006	Gempylidae	*Rexea prometheoides*	Royal Gemfish						*	
37 439002	Gempylidae	*Rexea solandri*	Gemfish	C					*	
37 439014	Gempylidae	*Rexichthys johnpaxtoni*	Paxton's Gemfish						*	
37 439003	Gempylidae	*Ruvettus pretiosus*	Oilfish	C						*
37 439001	Gempylidae	*Thyrsites atun*	Barracouta	C			*	*		
37 440010	Trichiuridae	*Aphanopus capricornis*	Capricorn Scabbardfish	C						*
37 440001	Trichiuridae	*Benthodesmus elongatus*	Slender Frostfish						*	*
37 440011	Trichiuridae	*Benthodesmus tuckeri*	Tucker's Frostfish							*
37 440002	Trichiuridae	*Lepidopus caudatus*	Frostfish	C				*	*	*
37 440004	Trichiuridae	*Trichiurus lepturus*	Largehead Hairtail	C		*		*		
37 441001	Scombridae	*Scomber australasicus*	Blue Mackerel	C	*	*	*	*		
37 442001	Xiphiidae	*Xiphias gladius*	Swordfish	C				*		
37 445004	Centrolophidae	*Centrolophus niger*	Rudderfish	C					*	*
37 445003	Centrolophidae	*Schedophilus huttoni*	New Zealand Ruffe	C					*	*
37 445005	Centrolophidae	*Seriolella brama*	Blue Warehou	C		*	*	*		
37 445011	Centrolophidae	*Seriolella caerulea*	White Warehou	C					*	
37 445006	Centrolophidae	*Seriolella punctata*	Silver Warehou	C		*	*		*	
37 446000	Ariommatidae	*Ariomma luridum*	Slope Driftfish					*		
37 446006	Nomeidae	*Cubiceps baxteri*	Black Cubehead							*
37 446013	Nomeidae	*Cubiceps whiteleggii*	Coastal Cubehead						*	

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CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 460043	Bothidae	*Arnoglossus fisoni*	Fison's Flounder		*					
37 460049	Bothidae	*Chascanopsetta lugubris*	Pelican Flounder						*	*
37 460066	Bothidae	*Crossorhombus valderostratus*	Broadbrow Flounder		*					
37 460012	Bothidae	*Engyprosopon grandisquama*	Spot-tail Wide-eye Flounder		*					
37 460068	Bothidae	*Engyprosopon hureaui*	Hureau's Wide-eye Flounder		*					
37 460013	Bothidae	*Engyprosopon maldivensis*	Olive Wide-eye Flounder		*					
37 460016	Bothidae	*Grammatobothus pennatus*	Pennant Flounder		*					
37 460010	Bothidae	*Grammatobothus polyophthalmus*	Threespot Flounder		*					
37 460001	Bothidae	*Lophonectes gallus*	Crested Flounder		*	*	*	*		
37 460009	Paralichthyidae	*Pseudorhombus arsius*	Largetooth Flounder	C	*	*	*			
37 460004	Paralichthyidae	*Pseudorhombus dupliciocellatus*	Three Twinspot Flounder	C	*					
37 460002	Paralichthyidae	*Pseudorhombus jenynsii*	Smalltooth Flounder	C	*	*	*	*		
37 460031	Paralichthyidae	*Pseudorhombus tenuirastrum*	Slender Flounder	C	*	*	*	*		
37 461001	Pleuronectidae	*Ammotretis rostratus*	Longsnout Flounder	C		*				
37 461002	Pleuronectidae	*Azygopus pinnifasciatus*	Banded-fin Flounder						*	
37 462001	Soleidae	*Aesopia cornuta*	Thickray Sole		*					
37 462040	Soleidae	*Aseraggodes nigrocirratus*	Bearded Sole		*					
37 462017	Soleidae	*Brachirus nigra*	Black Sole	C	*	*	*			
37 462029	Soleidae	*Pardachirus hedleyi*	Southern Peacock Sole		*	*	*			
37 462033	Soleidae	*Soleichthys microcephalus*	Smallhead Sole		*	*				
37 462018	Soleidae	*Synclidopus macleayanus*	Narrowbanded Sole		*	*	*			
37 462010	Soleidae	*Zebrias scalaris*	Manyband Sole		*	*	*			
37 463000	Cynoglossidae	*Cynoglossus* sp. cf. *maculipinnis*	Tongue Sole		*					
37 463001	Cynoglossidae	*Paraplagusia bilineata*	Lemon Tongue Sole	C	*	*	*			
37 463020	Cynoglossidae	*Symphurus australis*	Deepwater Tongue Sole						*	
37 464014	Triacanthodidae	*Macrorhamphosodes uradoi*	Common Trumpetsnout						*	
37 464003	Triacanthodidae	*Triacanthodes ethiops*	Shortsnout Spikefish						*	
37 465002	Monacanthidae	*Acanthaluteres vittiger*	Toothbrush Leatherjacket		*	*	*			
37 465022	Monacanthidae	*Aluterus monoceros*	Unicorn Leatherjacket	C		*	*			
37 465025	Monacanthidae	*Brachaluteres jacksonianus*	Southern Pygmy Leatherjacket		*	*				
37 465053	Monacanthidae	*Cantheschenia longipinnis*	Smoothspine Leatherjacket		*					
37 465013	Monacanthidae	*Chaetodermis penicilligera*	Tasselled Leatherjacket		*					
37 465039	Monacanthidae	*Eubalichthys bucephalus*	Black Reef Leatherjacket	C	*		*	*		
37 465003	Monacanthidae	*Eubalichthys mosaicus*	Mosaic Leatherjacket	C	*	*	*	*		
37 465036	Monacanthidae	*Meuschenia freycineti*	Sixspine Leatherjacket	C		*	*			

Appendix A										
CAAB	**Family**	**Species**	**Common Name**		**North inshore**	**Central inshore**	**South inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 465005	Monacanthidae	*Meuschenia scaber*	Velvet Leatherjacket	C		*	*	*	*	
37 465059	Monacanthidae	*Meuschenia trachylepis*	Yellowfin Leatherjacket	C	*	*	*			
37 465006	Monacanthidae	*Nelusetta ayraudi*	Ocean Jacket	C	*	*	*	*		
37 465024	Monacanthidae	*Paramonacanthus filicauda*	Threadfin Leatherjacket		*	*				
37 465085	Monacanthidae	*Paramonacanthus lowei*	Lowe's Leatherjacket		*					
37 465065	Monacanthidae	*Paramonacanthus otisensis*	Dusky Leatherjacket		*	*				
37 465066	Monacanthidae	*Pervagor alternans*	Yelloweye Leatherjacket		*					
37 465007	Monacanthidae	*Scobinichthys granulatus*	Rough Leatherjacket	C			*			
37 465037	Monacanthidae	*Thamnaconus degeni*	Bluefin Leatherjacket	C			*			
37 465012	Monacanthidae	*Thamnaconus hypargyreus*	Yellowspotted Leatherjacket		*	*		*		
37 465038	Monacanthidae	*Thamnaconus modestoides*	Modest Leatherjacket		*					
37 466002	Ostraciidae	*Anoplocapros inermis*	Eastern Smooth Boxfish		*	*	*	*		
37 466023	Ostraciidae	*Kentrocapros flavofasciatus*	Yellowstriped Boxfish					*		
37 466004	Ostraciidae	*Lactoria cornuta*	Longhorn Cowfish		*					
37 466007	Ostraciidae	*Lactoria diaphana*	Roundbelly Cowfish			*				
37 466018	Ostraciidae	*Lactoria fornasini*	Thornback Cowfish				*	*		
37 466008	Ostraciidae	*Tetrosomus reipublicae*	Smallspine Turretfish		*	*	*			
37 467005	Tetraodontidae	*Arothron firmamentum*	Starry Toadfish			*	*	*		
37 467038	Tetraodontidae	*Canthigaster callisterna*	Clown Toby		*	*	*			
37 467065	Tetraodontidae	*Lagocephalus cheesemanii*	Cheeseman's Puffer		*	*	*	*		
37 467008	Tetraodontidae	*Lagocephalus inermis*	Smooth Golden Toadfish		*		*			
37 467007	Tetraodontidae	*Lagocephalus sceleratus*	Silver Toadfish		*	*				
37 467002	Tetraodontidae	*Omegophora armilla*	Ringed Toadfish				*			
37 467050	Tetraodontidae	*Reicheltia halsteadi*	Halstead's Toadfish		*	*	*			
37 467004	Tetraodontidae	*Sphoeroides pachygaster*	Balloonfish					*	*	
37 467003	Tetraodontidae	*Tetractenos glaber*	Smooth Toadfish			*				
37 467054	Tetraodontidae	*Tetractenos hamiltoni*	Common Toadfish			*				
37 467056	Tetraodontidae	*Torquigener altipinnis*	Highfin Toadfish		*	*	*			
37 467030	Tetraodontidae	*Torquigener pleurogramma*	Weeping Toadfish		*	*				
37 467061	Tetraodontidae	*Torquigener squamicauda*	Scalytail Toadfish			*				
37 467062	Tetraodontidae	*Torquigener tuberculiferus*	Fringe-gill Toadfish		*					
37 469002	Diodontidae	*Allomycterus pilatus*	Australian Burrfish		*	*	*	*	*	
37 469014	Diodontidae	*Chilomycterus reticulatus*	Spotfin Porcupinefish		*					
37 469013	Diodontidae	*Dicotylichthys punctulatus*	Threebar Porcupinefish		*	*	*			
37 469005	Diodontidae	*Diodon holocanthus*	Freckled Porcupinefish		*		*			

Appendix A					North	Central	South			
CAAB	**Family**	**Species**	**Common Name**		**inshore**	**inshore**	**inshore**	**Shelf**	**Upper slope**	**Mid Slope**
37 469015	Diodontidae	*Diodon hystrix*	Spotted Porcupinefish		*					
37 469001	Diodontidae	*Diodon nicthemerus*	Globefish				*			

Appendix B. Relative abundances of molluscs (% no. and % capture) recorded from trawl surveys on inshore (<100 m), shelf (100-200 m) and upper slope (200-650 m) off NSW in 1993-97.

CAAB: CAAB no.; c: commercial; N=total number of molluscs; n=total number of trawls

Appendix B					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
					N=16235	n=179	N=12007	n=179	N=11817	n=128	N=49166	n=256	N=3183	n=79
Mollusca - Bivalvia														
23 231007	Glycymerididae	*Glycimeris grayana*	a dog cockle	C	-	-	3.61	8.38	-	-	-	-	-	-
23 231009	Glycymerididae	*Glycymeris holosericus*	a dog cockle		0.01	0.56	3.98	16.20	-	-	-	-	-	-
23 237002	Vulsellidae	*Malleus albus*	White hammer oyster		0.01	0.56	-	-	-	-	-	-	-	-
23 260000	Plicatulidae	*Plicatula essingtonsis*	a kitten's paw oyster		0.01	0.56	-	-	-	-	-	-	-	-
23 270001	Pectinidae	*Amusium balloti*	Ballot's saucer scallop	C	8.70	35.20	-	-	-	-	-	-	-	-
23 270004	Pectinidae	*Annachlamys flabellatus*	a fan scallop		0.01	0.56	-	-	0.02	0.78	-	-	-	-
23 270029	Pectinidae	*Chlamys challengeri*	a fan scallop		-	-	-	-	-	-	-	-	0.03	1.03
23 270021	Pectinidae	*Mesopeplum fenestratum*	a scallop		0.01	1.12	0.03	1.12	0.03	3.91	0.01	0.78	-	-
23 270007	Pectinidae	*Pecten fumatus*	Commercial scallop	C	0.02	1.68	4.38	18.99	0.01	0.78	-	-	-	-
23 280004	Trigoniidae	*Neotrigonia lamarkii*	a brooch shell		-	-	0.10	3.91	-	-	-	-	-	-
23 325015	Carditidae	*Venericardia amabilis*	a cockle		-	-	0.01	0.56	-	-	-	-	-	-
23 345001	Mactridae	*Mactra contraria*	a clam		0.01	0.56	-	-	-	-	-	-	-	-
23 370001	Glossidae	*Glossus vulgaris*	a heart cockle		0.01	0.56	-	-	-	-	-	-	-	-
23 380007	Veneridae	*Placamen tiara*	a venus cockle		-	-	0.13	3.35	-	-	-	-	-	-
23 380012	Lioconchidae	*Callista diemenensis*	a venus cockle		-	-	0.12	2.23	-	-	-	-	-	-
23 387008	Aloilididae	*Corbula tunicata*	a cockle		-	-	0.01	0.56	-	-	-	-	-	-
Mollusca - Cephalopoda					-	-	-	-	-	-	-	-	-	-
23 607001	Sepiidae	*Sepia apama*	Giant cuttlefish	C	-	-	0.02	1.12	0.69	21.88	0.01	1.17	-	-
23 607002	Sepiidae	*Sepia cultrata*	Knife-bone cuttlefish	C	-	-	-	-	-	-	2.69	75.00	52.91	76.29
23 607000	Sepiidae	*Sepia grahami*	Graham's cuttlefish	C	0.11	8.38	0.02	1.12	-	-	-	-	-	-
23 607021	Sepiidae	*Sepia hedleyi*	King cuttlefish	C	-	-	0.20	4.47	0.02	0.78	72.83	99.61	27.30	41.24
23 607024	Sepiidae	*Sepia limata*	Pygmy cuttlefish		0.25	15.08	1.17	16.20	-	-	-	-	-	-
23 607025	Sepiidae	*Sepia mestus*	Reaper cuttlefish	C	-	-	0.01	0.56	-	-	-	-	-	-
23 607026	Sepiidae	*Sepia mira*	Pink-edged cuttlefish		0.04	3.35	-	-	-	-	-	-	-	-
23 607006	Sepiidae	*Sepia opipara*	Staregaze cuttlefish	C	0.67	17.88	-	-	-	-	-	-	-	-
23 607012	Sepiidae	*Sepia plangon*	Mourning cuttlefish	C	9.21	84.92	0.01	0.56	-	-	-	-	-	-
23 607010	Sepiidae	*Sepia rozella*	Rosecone cuttlefish	C	26.35	79.89	29.92	75.98	17.38	61.72	0.20	13.67	-	-
23 609001	Sepiolidae	*Euprymna tasmanica*	Southern dumpling squid		0.13	5.59	0.02	1.12	0.01	0.78	-	-	-	-

Appendix B					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
					N=16235	n=179	N=12007	n=179	N=11817	n=128	N=49166	n=256	N=3183	n=79
23 608001	Sepioloididae	*Sepioloidea lineolata*	Pinstripe bottle-tailed squid		4.80	54.19	1.59	22.91	0.20	14.06	-	-	-	-
23 609005	Sepiolidae	*Austrorossia australis*	Deepwater dumpling squid		-	-	-	-	-	-	-	-	1.63	30.93
24 609006	Sepiolidae	*Neorossia leptons*	Deepwater dumpling squid		-	-	-	-	-	-	-	-	-	-
23 617005	Loliginidae	*Sepioteuthis australis*	Southern calamari	C	0.53	21.79	12.33	62.01	35.01	97.66	0.14	10.94	-	-
23 617000	Loliginidae	*Uroteuthis etheridgi*	Broad squid	C	0.02	1.12	1.30	16.20	1.32	19.53	-	-	-	-
23 617010	Loliginidae	*Uroteuthis noctiluca*	Luminous bay squid	C	9.15	16.20	5.17	10.06	0.03	0.78	-	-	-	-
23 617000	Loliginidae	*Uroteuthis* sp. (slender)	Slender squid	C	5.96	59.78	0.97	20.11	11.63	25.78	2.77	5.86	-	-
23 621000	Enoploteuthidae	*Abralia astrolineatus*	an armed squid		-	-	-	-	-	-	-	-	0.50	5.15
23 621003	Enoploteuthidae	*Enoploteuthis galaxias*	an armed squid		-	-	-	-	-	-	-	-	0.91	15.46
23 630006	Histioteuthidae	*Histioteuthis miranda*	Purple squid		-	-	-	-	-	-	-	-	0.75	9.28
23 636004	Ommastrephidae	*Nototodarus gouldi*	Gould's squid	C	0.22	8.94	18.39	38.55	23.82	70.31	20.67	97.27	8.29	32.99
23 636007	Ommastrephidae	*Ommastrephes bartrami*	Red ocean squid	C	-	-	-	-	-	-	-	-	0.03	1.03
23 636011	Ommastrephidae	*Todorodes filippovae*	Southern Ocean arrow squid	C	-	-	-	-	-	-	-	-	0.09	2.06
23 636013	Ommastrephidae	*Todaropsis eblanae*	Lesser flying squid	C	-	-	-	-	-	-	-	-	0.03	1.03
23 639000	Mastigoteuthidae	*Mastigoteuthis* sp.	Whiplash squid		-	-	-	-	-	-	-	-	-	-
23 653001	Opisthoteuthidae	*Opisthoteuthis persephone*	a jelly octopus		-	-	-	-	-	-	-	-	0.75	18.56
23 659009	Octopodidae	*Eledone palari*	an octopus		-	-	-	-	-	-	-	-	0.09	3.09
23 659014	Octopodidae	*Hapalochlaena fasciata*	Blue-lined octopus		0.02	2.23	0.02	1.68	-	-	-	-	-	-
23 659001	Octopodidae	*Octopus australis*	Southern octopus	C	22.25	96.65	11.26	73.18	8.72	69.53	-	-	-	-
23 659003	Octopodidae	*Octopus maorum*	Maori octopus	C	-	-	0.02	1.12	0.04	2.34	0.05	7.81	0.13	4.12
23 659000	Octopodidae	*Octopus marginatus*	Marginate octopus		0.01	1.12	-	-	-	-	-	-	-	-
23 659004	Octopodidae	*Octopus pallidus*	Pale octopus	C	-	-	0.01	0.56	0.14	3.91	0.40	32.42	0.03	1.03
23 659000	Octopodidae	*Octopus* sp.cf *kagoshimensis*	Eye-cross octopus	C	5.77	62.57	0.74	24.02	0.30	9.38	-	-	-	-
23 659019	Octopodidae	*Octopus* sp.cf. *bunurong*	Southern white-spot octopus		0.12	6.15	0.02	1.12	0.01	0.78	0.12	16.41	-	-
23 659026	Octopodidae	*Octopus* sp.cf. *kaurna*	Southern sand octopus		0.09	5.03	0.14	6.70	-	-	-	-	-	-
23 659029	Octopodidae	*Octopus supercilliosus*	Frilled pygmy octopus		-	-	-	-	0.01	0.78	-	-	-	-
23 659006	Octopodidae	*Octopus tetricus*	Gloomy octopus	C	0.99	36.31	1.55	39.11	0.48	19.53	-	-	-	-
Mollusca - Gastropoda					-	-	-	-	-	-	-	-	-	-
24 047020	Trochidae	*Astele speciosa*	a top shell		0.02	1.68	0.08	3.91	-	-	-	-	-	-
24 047000	Trochidae	*Calliotropus glyptus*	a top shell		-	-	-	-	-	-	-	-	0.09	2.06
24 125005	Strombidae	*Strombus campbelli*	a stromb		0.01	0.56	-	-	-	-	-	-	-	-
24 126001	Struthiolaridae	*Struthiolaria* sp.	a pelican-foot shell		0.01	0.56	-	-	-	-	-	-	-	-
24 130000	Hipponicidae	*Malluvium devotus*	Horse hoof limpet		-	-	-	-	-	-	-	-	0.28	6.19
24 145002	Xenophoridae	*Xenophora indica*	a carrier shell		0.58	24.02	-	-	-	-	-	-	-	-

Appendix B					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
					N=16235	n=179	N=12007	n=179	N=11817	n=128	N=49166	n=256	N=3183	n=79
24 145008	Xenophoridae	*Xenophora peroniana*	a carrier shell		0.65	16.20	-	-	-	-	-	-	-	-
24 155023	Cypraeidae	*Cypraea hesitata*	Deepsea cowrie		-	-	-	-	-	-	0.00	0.39	0.31	9.28
24 156002	Ovulidae	*Volva volva*	Spindle cowrie		0.01	0.56	0.01	0.56	-	-	-	-	-	-
24 171007	Cassididae	*Cassis nana*	a helmet shell		0.01	0.56	-	-	-	-	-	-	-	-
24 171001	Cassididae	*Semicassis bisulcatum*	a helmet shell		0.04	3.91	-	-	-	-	-	-	-	-
24 171020	Cassididae	*Semicassis labiatum*	a helmet shell		0.01	0.56	0.24	8.94	-	-	-	-	-	-
24 171024	Cassididae	*Semicassis thomsoni*	a helmet shell		-	-	0.10	5.59	-	-	-	-	-	-
24 172005	Ficidae	*Ficus subintermedius*	Figshell		0.06	3.91	-	-	-	-	-	-	-	-
24 176001	Ranellidae	*Fusitriton retiolus*	White triton		-	-	-	-	-	-	-	-	3.64	30.93
24 176002	Ranellidae	*Ranella australasia*	Deepwater white triton		-	-	0.31	5.03	-	-	-	-	-	-
24 176014	Buccinidae	*Charonia lampas rubicunda*	Red triton shell		-	-	-	-	-	-	0.02	2.73	-	-
24 176044	Ranellidae	*Cymatium vespaceum*	a triton shell		0.02	1.68	0.02	1.12	-	-	-	-	-	-
24 176017	Ranellidae	*Sassia parkinsonia*	a triton shell		-	-	0.02	1.12	-	-	-	-	-	-
24 177007	Tonnidae	*Tonna chinensis*	China tun shell		0.03	1.12	0.01	0.56	-	-	-	-	-	-
24 177010	Tonnidae	*Tonna sulcosa*	Banded tun shell		0.01	0.56	-	-	-	-	-	-	-	-
24 177012	Tonnidae	*Tonna tetracotula*	Pale tun shell		0.50	15.08	0.09	3.91	-	-	-	-	-	-
24 177001	Tonnidae	*Tonna variegata*	tun shell		1.60	37.43	0.15	5.03	-	-	-	-	-	-
24 200035	Magilidae	*Babelomurex lischkeana*	a coral shell		-	-	-	-	-	-	-	-	0.06	1.03
24 201004	Turbinellidae	*Columbarium hedleyi*	a pagoda shell		-	-	-	-	-	-	-	-	0.03	1.03
24 201006	Turbinellidae	*Columbarium pagodoides*	a pagoda shell		-	-	-	-	-	-	-	-	0.06	2.06
24 202005	Fasciolariidae	*Pleuroploca australasia*	Tulip shell		-	-	-	-	-	-	-	-	0.09	2.06
24 202017	Nassariidae	*Nassarius conoidalis*	a dog whelk		0.02	1.12	-	-	-	-	-	-	-	-
24 202025	Buccinidae	*Penion mandarinus*	Mandarin penion		-	-	-	-	-	-	-	-	1.63	21.65
24 202026	Buccinidae	*Penion maximus*	Giant penion		-	-	0.32	15.64	-	-	0.02	3.52	-	-
24 202029	Fasciolariidae	*Fusinus anni*	a spindle shell		-	-	-	-	-	-	-	-	0.06	2.06
24 202031	Fasciolariidae	*Fusinus novaehollandiae*	Spindle shell		-	-	0.07	3.91	0.02	1.56	0.00	0.39	-	-
24 202032	Fasciolariidae	*Fusinus undulatus*	a spindle shell		-	-	-	-	0.02	3.13	-	-	-	-
24 207007	Volutidae	*Amoria undulata*	Wavy volute		0.02	1.68	0.03	1.68	-	-	-	-	-	-
24 207062	Volutidae	*Cymbiolena magnifica*	Magnificent volute	C	0.22	11.73	0.14	7.26	0.04	3.13	-	-	-	-
24 207039	Volutidae	*Cymbiolista hunteri*	Hunter's volute		0.06	5.03	0.19	9.50	-	-	-	-	-	-
24 207009	Volutidae	*Ericusa papillosa*	Deepwater volute		-	-	-	-	-	-	-	-	0.03	1.03
24 207010	Volutidae	*Ericusa sowerbyi*	Sowerby's volute		-	-	-	-	-	-	0.01	1.95	0.03	1.03
24 207001	Volutidae	*Livonia mamilla*	False bailer shell	C	-	-	-	-	0.03	3.13	0.05	5.86	0.06	2.06
24 207038	Volutidae	*Zebramoria zebra*	Zebra volute		0.02	0.56	-	-	-	-	-	-	-	-
24 208027	Olividae	*Ancillista velesiana*	an ancillid olive		0.52	20.67	0.91	13.41	0.03	3.13	-	-	-	-

Appendix B					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
					N=16235	n=179	N=12007	n=179	N=11817	n=128	N=49166	n=256	N=3183	n=79
24 211005	Mitridae	*Mitra solida*	a mitre shell		-	-	0.02	1.68	-	-	-	-	-	-
24 220009	Turridae	*Bathytoma agnata*	a turrid shell		-	-	-	-	-	-	-	-	0.03	1.03
24 222000	Conidae	*Conus sydneyensis*	a cone shell		-	-	0.02	1.12	-	-	-	-	-	-
24 231001	Architectonicidae	*Architectonica perspectiva*	Spiral-staircase shell		0.01	0.56	-	-	-	-	-	-	-	-
24 231000	Architectonicidae	*Solatisonax injussa*	a spiral-staircase shell		-	-	-	-	-	-	-	-	0.06	2.06
24 392001	Umbraculidae	*Umbraculum umbraculum*	Umbrella shell		-	-	-	-	0.01	0.78	-	-	-	-
24 395000	Pleurobranchidae	*Euselenops luniceps*	a side-gill slug		0.13	7.26	-	-	-	-	-	-	-	-

Appendix C. Relative abundances of crustaceans (% no. and % capture) recorded from trawl surveys on inshore (<100 m), shelf (100–200 m) and upper slope (200–650 m) off NSW in 1993–97.

CAAB: CAAB no.; c: commercial; N=total number of molluscs; n=total number of trawls

Appendix C					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
Crustacea - Stomatopoda					N=51222	n=179	N=50499	n=179	N=2947	n=128	N=2602	n=256	N=35307	n=79
28 037001	Hemisquillidae	*Hemisquilla australiensis*	a mantis shrimp		-	-	<0.01	1.12	-	-	0.58	3.52	-	-
28 038002	Odontodactylidae	*Odontodactylus japonicus*	a mantis shrimp		<0.01	0.56	-	-	-	-	-	-	-	-
28 046001	Lysiosquillidae	*Lysiosquilla colemani*	a mantis shrimp		<0.01	1.12	<0.01	0.56	-	-	-	-	-	-
28 051009	Squillidae	*Anchisquilloides mcneilli*	a mantis shrimp		-	-	5.34	32.96	-	-	2.65	12.89	-	-
28 051003	Squillidae	*Belosquilla laevis*	a mantis shrimp		4.57	56.42	0.13	8.38	-	-	-	-	-	-
28 051032	Squillidae	*Erugosquilla grahami*	a mantis shrimp		<0.01	0.56	-	-	-	-	-	-	-	-
28 051037	Squillidae	*Harpiosquilla melanoura*	a mantis shrimp		0.01	2.79	-	-	-	-	-	-	-	-
28 051040	Squillidae	*Kempina mikado*	a mantis shrimp		-	-	0.03	6.70	-	-	0.77	6.25	-	-
28 051049	Squillidae	*Oratosquillina berentsae*	a mantis shrimp		<0.01	1.12	-	-	-	-	-	-	-	-
28 051057	Squillidae	*Quollastria gonyptes*	a mantis shrimp		0.06	8.38	-	-	-	-	-	-	-	-
Crustacea - Decapoda														
28 711046	Penaeidae	*Marsupenaeus japonicus*	Kuruma prawn	C	<0.01	0.56	-	-	-	-	-	-	-	-
28 711047	Penaeidae	*Melicertus latisulcatus*	Western king prawn	C	0.02	1.12	-	-	-	-	-	-	-	-
28 711052	Penaeidae	*Melicertus plebejus*	Eastern king prawn	C	32.12	96.65	48.53	92.74	37.33	36.72	15.72	19.53	-	-
28 711013	Penaeidae	*Metapenaeopsis lamellata*	Hunchback prawn		0.01	1.68	-	-	-	-	-	-	-	-
28 711015	Penaeidae	*Metapenaeopsis mogiensis*	Velvet prawn		0.13	7.26	-	-	-	-	-	-	-	-
28 711016	Penaeidae	*Metapenaeopsis novaeguineae*	Northern velvet prawn		0.50	17.88	0.01	2.23	-	-	-	-	-	-
28 711027	Penaeidae	*Metapenaeus ensis*	Red endeavour prawn	C	<0.01	0.56	-	-	-	-	-	-	-	-
28 711029	Penaeidae	*Metapenaeus macleayi*	School prawn	C	18.12	20.67	3.08	7.82	0.37	4.69	-	-	-	-
28 711035	Penaeidae	*Parapenaeus australiensis*	Red prawn	C	-	-	1.05	8.94	-	-	0.58	2.73	-	-
28 711044	Penaeidae	*Penaeus esculentus*	Brown tiger prawn	C	0.12	16.76	0.01	3.91	-	-	-	-	-	-
28 711051	Penaeidae	*Penaeus monodon*	Black tiger prawn	C	0.12	5.03	-	-	-	-	-	-	-	-
28 711055	Penaeidae	*Trachypenaeus curvirostris*	Southern rough prawn		21.02	92.74	2.61	49.16	0.24	4.69	-	-	-	-
28 712001	Aristeidae	*Aristeomorpha foliacea*	Red prawn	C	-	-	-	-	-	-	-	-	2.28	37.11
28 712011	Aristeidae	*Aristeus semidentatus*	Purple prawn	C	-	-	-	-	-	-	-	-	-	-
28 712003	Aristeidae	*Aristeus virilis*	Red striped prawn	C	-	-	-	-	-	-	-	-	0.01	3.09
28 712008	Aristeidae	*Aristaeopsis edwardsiana*	Giant scarlet prawn	C	-	-	-	-	-	-	-	-	0.06	3.09
28 714004	Solenoceridae	*Haliporoides cristatus*	Whitetail prawn		-	-	-	-	-	-	-	-	0.01	3.09
28 714005	Solenoceridae	*Haliporoides sibogae australiensis*	Royal-red prawn	C	-	-	-	-	-	-	-	-	19.62	57.73

Appendix C					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
28 714011	Solenoceridae	*Solenocera australiana*	Coral prawn		0.02	2.79	4.24	25.14	-	-	-	-	-	-
28 714903	Solenoceridae	*Solenocera* sp. 2	a coral prawn		0.04	9.50	0.04	5.03	-	-	-	-	-	-
28 715001	Sycionidae	*Sicyona cristata*	Ridgeback rock shrimp		0.08	15.08	-	-	-	-	-	-	-	-
28 751002	Eugonatonotidae	*Eugonatonotus crassus*	a carid prawn		-	-	-	-	-	-	-	-	<0.01	1.03
28 770001	Pandalidae	*Chlorotocus noveezelandiae*	a pandalid shrimp		-	-	0.10	2.23	-	-	0.19	1.17	-	-
28 770005	Pandalidae	*Heterocarpus sibogae*	White carid prawn		-	-	-	-	-	-	-	-	0.04	5.15
28 770014	Pandalidae	*Plesionika martia*	a carid prawn		-	-	-	-	-	-	-	-	3.44	38.14
28 770901	Pandalidae	*Plesionika ortmani*	a carid prawn		0.01	1.12	0.31	12.29	-	-	-	-	-	-
28 770023	Pandalidae	*Plesionika spinipes*	a carid prawn		-	-	0.26	6.15	-	-	2.88	1.17	-	-
28 820001	Palinuridae	*Jasus edwardsii*	Southern rocklobster	C	-	-	-	-	-	-	0.04	0.39	-	-
28 820002	Palinuridae	*Jasus verreauxi*	Eastern rocklobster	C	<0.01	0.56	0.01	1.68	0.14	2.34	0.27	1.95	-	-
28 820004	Palinuridae	*Linuparus trigonus*	Red champagne lobster	C	-	-	<0.01	0.56	-	-	0.08	0.78	-	-
28 821011	Scyllaridae	*Antarctus mawsoni*	a slipper lobster		-	-	-	-	-	-	-	-	<0.01	1.03
28 821014	Scyllaridae	*Biarctus sordidus*	a slipper lobster		0.01	0.56	0.01	1.68	-	-	-	-	-	-
28 821001	Scyllaridae	*Ibacus alticrenatus*	Deepwater bug	C	-	-	-	-	-	-	0.58	3.91	2.48	26.80
28 821019	Scyllaridae	*Ibacus chacei*	Smooth bug	C	7.86	78.77	0.87	50.84	0.37	7.03	3.92	15.23	-	-
28 821004	Scyllaridae	*Ibacus peronii*	Balmain bug	C	1.01	45.25	2.66	61.45	26.94	79.69	0.50	4.30	-	-
28 827001	Diogenidae	*Dardanus arrosor*	Striated hermit crab		0.04	8.94	1.22	30.17	0.41	2.34	3.38	26.56	1.22	36.08
28 827054	Diogenidae	*Dardanus crassimanus*	a hermit crab		0.06	13.97	-	-	-	-	-	-	-	-
28 827063	Diogenidae	*Diogenes custos*	a hermit crab		-	-	0.81	5.03	-	-	-	-	-	-
28 827002	Diogenidae	*Strigopagurus strigimanus*	Red hermit crab		-	-	0.10	8.94	0.78	5.47	3.04	22.66	0.17	22.68
28 835000	Paguridae	*Pagurus* cf. *investigatoris*	a hermit crab		-	-	-	-	-	-	-	-	1.11	54.64
28 837013	Parapaguridae	*Paragiopagurus diogenes*	a hermit crab		0.25	18.99	0.01	3.35	-	-	0.12	1.17	<0.01	1.03
28 837019	Parapaguridae	*Parapagurus bouvieri*	a hermit crab		-	-	-	-	-	-	-	-	0.13	27.84
28 837004	Parapaguridae	*Strobopagurus sibogae*	a hermit crab		-	-	-	-	-	-	-	-	0.01	1.03
28 840003	Galatheidae	*Munida haswelli*	Long-armed craylet		-	-	-	-	-	-	-	-	<0.01	1.03
28 852015	Dromiidae	*Dromidia australis*	Southern sponge crab		-	-	<0.01	0.56	-	-	-	-	-	-
28 852002	Dromiidae	*Lamarckdromia globosa*	Fringed sponge crab		-	-	-	-	-	-	0.04	0.39	-	-
28 860001	Homolidae	*Dagnaudus petterdi*	Antlered crab		-	-	-	-	-	-	-	-	1.75	57.73
28 860002	Homolidae	*Homola orientalis*	a carrier crab		<0.01	0.56	0.01	3.35	-	-	0.04	0.39	-	-
28 860003	Homolidae	*Homolochunia kular*	a carrier crab		-	-	-	-	-	-	-	-	0.01	3.09
28 861000	Latreilliidae	*Latriella philargium*	a carrier crab		0.12	2.79	0.07	2.79	-	-	8.22	7.03	-	-
28 865002	Raninidae	*Lyreidus tridentatus*	Frog crab		<0.01	1.12	0.38	11.73	-	-	0.12	1.17	-	-
28 865001	Raninidae	*Ranina ranina*	Spanner crab	C	<0.01	0.56	-	-	0.03	0.78	-	-	-	-
28 870001	Dorippidae	*Dorippe quadridens*	a crab		<0.01	0.56	-	-	-	-	-	-	-	-
28 875005	Calappidae	*Calappa lophus*	Red-streaked box crab		0.02	5.03	<0.01	1.12	-	-	-	-	-	-

Appendix C					Nthn inshore		Cent. inshore		Sthn inshore		Shelf		Upper slope	
CAAB	**Family**	**Species**	**Common Name**		%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.	%N	%Capt.
28 875001	Calappidae	*Calappa philargius*	Red-spotted box crab		0.02	5.03	-	-	-	-	-	-	-	-
28 875003	Calappidae	*Mursia curtispina*	Twospined box crab		-	-	0.03	5.03	-	-	0.38	3.13	-	-
28 876006	Leucosidae	*Arcania undecimspinosa*	a pebble crab		0.01	3.35	<0.01	1.12	-	-	-	-	-	-
28 876009	Leucosidae	*Leucosia anatum*	Painted pebble crab		<0.01	0.56	-	-	-	-	-	-	-	-
28 877005	Matutidae	*Matuta planipes*	Reticulated surf crab		0.04	1.12	-	-	-	-	-	-	-	-
28 880072	Majidae	*Ephippias endeavouri*	Endeavour crab		<0.01	1.12	-	-	-	-	0.04	0.39	-	-
28 880139	Majidae	*Leptomaia tuberculata*	a spider crab		0.27	10.61	2.58	38.55	0.17	3.91	0.08	0.78	-	-
28 880024	Majidae	*Leptomithrax waitei*	a spider crab		-	-	0.06	6.15	-	-	46.31	62.89	-	-
28 880143	Majidae	*Naxoides robillardi*	a spider crab		-	-	0.02	3.91	-	-	-	-	-	-
28 880038	Majidae	*Phalangipus australiensis*	a spider crab		0.03	7.82	-	-	-	-	-	-	-	-
28 880021	Majidae	*Teratomaia richardsoni*	Richardson's spider crab		-	-	-	-	-	-	-	-	0.02	5.15
28 900002	Corystidae	*Jonas luteanus*	a crab		0.02	4.47	-	-	-	-	-	-	-	-
28 910001	Geryonidae	*Chaceon bicolor*	Crystal crab	C	-	-	-	-	-	-	-	-	0.03	2.06
28 911018	Portunidae	*Charybdis bimaculata*	a swimmer crab		0.19	19.55	13.98	58.10	0.68	3.13	9.03	16.02	-	-
28 911001	Portunidae	*Charybdis feriata*	Coral crab	C	0.26	35.75	0.02	4.47	-	-	-	-	-	-
28 911000	Portunidae	*Charybdis granulata*	a swimmer crab		0.32	32.40	-	-	-	-	-	-	-	-
28 911019	Portunidae	*Charybdis miles*	a swimmer crab		0.20	16.76	4.25	41.34	-	-	-	-	-	-
28 911002	Portunidae	*Charybdis natator*	Hairyback crab		0.30	38.55	-	-	-	-	-	-	-	-
28 911016	Portunidae	*Liocarcinus corrugatus*	Dwarf swimmer crab		-	-	0.01	2.23	-	-	-	-	-	-
28 91100	Portunidae	*Lupocyclas* sp.	a swimmer crab		0.03	6.70	-	-	-	-	-	-	-	-
28 911003	Portunidae	*Ovalipes australiensis*	Common sand crab		0.01	1.12	3.07	29.05	22.06	42.97	-	-	-	-
28 911020	Portunidae	*Ovalipes molleri*	Swimmer crab		-	-	-	-	-	-	0.19	0.39	67.59	39.18
28 911032	Portunidae	*Portunus argentatus*	a swimmer crab		1.49	41.90	-	-	-	-	-	-	-	-
28 911063	Portunidae	*Portunus orbitosinus*	a swimmer crab		0.12	6.15	-	-	-	-	-	-	-	-
28 911005	Portunidae	*Portunus pelagicus*	Blue swimmer crab	C	1.16	53.07	3.67	69.27	10.49	49.22	-	-	-	-
28 911026	Portunidae	*Portunus rubromarginatus*	a swimmer crab		5.32	60.34	0.02	3.35	-	-	-	-	-	-
28 911006	Portunidae	*Portunus sanguinolentus*	Three-spotted crab	C	3.87	38.55	0.03	2.23	-	-	-	-	-	-
28 911022	Portunidae	*Thalamita sima*	Four-lobed swimmer crab		0.01	3.91	-	-	-	-	-	-	-	-
28 922002	Goneplacidae	*Carcinoplax meridionalis*	a goneplacid crab		-	-	0.26	7.82	-	-	0.04	0.39	<0.01	1.03
28 922011	Goneplacidae	*Carcinoplax victoriensis*	a goneplacid crab		-	-	-	-	-	-	-	-	0.01	3.09
28 922012	Goneplacidae	*Neopilumnoplax heterochir*	a goneplacid crab		-	-	-	-	-	-	-	-	0.01	2.06
28 922007	Goneplacidae	*Ommatocarcinus macgillivrayi*	a crab		-	-	0.08	10.61	-	-	-	-	-	-
28 922000	Goneplacidae	*Psopheticus* cf. *insignis*	a goneplacid crab		-	-	0.02	4.47	-	-	0.23	1.17	-	-
28 926020	Pilumnidae	*Eumedonus niger*	an urchin crab		0.02	2.23	-	-	-	-	-	-	-	-
28 926000	Pilumnidae	*Eumedonus zebra*	an urchin crab		<0.01	0.56	-	-	-	-	-	-	-	-
28 930037	Grapsidae	*Planes cyaneus*	a shore crab		-	-	<0.01	0.56	-	-	-	-	-	-

Appendix D. Summary of prawns captured in EMR commercial fisheries.

Highlight indicates targeted species. Source: Australian Faunal Directory: http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/search.html

Scientific name	Common names	Distribution	Ecology & fishery importance	References
Family Penaeidae				
Metapenaeus bennettae Racek & Dall, 1965	Bay Prawn, Greentail Prawn, Greentail Shrimp (FAO), Inshore Greasy Back Prawn, River Prawn	from Bass Strait, VIC to about Hervey Bay, QLD	trade (food); adults found in coastal rivers up to 15 km from the mouth, tolerates salinities from 0–35‰, depth 0–30 m	12; 1; 6
Metapenaeus demani stephani Miquel, 1982		QLD (NE coast); S Papua New Guinea	trade (minor trawl catches); shallow, silty, coastal waters, to 50 m depth but rarely deeper than 30 m	
Metapenaeus endeavouri (Schmitt, 1926)	Brown Prawn (Aust.), Endeavour Prawn (Aust.), Endeavour Shrimp (FAO)	northern Australia from Shark Bay, WA to N NSW; Gulf of Papua, New Guinea	trade (important commercial fishery); juveniles in shallow estuarine areas, depth 44–50 m	
Metapenaeus ensis (De Haan, 1844)	Greasyback Shrimp (FAO), Offshore Greasyback Prawn	northern Australia from central W coast,WA to Lower E coast, NSW; Indo-west Pacific Oceans (India, Sri Lanka through Indo-Malaysia to Japan, Taiwan, Philipppines and New Guinea)	trade (important commercial fishery); juveniles inhabit estuaries or rivers, adults inhabit estuaries or marine, depth 3–64 m	
Metapenaeus insolitus Racek & Dall, 1965	Greasyback Prawn (Aust.) Emerald Shrimp (FAO)	NT (N coast), QLD (Gulf of Carpentaria)	trade (minor commercial importance); found from brackish into coastal waters over sandy to muddy substrates, depths of 4 to 35 m, but commonly less than 8 m	
Metapenaeus macleayi (Haswell, 1879)	School Prawn (Aust.) Eastern School Shrimp (FAO)	eastern Australia between Moreton Bay, SE QLD and NE Victoria	trade (important commercial fishery); juveniles in shallower water, preference for turbid water and soft sediments, depth to 60 m	7
Parapenaeopsis cornuta (Kishinouye, 1900)	Coral Prawn (Aust.), Coral Shrimp (FAO)	northern Australia from Exmouth Gulf, WA to N NSW; Indo-west Pacific Oceans (W India to Japan, Philippines, Indonesia and southern New Guinea)	trade (minor commercial importance); trawled over mud to sandy mud substrates, very shallow, inshore waters, often abundant in river mouths and estuaries, depth 1–37 m	
Penaeus (Fenneropenaeus) merguiensis de Man, 1888	Banana Prawn (Aust. & FAO), White Prawn (Aust.)	northern Australia from Shark Bay, WA to N NSW; Indo-west Pacific Oceans (Persian Gulf to Thailand, Indonesia, Hong Kong, Philippines, New Guinea, New Caledonia)	trade (major commercial importance); trawled over muddy substrates, juveniles enter shallow rivers and estuaries as part of life cycle, depth 10–45 m	
Penaeus (Melicertus) latisulcatus Kishinouye, 1896	Western King Prawn, Blue-legged King Prawn (Aust. & FAO)	south west and northern Australia from Gulf St Vincent to NSW (Central E coast); Indo-west	trade (commercially important in SA and WA); trawled over hard substrates, sand, sandy mud or	

Scientific name	Common names	Distribution	Ecology & fishery importance	References
		Pacific Oceans (East Africa to Korea, Japan, Indo-Malaysia, southern New Guinea)	gravel, depths of 0–90 m, juveniles can occupy nursery areas in shallow waters of high salinity	
Penaeus (Melicertus) longistylus Kubo, 1943	Redspot King Prawn (Aust. & FAO), Red-spotted Prawn (Aust.)	Shark Bay, WA to QLD, and Lord Howe Island; central Indo-west Pacific Oceans (Indonesia, Malaysia, South China Sea, Philippines, southern New Guinea)	trade (moderate commercial significance); trawled over hard substrates near reefs, depth 35–55 m	
Penaeus (Melicertus) plebejus Hess, 1865	Eastern King Prawn (Aust. & FAO), King Prawn (Aust.), Sand Prawn (Aust.)	NE QLD to Bass Strait	trade (commercially important) adults—marine, juveniles—estuarine; trawled over sandy substrates, depth 2–220 m	8
Penaeus (Penaeus) esculentus Haswell, 1879	Brown Tiger Prawn (Aust. & FAO), Common Tiger Prawn	northern Australia from Central W coast, WA to Central E coast, NSW	trade (commercially important); typically trawled over mud or sandy mud substrates in 10–22 m depth, juveniles occupy shallow waters in estuaries, adults found offshore to 200 m	5
Penaeus (Penaeus) monodon Fabricius, 1798	Giant Tiger Prawn, Blue Tiger Prawn (Aust. & FAO), Jumbo Tiger Prawn, Leader Prawn, Panda Prawn (Aust.)	Exmouth Gulf, WA to Moreton Bay, QLD; Indo-west Pacific Oceans (South Africa to Japan, Philippines and southern New Guinea).	trade (minor commercial importance); trawled over mud to sand substrates, juveniles occasionally enter rivers, depths to 110 m	10
Penaeus (Penaeus) semisulcatus De Haan, 1844	Grooved Tiger Prawn, Northern Tiger Prawn (Aust.) Green Tiger Prawn (Aust. & FAO)	northern Australia from NW coast, WA to Central E coast, NSW; Indo-west Pacific Oceans (East Africa and Madagascar to Japan, Philippines, New Guinea and east to Fiji)	trade (minor commercial importance); trawled over sand to mud substrates, juveniles found in shallow waters generally associated with seagrass beds, depth 2–130 m	
Trachypenaeus (Megokris) granulosus (Haswell, 1879)	Hardback Prawn (Aust.), Coarse Shrimp (FAO)	from NW Cape York to Princess Charlotte Bay, QLD; Indo-west Pacific Oceans (Arabian Gulf east through Indo-Malaysia, to Taiwan, Philippines and southern New Guinea)	trade (little commercial significance); trawled over mud substrates, depth 9–81 m	
Trachypenaeus (Trachysalambria) curvirostris (Stimpson, 1860)	Hardback Prawn, Southern Rough Prawn, Southern Rough Shrimp (FAO)	from Shark Bay, WA through northern waters to Sydney, NSW; Indo-west Pacific Oceans (East Africa to Japan), through Suez to Mediterranean (Egypt, Israel and Turkey)	trade (minor commercial importance); trawled over muddy sand substrates, depths 13–150 m	
Trachypenaeus (Trachysalambria) fulvus Dall, 1957	Brown Rough Prawn (Aust.)	from Shark Bay, WA, through NT to Moreton Bay, QLD	trade (minor commercial importance); trawled over muddy substrates, depth to 60 m	
Solenoceridae				
Haliporoides sibogae de Man,	Royal Red Prawn, Jack-knife Shrimp,	northern Australia from NW coast, WA to Lower E coast, NSW; Indo-west Pacific Oceans	trade (fished commercially off eastern Australia); from 100–900 m depth, but all Australian records	

Scientific name	Common names	Distribution	Ecology & fishery importance	References
1907	Pink Prawn	(Madagascar to Indonesia, South China Sea, Japan, New Zealand)	from deeper than 350 m	
Penaeidae				
Atypopenaeus formosus Dall, 1957	Go Home Prawn, Orange Prawn (Aust.), Orange Shrimp (FAO)	northern Australia from N coast, NT to Lower E coast, NSW; Irian Jaya, southern Papua New Guinea	typically over soft mud substrates, predominantly shallow inshore waters, depth to 30 m	
Funchalia villosa (Bouvier, 1905)		Lord Howe Island, NSW (Central E coast, Lower E coast, SE oceanic); Atlantic-Indo-west Pacific Oceans	depths of 50–666 m	
Funchalia woodwardi Johnson, 1867		NSW (Central E coast, Lower E coast), WA (SW coast); Atlantic and Indo-west Pacific Oceans	depths of 250–540 m	
Metapenaeopsis commensalis Borradaile, 1898	Reef Shrimp (FAO)	QLD (NE coast), Territory of Ashmore & Cartier Islands; Murray Island, Torres Strait, east Indo-west Pacific Oceans	depths 1–3 m	
Metapenaeopsis lamellata (De Haan, 1844)	Hunchback Prawn (Aust.), Hunchback Shrimp (FAO), Rooster Prawn (Aust.)	Shark Bay, WA to NE QLD; east Indo-west Pacific Oceans	typically in association with hard substrates (rock and coral reefs, coral rubble), depths 4–200 m	
Metapenaeopsis mogiensis complanata Crosnier, 1991	Coral Prawn (Aust.), North Velvet Shrimp (FAO), Velvet Prawn (Aust.)	northern Australia from NW coast, WA to Great Barrier Reef, QLD; Coral Sea, New Caledonia	trawled from hard substrates adjacent to coral reefs, depth 8–90 m	
Metapenaeopsis novaeguineae (Haswell, 1879)	New Guinea Prawn, Northern Velvet Shrimp (FAO)	south west and northern Australia from Gulf St Vincent to Lower E coast, NSW; east Indo-west Pacific Oceans	trawled over muddy to sandy substrates, depths 5–30 m	
Metapenaeopsis palmensis (Haswell, 1879)	Southern Velvet Prawn, Southern Velvet Shrimp (FAO)	Shark Bay, WA to Sydney, NSW; central Indo-west Pacific Oceans (Indonesia, southern New Guinea)	trawled over muddy to sandy substrates, depths of 5–30 m	13
Metapenaeopsis provocatoria provocatoria Racek & Dall, 1965		QLD (Central E coast); west Pacific Ocean (New Caledonia, Indonesia, Philippines)	depth 90–390 m	
Metapenaeopsis rosea Racek & Dall, 1965	Rosy Prawn (Aust.)	Darwin, NT to Mackay, QLD; southern New Guinea	trawled over muddy substrates, depth to 30 m	13
Metapenaeopsis sinica Liu & Zhong, 1988		QLD (NE coast); central Indo-west Pacific Ocean	trawled over muddy to sandy substrates, depth to 142 m	

Scientific name	Common names	Distribution	Ecology & fishery importance	References
Metapenaeopsis sinuosa Dall, 1957		from near Linderman Island, QLD, and Van Diemen Gulf, NT	trawled over hard substrates and coarse mud, depths of 12–24 m	
Metapenaeopsis toloensis Hall, 1962		QLD (NE coast), WA (NW coast); Indo-west Pacific Oceans	depth 20–65 m	
Metapenaeopsis velutina (Dana, 1852)		NSW (Central E coast, Lower E coast), QLD (Central E coast, NE coast), WA (Central W coast); Indo-west Pacific Oceans	trawled over sandy substrates, depths of 55–320 m	
Metapenaeus eboracensis Dall, 1957	York Prawn	Darwin, NT to Gulf of Carpentaria, Cape York and south to Townsville, QLD; southern New Guinea	inshore waters in rivers and estuaries out to 30 m, depth 2–27 m	
Parapenaeopsis maxillipedo Alcock, 1905	Torpedo Shrimp (FAO)	NSW (Central E coast), QLD (Central E coast, NE coast); Indo-west Pacific Oceans	trawled over muddy substrates, depths of 9–11 m	
Parapenaeopsis sculptilis (Heller, 1862)	Coral Prawn (Aust.), Rainbow Prawn (Aust.), Rainbow Shrimp (FAO)	northern Australia from NW coast WA to NE coast, QLD; Indo-west Pacific Oceans	trawled over coarse sand to fine mud substrates, most abundant in waters to 16 m, but found to 90 m	9
Parapenaeopsis tenella (Bate, 1888)	Smoothshell Shrimp (FAO)	Darwin, NT, to Princess Charlotte Bay, NE QLD; Indo-west Pacific Oceans	trawled over mud to sandy mud substrates, inshore waters to 35 m	
Parapenaeopsis venusta de Man, 1907	Adonis Shrimp (FAO)	only recorded in Australia from Albany Passage, Cape York; Indonesia, Malaysia	trawled over substrates of sand, shells, stones and mud, depth 11–44 m	
Parapenaeus australiensis Dall, 1957	Australian Rose Shrimp (FAO), Red Prawn (Aust.)	from Cape Howe, NSW to Heron Island, QLD; western Pacific Ocean	over soft mud, depth 124–180 m	
Parapenaeus sextuberculatus Kubo, 1949		NSW (SE oceanic); Indo-west Pacific Oceans	depth 250–350 m	
Penaeopsis eduardoi Pérez Farfante, 1977	Red-flecked Prawn	NSW (SE oceanic), NT (N coast), WA (NW oceanic); east Indo-west Pacific Oceans	depths of 250–570 m, mainly 250–400 m	
Penaeus (*Fenneropenaeus*) *indicus* H. Milne Edwards, 1837	Banana Prawn (Aust.), Indian Prawn (Aust.), Indian White Prawn (FAO), Red Legged Banana Prawn (Aust.)	northern Australia from NW coast, WA to NE coast, QLD; Indo-west Pacific Oceans	trawled over muddy to sandy substrates, adults marine, juveniles estuarine, depth 2–90 m	11
Penaeus (*Marsupenaeus*) *japonicus* Bate, 1888	Japanese King Prawn (Aust.), Kuruma Prawn (FAO)	N coast, NT to NE coast, QLD; Indo-west Pacific Oceans	trawled over sandy mud to sand substrates, inshore waters to 90 m	3

Scientific name	Common names	Distribution	Ecology & fishery importance	References
Penaeus (*Melicertus*) *canaliculatus* (Olivier, 1811)	Striped Prawn, Witch Prawn (FAO)	in Australia recorded only from Torres Strait; Indo-west Pacific Oceans	depth 33–46 m	
Penaeus (*Melicertus*) *marginatus* Randall, 1840	Aloha Prawn (FAO)	QLD (NE coast), WA (NW coast); Indo-west Pacific Oceans	trawled over sand to muddy sand substrates, from inshore waters to 300 m	
Trachypenaeus (*Megokris*) *gonospinifer* Racek & Dall, 1965	Hardback Prawn (Aust.), Northern Rough Shrimp (FAO), Rough Prawn	from Joseph Bonaparte Gulf through the Arafura Sea to the Gulf of Papua, New Guinea	trawled over muddy substrates, depth 13–52 m	
Trachypenaeus (*Trachypenaeus*) *anchoralis* (Bate, 1881)	Hardback Shrimp (FAO), Northern Rough Prawn (Aust.)	from Shark Bay, WA, to Keppel Bay, QLD	trawled over varying bottom types from mud to coral debris, depth to 60 m	
Aristeidae				
Aristaeomorpha foliacea (Risso, 1827)	Giant Red Prawn, Red Prawn, Royal Red Prawn	NSW (SE oceanic), SA (Great Australian Bight), TAS (SE oceanic), WA (NW oceanic, W oceanic); Atlantic, Mediterranean, Indo-west central Pacific Oceans	depths of 61–2000 m, in Australia typically from 250–700 m, on mud to muddy sand	4

Appendix D References:

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Appendix E. List of chondrichthyans recorded from the EMR with distributions and habitat parameters. Main sources: Last & Stevens (1994), CAAB (2007), Rose & SAG (2001).

Distribution, Endemic: Australia only; Cos: cosmopolitan (all oceans), I: Indian, P: Pacific,E: Eastern,W: Western, AU: Australia, NG: New Guinea, NZ: New Zealand; D/P, D: Demersal, P: Pelagic; Area, CSh: Continental Shelf, CSl: Continental Slope, ISh, Insular Shelf, AP: Abyssal Plains, Oc: Oceanic, SM: Sea Mounts, O: Outer, U: Upper; NSW & Qld, P: protected, C: commercial species

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 005001	Hexanchidae	*Heptranchias perlo*	Sharpnose Sevengill Shark	Cos	D	UCSI	100-1000	*	*
37 005005	Hexanchidae	*Hexanchus griseus*	Bluntnose Sixgill Shark	Cos	D,P	CSh,ISh,UCSI	10- >1000	*	*
37 005004	Hexanchidae	*Hexanchus nakamurai*	Bigeye Sixgill Shark	Cos	D	OCSh,UCSI	90-600	*	*
37 005002	Hexanchidae	*Notorynchus cepedianus*	Broadnose Sevengill Shark	Cos	D	CSh	0-136	*	
37 006001	Chlamydoselachidae	*Chlamydoselachus anguineus*	Frill Shark	Cos	D	CSl	500-1200	*	
37 007003	Heterodontidae	*Heterodontus galeatus*	Crested Port Jackson Shark	Endemic	D	CSh	<90	*	*
37 007001	Heterodontidae	*Heterodontus portusjacksoni*	Port Jackson Shark	AU, NZ?	D	CSh	<275	*	
37 008001	Odontaspididae	*Carcharias taurus*	Grey Nurse Shark	Cos	D,P	CSh	0-200	P	P
37 008003	Odontaspididae	*Odontaspis ferox*	Sand Tiger Shark	Cos	D,P	CSh,ISh,UCSl	<420	P	
37 009002	Mitsukurinidae	*Mitsukurina owstoni*	Goblin Shark	Cos	D	CSl	500-1200	*	
37 009003	Pseudocarchariidae	*Pseudocarcharias kamoharai*	Crocodile Shark	Cos	P	Oc	0-590		*
37 010003	Lamnidae	*Carcharodon carcharias*	White Shark	Cos	P	CSh,Ish,CSl,Oc	0-1280	P	P
37 010001	Lamnidae	*Isurus oxyrinchus*	Shortfin Mako	Cos	P	Oc	0-150	C	C
37 010002	Lamnidae	*Isurus paucus*	Longfin Mako	Cos	P	Oc	0-150	C	C
37 012002	Alopiidae	*Alopias superciliosus*	Bigeye Thresher	Cos	P	CSh,Oc	0-500	C	
37 012001	Alopiidae	*Alopias vulpinus*	Thresher Shark	Cos	P	CSh,Oc	0-370	C	
37 013013	Brachaeluridae	*Brachaelurus colcloughi*	Colcloughs Shark	Endemic	D	CSh	<217	*	*
37 013007	Brachaeluridae	*Brachaelurus waddi*	Blind Shark	Endemic	D	CSh	<140	*	*
37 013010	Ginglymostomatidae	*Nebrius ferrugineus*	Tawny Shark	I,P	D	CSh,ISh	70		*
37 013008	Hemiscyllidae	*Chiloscyllium punctatum*	Grey Carpetshark	I,WP	D	CSh	85	*	*
37 013014	Hemiscyllidae	*Hemiscyllium ocellatum*	Epaulette Shark	AU,NG	D	CSh	shallow	*	*
37 013015	Hemiscyllidae	*Hemiscyllium trispeculare*	Speckled Carpetshark	I,P	D	CSh	<100		*
37 013011	Orectolobidae	*Eucrossorhinus dasypogon*	Tassled Wobbegong	I,P	D	CSh	<100		*
37 013020	Orectolobidae	*Orectolobus halei*	Hale's Wobbegong	Endemic	D	CSh	<100	C	*
37 013003	Orectolobidae	*Orectolobus maculatus*	Spotted Wobbegong	Endemic	D	CSh	0-110	C	*
37 013001	Orectolobidae	*Orectolobus ornatus*	Banded Wobbegong	AU,NG	D	CSh	0-117	C	*

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 013017	Orectolobidae	*Orectolobus wardi*	Northern Wobbegong	Endemic	D	CSh	<100		*
37 013002	Parascyllidae	*Parascyllium collare*	Collar Carpetshark	Endemic	D	CSh	20-160	*	*
37 013006	Stegastomatidae	*Stegostoma fasciatum*	Zebra Shark	I,WP	D	CSh,ISh		*	*
37 014001	Rhincodontodae	*Rhincodon typus*	Whale Shark	Cos	P	CSh,Oc			*
37 015021	Scyliorhinidae	*Apristurus longicephalus*	Smoothbelly Catshark	WP	D	CSl	680-900		*
37 015014	Scyliorhinidae	*Apristurus* sp A	Deepwater Catshark	Endemic?	D	CSl		*	
37 015015	Scyliorhinidae	*Apristurus* sp B	Bigfin Catshark	Endemic	D	CSl	730-1000	*	*
37 015016	Scyliorhinidae	*Apristurus* sp C	Deepwater Catshark	WP	D	CSl		*	
37 015018	Scyliorhinidae	*Apristurus* sp E	Deepwater Catshark	Endemic	D	CSl		*	
37 015020	Scyliorhinidae	*Apristurus* sp G	Deepwater catshark	Endemic?	D	UCSl		*	*
37 015027	Scyliorhinidae	*Asymbolus analis*	Grey Spotted Catshark	Endemic	D	CSh	40-79	*	
37 015025	Scyliorhinidae	*Asymbolus pallidus*	Pale Spotted Catshark	Endemic	D	UCSl			*
37 015024	Scyliorhinidae	*Asymbolus rubiginosus*	Orange Spotted Catshark	Endemic	D	CSh	80-290	*	*
37 015001	Scyliorhinidae	*Cephaloscyllium laticeps*	Draughtboard Shark	Endemic	D	CSh	>60	*	
37 015013	Scyliorhinidae	*Cephaloscyllium* sp. A	Whitefin Swell Shark	Endemic	D	UCSl	240-550	*	
37 015030	Scyliorhinidae	*Cephaloscyllium* sp. B	Swell Shark	Endemic	D	UCSl			*
37 015031	Scyliorhinidae	*Cephaloscyllium* sp. C	Swell Shark	Endemic	D	CSh		*	
37 015032	Scyliorhinidae	*Cephaloscyllium* sp. D	Swell Shark	Endemic	D	UCSl			*
37 015033	Scyliorhinidae	*Cephaloscyllium* sp. E	Swell Shark	Endemic	D	CSl			*
37 015009	Scyliorhinidae	*Galeus boardmani*	Sawtail Shark	Endemic	D	OCSh,UCSI	150-640	*	*
37 015034	Scyliorhinidae	*Galeus* sp. B	Sawtail Shark	Endemic	D	UCSl			*
37 015036	Scyliorhinidae	*Parmaturus* sp. A	Short-tail Catshark	Endemic	D	UCSl			*
37 017008	Triakidae	*Galeorhinus galeus*	School Shark	Cos	D	CSh,UCSl	0-550	C	
37 017010	Triakidae	*Hemitriakis abdita*	Darksnout Hound Shark	Endemic?	D	UCSl			*
37 017006	Triakidae	*Hypogaleus hyugaensis*	Pencil Shark	I,WP	D	CSh	40-230	C	C
37 017007	Triakidae	*Iago garricki*	Longnose Hound Shark	W Pacific	D	UCSl			*
37 017001	Triakidae	*Mustelus antarcticus*	Gummy Shark	Endemic	D	CSh	0-80	C	C
37 017004	Triakidae	*Mustelus* sp B	White-spotted Gummy Shark	Endemic	D	OCSh,UCSI			*
37 018027	Carcharinidae	*Carcharhinus albimarginatus*	Silvertip Shark	I,P	P	CSh,ISh	0-800		*
37 018012	Carcharinidae	*Carcharhinus altimus*	Bignose Shark	Cos	D,P	CSh,ISh,UCSl	80-430	C	*
37 018033	Carcharinidae	*Carcharhinus amblyrhynchoides*	Graceful Shark	I,WP	P	CSh,ISh	0->50		C
37 018030	Carcharinidae	*Carcharhinus amblyrhynchos*	Grey Reef Shark	I,P	P	CSh,ISh	0-280		C
37 018026	Carcharinidae	*Carcharhinus amboinensis*	Pigeye Shark	Cos	D,P	CSh,ISh	0-100		C

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 018001	Carcharinidae	*Carcharhinus brachyurus*	Bronze Whaler	Cos	P	CSh	0-100	C	
37 018023	Carcharinidae	*Carcharhinus brevipinna*	Spinner Shark	Cos	P	CSh,ISh	0->75	C	C
37 018034	Carcharinidae	*Carcharhinus cautus*	Nervous Shark	WP	D,P	CSh,ISh	0-100		C
37 018009	Carcharinidae	*Carcharhinus dussumieri*	Whitecheek Shark	I,WP	D	CSh,ISh	-170		C
37 018008	Carcharinidae	*Carcharhinus falciformis*	Silky Shark	Cos	P	CSh,Ish,Oc	0->500	C	C
37 018035	Carcharinidae	*Carcharhinus fitzroyensis*	Creek Whaler	Endemic	D	CSh	0-40		C
37 018040	Carcharinidae	*Carcharhinus galapagensis*	Galapagos Shark	Cos	P	ISh,Oc			*
37 018021	Carcharinidae	*Carcharhinus leucas*	Bull Shark	Cos	D	CSh	0->150	C	C
37 018039	Carcharinidae	*Carcharhinus limbatus*	Common Blacktip Shark	Cos	P	CSh,ISh	0-94	C	C
37 018032	Carcharinidae	*Carcharhinus longimanus*	Oceanic Whitetip Shark	Cos	P	CSh,Oc	0->150	C	C
37 018025	Carcharinidae	*Carcharhinus macloti*	Hardnose Shark	I,WP	P	CSh,ISh	0-170		C
37 018036	Carcharinidae	*Carcharhinus melanopterus*	Blacktip Reef Shark	I,P	D	CSh	shallow		C
37 018003	Carcharinidae	*Carcharhinus obscurus*	Dusky Shark	Cos	D,P	CSh,ISh	0-400	C	C
37 018007	Carcharinidae	*Carcharhinus plumbeus*	Sandbar Shark	Cos	D	CSh,ISh	0-280	C	C
37 018013	Carcharinidae	*Carcharhinus sorrah*	Spot-tail Shark	I,WP	P	CSh,ISh	0->80		C
37 018014	Carcharinidae	*Carcharhinus tilstoni*	Australian Blacktip Shark	Endemic	P	Csh	0-150		C
37 018022	Carcharinidae	*Galeocerdo cuvier*	Tiger Shark	Cos	P	CSh,Oc	0-150	C	C
37 018005	Carcharinidae	*Loxodon macrorhinus*	Sliteye Shark	I,WP	D	CSh,ISh	0-100		C
37 018029	Carcharinidae	*Negaprion acutidens*	Lemon Shark	I,P	D	CSh,Ish	0-30		C
37 018004	Carcharinidae	*Prionace glauca*	Blue Shark	Cos	P	Oc	0-350	C	C
37 018006	Carcharinidae	*Rhizoprionodon acutus*	Milk Shark	Cos	D,P	CSh,ISh	0-200		C
37 018024	Carcharinidae	*Rhizoprionodon taylori*	Australian Sharpnose Shark	AU,NG	D,P	CSh	0->110		C
37 018038	Carcharinidae	*Triaenodon obesus*	Whitetip Reef Shark	I,P	D	CSh	0-300		C
37 018020	Hemigaleidae	*Hemigaleus australiensis*	Weasel Shark	I,WP	D	CSh,ISh	-170	C	C
37 018011	Hemigaleidae	*Hemipristis elongata*	Fossil Shark	I,WP	D	CSh,ISh	-130		C
37 019003	Sphyrnidae	*Eusphyra blochii*	Winghead Shark	I,P	D,P	CSh,Ish	shallow		C
37 019001	Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead	Cos	P	CSh,ISh	0-275	C	C
37 019002	Sphyrnidae	*Sphyrna mokarran*	Great Hammerhead	Cos	P	CSh,Ish,Oc	0->80	C	C
37 019004	Sphyrnidae	*Sphyrna zygaena*	Smooth Hammerhead	Cos	P	CSh,ISh	0->20	C	
37 020023	Centrophoridae	*Centrophorus granulosus*	Gulper Shark	Cos	D	CSl			*
37 020010	Centrophoridae	*Centrophorus harrissoni*	Harrisson's Dogfish	Endemic	D	CSl	220-790	C	*
37 020044	Centrophoridae	*Centrophorus moluccensis*	Endeavour Dogfish	I,WP	D	OCSh,UCSl	125-820	C	*
37 020009	Centrophoridae	*Centrophorus squamosus*	Leafscale Gulper Shark	Cos	D	CSl	230-2400	C	

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 020011	Centrophoridae	*Centrophorus uyato*	Southern Dogfish	Endemic	D	CSl	50-1400	C	
37 020003	Centrophoridae	*Deania calcea*	Brier Shark	Cos	D	CSl	400-900	C	
37 020004	Centrophoridae	*Deania quadrispinosa*	Longsnout Dogfish	Cos	D	CSl	150-820	C	*
37 020002	Dalatiidae	*Dalatias licha*	Black Shark	Cos	D, P	CSl	40-1800	C	*
37 020014	Dalatiidae	*Isistius brasiliensis*	Smalltooth Cookiecutter Shark	Cos	P	CSl		*	*
37 020043	Dalatiidae	*Isistius plutodus*	Largetooth Cookiecutter Shark	Cos	P	CSl			*
37 020017	Dalatiidae	*Squaliolus aliae*	Smalleye Pygmy Shark	I,P	D,P	CSl		*	
37 020024	Etmopteridae	*Centroscyllium kamoharai*	Bareskin Dogfish	I,WP	D	CSl	730-1200	*	
37 020027	Etmopteridae	*Etmopterus bigelowi*	Smooth Lanternshark	Endemic	D	CSl		*	
37 020029	Etmopteridae	*Etmopterus dianthus*	Pink Lanternshark	Endemic	D	CSl			*
37 020031	Etmopteridae	*Etmopterus dislineatus*	Lined Lanternshark	Endemic	D	CSl			*
37 020005	Etmopteridae	*Etmopterus lucifer*	Blackbelly Lantern Shark	Cos	D	CSl	183-1000	*	*
37 020033	Etmopteridae	*Etmopterus molleri*	Moller's Lanternshark	WP	D	UCSl		*	
37 020015	Etmopteridae	*Etmopterus pusillus*	Slender Lantern Shark	Cos	D	CSl	275-1000	*	
37 020022	Etmopteridae	*Etmopterus* sp B	Bristled Lantern Shark	Endemic	D	CSl	750-1380	*	
37 020025	Somniosidae	*Centroscymnus coelolepis*	Portugese Dogfish	Cos	D	CSl,AP	270-3700	C	
37 020019	Somniosidae	*Centroscymnus owstoni*	Owston' Dogfish	Cos	D	UCSl	500-1400	C	
37 020012	Somniosidae	*Centroselachus crepidater*	Golden Dogfish	Cos	D	CSl	270-1300	C	
37 020013	Somniosidae	*Proscymnodon plunketi*	Plunkets Dogfish	AU.NZ	D	CSl	240-1550	C	
37 020042	Somniosidae	*Zameus squamulosus*	Velvet Dogfish	Cos	D,P	CSl,SM	555-2000	*	
37 020026	Squalidae	*Cirrhigaleus barbifer*	Mandarin Shark	I,P	D	UCSl		C	
37 020038	Squalidae	*Squalus albifrons*	[a dogfish]	Endemic	D	OCSh,UCSI		C	*
37 020048	Squalidae	*Squalus chloroculus*	Geeneye Spurdog	Endemic	D	UCSl	180-600	C	
37 020041	Squalidae	*Squalus grahami*	Eastern Longnose Spurdog	Endemic	D	OCSh,UCSI		C	*
37 020006	Squalidae	*Squalus megalops*	Piked Spurdog	Endemic	D	OCSh,UCSl	<510	C	*
37 020047	Squalidae	*Squalus montalbani*		WP	D	UCSl		C	*
37 020037	Squalidae	*Squalus notocaudatus*	Bartail Spurdog	Endemic	D	UCSl			*
37 021001	Oxynotidae	*Oxynotus bruniensis*	Prickly dogfish	AU,NZ	D	UCSl	450-650	*	
37 023001	Pristiophoridae	*Pristiophorus nudipinnis*	Southern Sawshark	Endemic	D	CSh	<70	C	
37 023003	Pristiophoridae	*Pristiophorus* sp A	Eastern Sawshark	Endemic	D	OCSh,UCSl		C	
37 023004	Pristiophoridae	*Pristiophorus* sp B	Northern Sawshark	Endemic	D	UCSl			*
37 024001	Squatinidae	*Squatina australis*	Australian Angel Shark	Endemic	D	CSh	0-130	C	
37 024004	Squatinidae	*Squatina* sp A	Eastern Angel Shark	Endemic	D	OCSh,UCSl	130-315	C	*

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 025004	Pristidae	*Pristis clavata*	Dwarf Sawfish	AU, I?	D	CSh,Rivers			*
37 025001	Pristidae	*Pristis zijsron*	Green Sawfish	I,WP	D	CSh			*
37 026002	Rhynchobatidae	*Rhina ancylostoma*	Shark Ray	I,WP	D	CSh		*	*
37 026001	Rhynchobatidae	*Rhynchobatus australiae*	White-spotted Guitarfish	I,WP	D	CSh		C	C
37 027009	Rhinobatidae	*Aptychotrema rostrata*	Eastern Shovelnose Ray	Endemic	D	CSh	0-50	C	*
37 027010	Rhinobatidae	*Rhinobatos typus*	Giant Shovelnose Ray	I,P	D	CSh	0-100		*
37 027006	Rhinobatidae	*Trygonorrhina* sp A	Eastern Fiddler Ray	Endemic	D	CSh	0-100	C	
37 028001	Hypnidae	*Hypnos monopterygium*	Coffin Ray	Endemic	D	CSh		*	*
37 028008	Narcinidae	*Narcine* sp C	a numbfish	Endemic	D	UCSl			*
37 028002	Narcinidae	*Narcine tasmaniensis*	Tasmanian Numbfish	Endemic	D	OCSh,UCSI		*	
37 028003	Torpedinidae	*Torpedo macneilli*	Short-tail Torpedo Ray	Endemic	D	OCSh,UCSl	90-750	*	*
37 028006	Torpedinidae	*Torpedo* sp A	a torpedo ray	Endemic	D	UCSl		*	*
37 031002	Rajidae	*Dipturus australis*	Sydney Skate	Endemic	D	OCSh,UCSI		*	*
37 031010	Rajidae	*Dipturus gudgeri*	Bight Skate	Endemic	D	UCSl	160-700	*	
37 031042	Rajidae	*Dipturus polyommata*	Argus Skate	Endemic	D	OCSh,UCSI		*	*
37 031005	Rajidae	*Dipturus* sp A	Longnose Skate	Endemic	D	OCSh,UCSl	40-250	*	
37 031028	Rajidae	*Dipturus* sp B	Grey Skate	Endemic	D	UCSl		*	
37 031029	Rajidae	*Dipturus* sp C	Graham's Skate	Endemic	D	UCSl		*	
37 031032	Rajidae	*Dipturus* sp G	Pale Tropical Skate	Endemic	D	CSl			*
37 031033	Rajidae	*Dipturus* sp H	Blacktip Skate	Endemic	D	CSl		*	*
37 031034	Rajidae	*Dipturus* sp I	Weng's Skate	Endemic	D	CSl		*	*
37 031035	Rajidae	*Dipturus* sp J	Deepwater Skate	Endemic	D	CSl		*	
37 031036	Rajidae	*Dipturus* sp K	Queensland Deepwater Skate	Endemic	D	CSl			*
37 031006	Rajidae	*Dipturus whitleyi*	Melbourne Skate	Endemic	D	CSh,UCSl	0-170	*	
37 031021	Rajidae	*Notoraja laxipella*	Eastern Looseskin Skate	Endemic	D	CSl			*
37 031018	Rajidae	*Notoraja* sp A	Blue Skate	Endemic	D	CSl		*	
37 031019	Rajidae	*Notoraja* sp B	Pale Skate	Endemic	D	CSl			*
37 031009	Rajidae	*Pavoraja nitida*	Peacock Skate	Endemic	D	OCSh,UCSI		*	
37 031024	Rajidae	*Pavoraja* sp D	Mosaic Skate	Endemic	D	UCSl			*
37 031025	Rajidae	*Pavoraja* sp E	False Peacock Skate	Endemic	D	UCSl			*
37 031026	Rajidae	*Pavoraja* sp F	Dusky Skate	Endemic	D	UCSl		*	*
37 031040	Rajidae	*Rajella* sp P	Challenger Skate	Endemic	D	CSl	860-1500	*	
37 033002	Anacanthobatidae	*Anacanthobatis* sp B	Legskate	Endemic	D	CSl			*

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 035001	Dasyatididae	*Dasyatis brevicaudata*	Smooth Stingray	I,WP	D	CSh	<100-480	*	*
37 035008	Dasyatididae	*Dasyatis fluviorum*	Estuary Stingray	AU,NG	D	CSh	0-28	*	*
37 035004	Dasyatididae	*Dasyatis kuhlii*	Blue-spotted Maskray	I,WP	D	CSh	0-90	*	*
37 035013	Dasyatididae	*Dasyatis leylandi*	Painted Maskray	AU,NG	D	CSh	<5-75		*
37 035002	Dasyatididae	*Dasyatis thetidis*	Black Stingray	I,WP	D	CSh	0-360	*	
37 035010	Dasyatididae	*Dasyatis violacea*	Pelagic Stingray	Cos	P	Oc		*	*
37 035024	Dasyatididae	*Himantura fai*	Pink Whipray	I?,WP	D	CSh	shallow		*
37 035019	Dasyatididae	*Himantura granulata*	Mangrove Whipray	I,WP	D	CSh	shallow		*
37 035022	Dasyatididae	*Himantura sp A*	Brown Whipray	Endemic	D	CSh	shallow		*
37 035020	Dasyatididae	*Himantura toshi*	Black -spotted Whipray	AU,NG	D	CSh	10-140		*
37 035003	Dasyatididae	*Himantura uarnak*	Reticulate Whipray	I,P	D	CSh	0->45		*
37 035011	Dasyatididae	*Pastinachus sephen*	Cowtail Stingray	I,P	D	CSh,Rivers	0-60	*	*
37 035009	Dasyatididae	*Taeniura lymma*	Bluespotted Fantail Ray	I,WP	D	CSh			*
37 035017	Dasyatididae	*Taeniura meyeni*	Blotched Fantail Ray	I,WP	D	CSh			*
37 035027	Dasyatididae	*Urogymnus asperrimus*	Porcupine Ray	Cos	D	CSh	shallow		*
37 037002	Hexatrygonidae	*Hexatrygon bickelli*	Sixgill Stingray	Endemic	D	CSl	900-1120		*
37 037001	Gymnuridae	*Gymnura australis*	Australian Butterfly Ray	AU,NG	D	CSh	0->50	*	*
37 038023	Urolophidae	*Plesiobatis daviesi*	Giant Stingaree	I,P	D	CSh,UCSl	350-680	*	*
37 038014	Urolophidae	*Trygonoptera* sp B	Eastern Shovelnose Stingaree	Endemic	D	CSh	>120	*	
37 038006	Urolophidae	*Trygonoptera testacea*	Common Stingaree	Endemic	D	CSh	0-60	*	*
37 038001	Urolophidae	*Urolophus bucculentus*	Sandyback Stingaree	Endemic	D	OCSh,UCSI	75-300	C	*
37 038002	Urolophidae	*Urolophus cruciatus*	Banded Stingaree	Endemic	D	OCSh,UCSI		*	
37 038010	Urolophidae	*Urolophus flavomosaicus*	Patchwork Stingaree	Endemic	D	CSh	60-300		*
37 038018	Urolophidae	*Urolophus kapalensis*	Kapala Stingaree	Endemic	D	CSh	10-100	*	
37 038004	Urolophidae	*Urolophus paucimaculatus*	Sparsely-spotted Stingaree	Endemic	D	CSh	0->150	*	
37 038019	Urolophidae	*Urolophus piperatus*	Coral Sea Stingaree	Endemic	D	UCSl			*
37 038005	Urolophidae	*Urolophus sufflavus*	Yellowback Stingaree	Endemic	D	OCSh,UCSI		*	*
37 038007	Urolophidae	*Urolophus viridis*	Greenback Stingaree	Endemic	D	OCSh,UCSI		*	*
37 039003	Myliobatidae	*Aetobatus narinari*	White-spotted Eagle Ray	Cos	D,P	CSh	0-60	*	C
37 039002	Myliobatidae	*Aetomylaeus nichofii*	Banded Eagle Ray	I,WP	D	CSh	0-70		*
37 039001	Myliobatidae	*Myliobatis australis*	Southern Eagle Ray	AU/NZ ?	D	CSh	0-85	C	*
37 039004	Myliobatidae	*Myliobatis hamlyni*	Purple Eagle Ray	Endemic	D	OCSh,UCSI	120-300	*	*
37 040001	Rhinopteridae	*Rhinoptera neglecta*	Australian Cownose Ray	Endemic	D	CSh		*	C

CAAB No.	Family	Species	Common Name	Distribution	D/P	Habitat	Depth (m)	NSW	Qld
37 041004	Mobulidae	*Manta birostris*	Manta Ray	Cos	P	CSh		*	*
37 041001	Mobulidae	*Mobula eregoodootenkee*	Pygmy Devilray	I,WP	P	CSh			*
37 042006	Chimaeridae	*Chimaera* sp B	a shortnose chimaera	Endemic	D	CSl		C	*
37 042007	Chimaeridae	*Chimaera* sp C	a shortnose chimaera	Endemic?	D	CSl		C	
37 042001	Chimaeridae	*Hydrolagus ogilbyi*	Ogilby's Ghostshark	Endemic	D	OCSh,UCSl	120-350	C	*
37 042010	Chimaeridae	*Hydrolagus* sp A	Black Ghostshark	AU,NZ	D	CSl,SM	900-1400	*	
37 042011	Chimaeridae	*Hydrolagus* sp B	a shortnose chimaera	Endemic	D	CSl		*	*
37 044001	Rhinochimaeridae	*Harriotta raleighana*	Bigspine Spookfish	Cos	D	CSl		*	
37 044002	Rhinochimaeridae	*Rhinochimaera pacifica*	Pacific Spookfish	EI,P	D	CSl	760-1290	C	