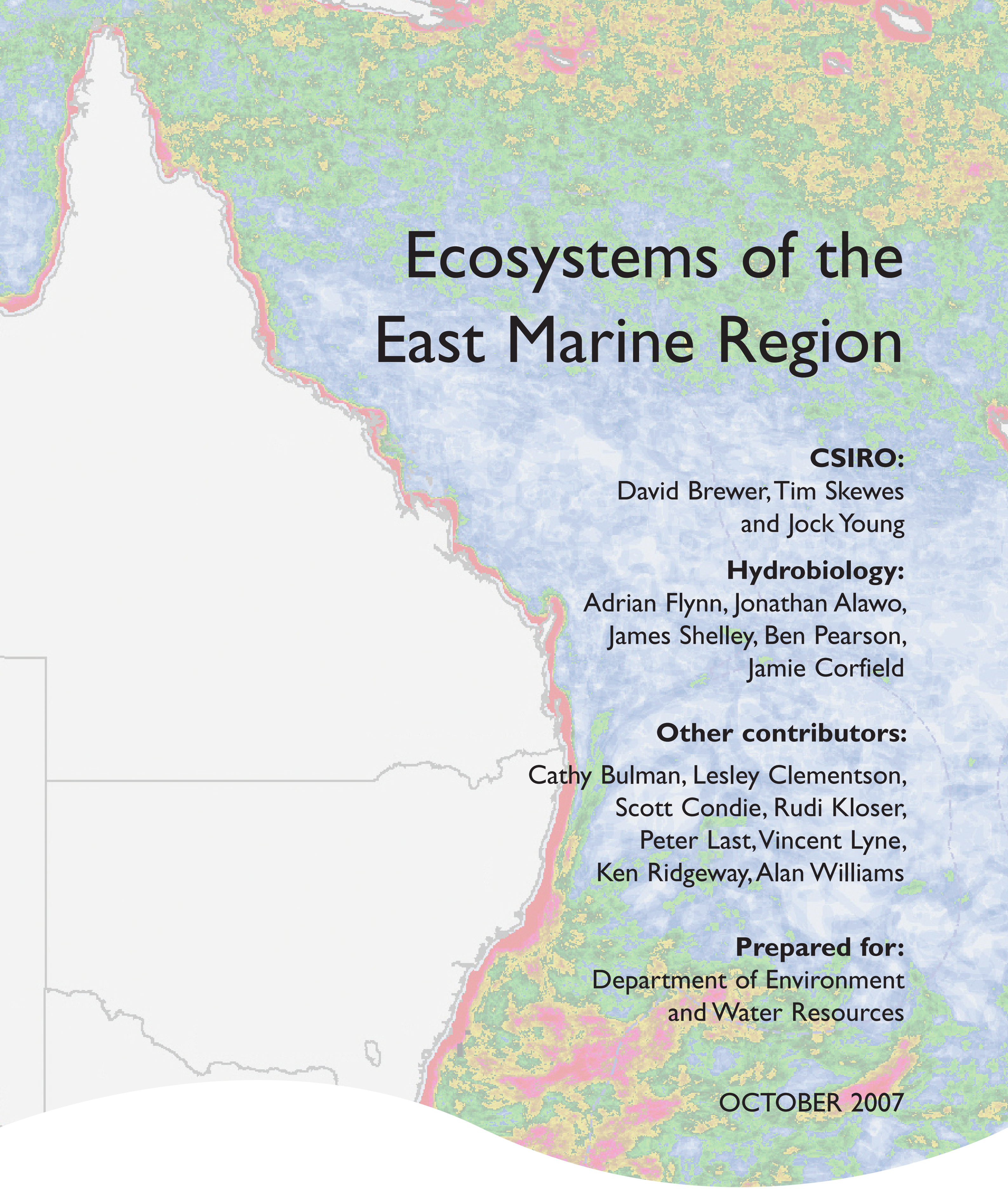

Ecosystems of the East Marine Region

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Prepared for:
Department of Environment and Water Resources

OCTOBER 2007

Australian Government
Department of the Environment and Water Resources

Hydrobiology Pty Ltd
Environmental Services

CSIRO

Published by CSIRO Marine Research

This publication should be cited as:
Brewer, D.T., Flynn, A., Skewes, T.D., Corfield, J., Pearson, B., Alowa, J., and Young, J. W. (2007). Ecosystems of the East Marine Planning Region. Report to Department of Environment and Water Resources. CSIRO, Cleveland. 150 pg.

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1. EXECUTIVE SUMMARY

The Australian Government is in the process of preparing Marine Bioregional Plans for all Commonwealth waters. This report contributes to that process by gathering, reviewing and summarising of the best available information to identify and describe the ecosystems, sub-systems, functional groups and relationships, links across systems and large scale drivers for use in the East Marine Regional Profile.

Researchers at the CSIRO Marine and Atmospheric Research (CMAR) undertook a description of the eco-physical systems of the East Marine Region (EMR) to assist The Department of the Environment and Water Resources (DEW) in developing an understanding of how the EMR ecological systems function. The restricted timeframe negated the option of collecting new data or even new analysis of existing data. Thus, the report was compiled with the intention of providing a broad overview of existing information and limited summaries of exiting data, to provide an integrated understanding of the eco-physical systems of the EMR and its important features. This report, together with a number of other reports commissioned or written by DEW in consultation with various experts and stakeholders, will subsequently be used by DEW to compile the EMR Bioregional Profile.

Our approach to the information compilation was systematic and selective but ultimately constrained by the available information and the time limits of this project. Thus some regions of the EMR are described in greater detail than others. The information gaps have been noted where possible in our descriptions so as to guide future data gathering efforts. The key guiding principle that we developed to aid the information compilation was to focus on providing a “systems” view of the EMR at a range of scales of interest to DEW. We began by developing a conceptual definition of a system and then progressively compiling the information required to implement this definition for the EMR.

The systems approach we developed required defining firstly a broad set of regional systems that were differentiated by large scale oceanographic drivers. Within this regional set of systems, sub-regions were defined based primarily on differences in processes operating on the continental shelf, the continental slope and the deep ocean or abyssal plains (beyond about 4000m depth). Secondarily, subregions were defined within this schema based on differences in other important habitat drivers such as water temperature, current patterns and geomorphology, such that each sun-region has a unique set of habitats, communities and other features. Important ecological features and specific processes associated with those features provides the finest level of description attempted in this project. Using this process, we identified 12 major sub-regions. The derivation of the eco-physical sub-regions was confirmed through the analysis of a wide range of available abiotic physical datasets. Each of the 12 sub-regions is then described in detail, including their eco-physical characteristics and important features.

An important principal arising from this review is that, while water mass differentiation was used to distinguish generally tropical waters from temperate waters, the pelagic environment is a continuous, connected system with no physical boundaries, harbouring organisms that are adapted to a long-ranging, transitory life-history. The open ocean is also layered and while surface waters are laterally connected, there are limitations to vertical mixing and vertical distribution of organisms, due primary to temperature, light, density and other physical depth-dependent factors. While some surface characteristics can extend into deep water, such as higher temperatures under eddy features extending to the seafloor some 1000 m below, the separation of surface waters from bottom waters is reflected in the delineation of the surface water and bottom water ocean masses – for example, the bottom waters of most of the EMR are dominated by the generally north-flowing Sub-Antarctic Water Mass, a relatively uniform body of water. There is some vertical differentiation in the pelagic environment (i.e. pelagic, mesopelagic, bathypelagic zones) with processes such as diurnal vertical migration of zooplankton, coastal upwelling and topographically-induced upwelling providing avenues for mixing through these layers.

The EMR contains a number of regionally significant ecological features and processes that are either unique to the region, characterise the region, or are primary ecological drivers of the region. The most obvious pelagic feature in the EMR is the East Australian Current (EAC), an iconic oceanographic feature that originates in the north of the region and migrates south. This current system, and its associated gyres and eddies, is the primary process whereby warm waters are delivered to southern coastal waters, and therafter eastwards to the outlying Lord Howe and Norfolk islands, and the primary driver of abundance, distribution and dispersal of pelagic and shelf-slope demersal organisms. True coastal upwelling (the delivery of deep-nutrient-rich waters into the euphotic zone), driven by the southerly flow of the EAC, has some level of predictability or periodicity for some locations, particularly off the northern NSW coast and is recognised as an important pelagic feature.

While the EAC operates on a large spatial scale and is a permanent feature, the pelagic environment in the open ocean also responds to transient oceanographic features that operate on a smaller spatial scale such as temporary eddies, gyres and fronts. These ephemeral oceanographic conditions have the effect of ‘concentrating’ phytoplankton and zooplankton (i.e. productivity) which attracts highly mobile and transient consumers such as small fish and squid schools which in-turn attracts highly mobile, transient pelagic predators that range throughout the region. While some aggregations are periodic, or able to be predicted from proxies such as water temperature (e.g. southern bluefin tuna), the drivers of pelagic predator distribution are not well understood for some species which roam through very large areas of the open ocean to locate these areas of high productivity.

The pelagic environment of the EMR also provides habitat for migrating or transient marine mammals, the most notable of which is probably the annual humpback whale migrations between the Southern Ocean and breeding areas off the coast of Queensland. Seabirds are also a significant feature of the pelagic environment in the East Marine Region.

The demersal environment of the EMR contains a diverse array of identifiable features including: Eastern Cape York slope and reefs; the Coral Sea islands and reefs; the Queensland and Marion Plateaux and neighbouring Queensland and Townsville troughs; the Tasmantid and Lord Howe seamount chains; the east Australian shelf and slope; the Lord Howe Rise; and the Norfolk Ridge. These are large-scale geomorphic features interact with water column characteristics, bathymetry and seabed facies to produce a vast variety of demersal communities.

The Queensland and Marion Plateaux support islands and coral reefs that are interesting in that the shallow demersal assemblages display some biogeographical differentiation from the neighbouring Great Barrier Reef (GBR). These plateaux also support ecophysical systems that underlie significant commercial and recreational fisheries.

The extensive seamount systems are iconic features that have been demonstrated to be hotspots of demersal biodiversity, typically in the form of deepwater reefs, dominated by filter-feeders that benefit from topographically-induced upwelling and increased availability of particulate organic matter and other nutrient sources. As a result, seamounts are also known to represent aggregation sites of deep-water fin-fish, including orange roughy.

The eastern shelf and slope are focus areas of demersal fisheries and the southern slope is part of the South East Fishery (SEF), with slope habitats offshore of Ulladulla-Bateman's Bay and Sydney-Newcastle targeted for demersal fin-fish and the deepwater prawn fishery. To the north of Barrenjoey Point (north of Sydney) to Smoky Cape (near Southwest Rocks) the shelf and slope are fished in the NSW ocean trawl fishery that targets finfish and prawns out to 4000 m depth. From Smoky Cape to the NSW/QLD border, the shelf and slope are targeted for deepwater prawns. Slope habitats typically display vertical zonation in sessile benthic community assemblages and demersal fish assemblages. The eastern slope encompasses a large number of canyons (although not in the density of those in the Southeast Marine Region) which, in other regions, are reported to represent areas of high biodiversity and areas of topographically-induced upwelling.

The ecology of the demersal environments of Lord Howe and Norfolk regions have not been studied in detail but research to date has identified some peculiarities. Shallow-water demersal communities at Lord Howe Island, for example, includes a mix of species that would be expected from these latitudes as well as sub-tropical species. This phenomenon that may be related to the easterly migration of warm eddies from sub-tropical waters into the area. Norfolk Island is quite distinct within the EMR in that its demersal assemblages have more affinities with New Caledonia than with eastern Australia.

The resilience and vulnerability of eco-physical systems in the EMR varies between different sub-regions and more locally between different ecological communities, although many of the potential impacts are not well understood. Climate change may be the most significant threat to this region with its potential to displace species distributions southward, bleach shallow water corals, alter key ocean current patterns, and therefore alter community structure and key food web species abundances. Deeper water communities may be less vulnerable to this change although there are some potential impacts even at great depths, due to changes in water chemistry and global current patterns. Fishing also has the potential to impact species community composition, including potentially important regulatory species such as the large pelagics and sea cucumbers (beche-de-mer), and cause mortality of highly vulnerable or listed species such as albatross, sea turtles and elasmobranchs. Other threats to the long-term survival of communities in this region include oil and gas drilling activities and waste disposal and the introduction of exotic pest species.

During this process we have identified a number of information gaps in the understanding of biological and ecological processes in this region. For example, the remote areas of the Cape Province, Lord Howe Island and Norfolk Island are clearly under-represented in the research literature. The Coral Sea Islands have received some research attention but are also generally under-studied. Seamounts in the East Marine Region are generally less well-studied than those in southern areas and research has been focussed on a small number of seamounts that are of fisheries interest. The literature also tends to be focussed towards charismatic species or species of fisheries/by-catch significance, and some of the information gaps are surprising given the East Region's proximity to Australia's eastern seaboard population centres.

Five broad areas have been identified that are poorly understood and have high relevance to broad-scale scale conservation planning in the region — deepwater faunal assemblages; endemism; dispersal and connectivity; regionally iconic areas; and trophic webs and life-cycles of important species. The details of the information gaps for each of these are described in the body of the report.

Acknowledgements

Despite the limitations of the project, we have thoroughly enjoyed the scientific challenge presented to us by DEW. We also acknowledge the wealth of information compiled by researchers who have worked in this region. While we are unable to fully acknowledge and include the work of these researchers, this project should be viewed as the beginning of a coherent attempt at gaining an integrated understanding of the EMR. We apologise in advance to those whose work we may have overlooked but trust that they will have the opportunity to provide substantive input in the EMR planning efforts.

We also thank those who helped produce the report including Donna Bugden and Toni Cannard (project support, report compilation and formatting) and Louise Bell (front cover).

The case study on 'Trophic interactions in oceanic waters off eastern Australia' was an extract from an FRDC project report Number 2004/063.

2. GLOSSARY OF TERMS

Advection Transport in a fluid from one region to another, can be vertically or horizontally.

Basin A geological feature where a large part of the earth is covered by seawater, often where the edges of the feature are shallower then the central portion.

Biodiversity In an oceans context, the variety of living organisms in the estuaries and oceans, their genes, and the ecosystems of which they form a part (National Strategy for the Conservation of Australia's Biological Diversity, 1996)

Bioregion An area defined by a combination of biological, social and geographic criteria, rather than by geopolitical considerations. Generally, a system of related, interconnected ecosystems (Commonwealth of Australia 1996).

Bioregionalisation A process of identifying and mapping broad ecological patterns based on physical and/or biological attributes for planning and management purposes.

Community A group of organisms, both animals and plants, living together in an ecologically related fashion in a defined area or habitat.

Driver A feature or process that promotes or controls the onset and onward course of an action.

Drogues Devices used to assess ocean current movement patterns by passively floating at a specific depth

Ecosystem A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (UNEP Convention on Biological Diversity, June 1992)

EEZ The Exclusive Economic Zone. The area between the lines 12 nautical miles and 200 nautical miles seaward of the territorial sea baselines. In this area, Australia has the right to explore and exploit living and non-living resources, and the concomitant obligation to protect and conserve the marine environment.

Eurythermal Capable of withstanding a wide range of temperature.

Functional group Groups of organisms that occupy a similar position in a trophic system or food web.

Gyre	Circulation or rotation of ocean water usually dictated by prevailing winds and the Coriolis effect
Habitat	The place or type of site where an organism or population naturally occurs (UNEP 1994).
IMCRA	Interim Marine Coastal Regionalisation for Australia. An ecosystem-based classification for marine and coastal environments. It provides ecologically based regionalisations at the meso-scale (100–1000 km) and at a provincial scale (greater than 1000 km).
MPA	Marine Protected Area. An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN 1994).
Nutricline	A sharp variation in the content of nutrients in the sea, according to depth.
Oligotrophic	Waters that are relatively low in nutrients and cannot support much plant life, such as the open oceans and some lakes.
State waters	Australia's Offshore Constitutional Settlement established Commonwealth, State and Territory jurisdictions over marine areas. States generally have primary jurisdiction over marine areas to 3 nautical miles from the baseline.
Trophic systems	Is the interconnected web that describes the various positions which organisms that live within an area occupies in a food chain (what it eats and what eats it).
Trough	An elongated geological feature where a large part of the earth is covered by seawater, often where the edges of the feature are shallower then the central portion.
Upwelling	An oceanographic phenomenon that involves the movement of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water.

3. INTRODUCTION

The Australian Government is in the process of preparing Marine Bioregional Plans (MBP) for Commonwealth waters. This is being done separately for the South East, South West, North, North West and Eastern Marine Regions. This firstly requires the gathering, reviewing and summarising of the best available information on important habitats, species, natural processes, heritage values, human uses and benefits into a Regional Profile for use in the MBP process.

The East Marine Region (EMR) covers more than 2.4 million square kilometres of water under Commonwealth jurisdiction from Bermagui in the south (150° 7' E, 36° 30' S) to the northern extent of the Great Barrier Reef (144° 28' E, 9° 39' S) from the limit of state waters (3 nm from the coastal baseline), but not including the Great Barrier Reef Marine Park, to the limit of Australia's EEZ, 1,000 km offshore at its widest extent. It also includes the EEZ territory surrounding Norfolk Island.

This report, jointly produced by the CSIRO and Hydrobiology, will contribute to the formulation of the Regional Profile of the East Marine Region by attempting to characterise the ecological systems of the EMR. This includes identifying ecosystems, sub-systems, functional groups and relationships, links across systems and large scale drivers.

4. OBJECTIVES

The objectives of this project are broadly described as follows:

- Identify and describe the location of major eco-physical systems within the region;
- Identify and map, where possible, ecological or physical sub-systems, where known, and describe what physical strata define them;
- Characterise each ecological system focussing on functional and trophic groups and relationships by identifying and describing biological components of the systems, links among them, major inputs to the system and important physical and biological drivers within the system. Comment on the vulnerability of components of the system. Illustrate the functioning of a number of case studies using conceptual diagrams and narrative text.
- Identify and describe regional scale interactions and processes, including connectivity amongst sub-systems, productivity, ecological roles of particular areas, and large scale patterns in biodiversity; and
- Identify any information gaps, areas for further investigation and known projects in the Region that may assist in later stages of developing the East Marine Bioregional Plan.

5. APPROACH TO DESCRIBING ECO-PHYSICAL SYSTEMS

5.1 Method, justification and context

Describing eco-physical systems for a region as large as the East Marine Region (EMR) is potentially a very large and difficult task. Defining the boundaries of individual systems is complex. However, to provide an adequate, but useful level of information on this region for the purpose of the bioregional profile, we restricted the description to a relatively small number (12) of eco-physical systems. These were created and agreed on through the workshops and discussions, using a combination of the main physical drivers and known ecological community boundaries (see Section 5, below). We also used maps of the region and conceptual models (see 4.2, below) to help describe each system.

Note that, due to the paucity of data in some instances for the East Marine Region, relevant information from other parts of the Pacific Ocean are used in this report to build an understand of the likely ecological processes at play.

Defining the eco-physical systems (referred to as sub-regions later in this report) was done using a hierarchical process beginning with the major physical drivers that form the foundations of habitats and determine the biogeochemical characteristics of the region. These include the major water masses, currents, depth, geomorphology and coastal influences. The physical derivation of the eco-physical systems was confirmed through the analysis of a wide range of available abiotic physical datasets. Differences in species community types are less well documented and were used as a secondary determinant of the system boundaries. In characterising the eco-physical systems in the EMR we used a combination of known scientific information and expert opinion. Much of the scientific information exists in either scientific papers or reports. The expert opinion was gathered during workshops held with scientists from CSIRO (Hobart – 8th May), and through emails and phone calls to individual experts.

The spatial boundaries for the eco-physical systems were informed by the range and differences in the summary statistics for various physical drivers and ecological data. However, they are by their nature, approximate boundaries and should not be seen as hard and fast system boundaries.

The eco-physical systems defined in this study are described using maps, conceptual models, diagrams and a written narrative. The ecological descriptions presented here are designed to give a relatively succinct, but accurate depiction of the eco-physical systems in the EMR. The conceptual models, case studies and examples used in the narrative have focussed on the species and species groups (e.g. trophic functional groups) that play a significant ecological role in the system being described. More comprehensive species lists may be available for some regions and can be obtained by way of the literature cited in the document.

Following on from this approach, we developed a generic conceptual representation of how the regions systems (hereafter referred to as “systems”), the eco-physical systems (hereafter referred to “sub-regions”) and their important features, all relate to each other. A model of this concept is illustrated in Figure 5-1.

- At the broadest level, the EMR is one of a number of regional systems responding to regional oceanographic, climatic, geophysical and biological drivers, and it is characterised at the regional level by environments that are quite different to its neighbouring systems. As a regional system, the EMR may provide services to the community, conservation, various industries and other uses, including services to neighbouring systems.

- Within the system, there is a collection of sub-regions which also respond to a set of local drivers and in turn interact with other sub-regions. Sub-regions may be responsible for elements of services provided by the regional system and they may also preferentially, or otherwise, use the services provided by neighbour systems. At the sub-region level, drivers and services are internalised in the sense that these exchanges occur between the sub-regions and the environment surrounding them within the system. Thus each sub-region has a local set of drivers and services including exchanges with neighbouring sub-regions. Within each sub-region there is a collection of trophic elements (denoted by “T”) which may comprise functional groups or biota that are of importance to the functioning of the sub-region and/or to the services it provides. The trophic elements interact with a set of habitats (denoted by “H”).

- Part of the exchange, or linkage, between sub-regions may be from a dependence of a set of trophic elements on habitats in more than one sub-region (denoted for example by the red dashed line that crosses sub-regions 1 and 2). Features within sub-regions may comprise important trophic elements (denoted by “t” within the larger “T” trophic groups), which in turn are associated with one or more important sub-habitats (denoted by “s” within “H”) that are part of the sub-region suite of habitats.

- The issue of linkage between habitats and trophic elements is highlighted as dashed lines which show the types of interactions that are possible. An important aim of the sub-region descriptions is to identify and characterise these linkages.

The generic model developed in above was implemented in the EMR by identifying the broad regional differences in oceanographic forcing that would affect the eco-physical systems. Key considerations we took into account included an assessment of drivers of the EMR (e.g. oceanography, sediments, geomorphology, productivity/nutrients, climate, habitats, species composition, terrestrial inputs) and how these might result in differences in broad ecological systems across the region.

5.2 Conceptual eco-physical system models

Conceptual eco-physical system models have been used to help describe the eco-physical systems within this marine region. These show a range of characteristics, including:

- the main environments and habitats in each system;

- the main physical drivers are impinging on each system;

- the main species functional groups within each system;

- examples of the species from each functional group;
- the main services exported from and imported into each system; and
- an indication of the level of certainty we have in each of the components

The conceptual models are designed to display the main functional groups in each system and their links, providing a snapshot of the trophic dynamics within the system (see trophic model template - Figure 5-2). Most of the regions eco-physical systems are more complex than shown here due to the diverse nature of marine shelf and adjacent environments (and habitats) at this scale. We overcome this in part by embedding the main functional groups for key habitats within the larger systems, and any extra complexity is described in the narrative only. This helps to keep the models both informative but simple enough to be easily interpreted.

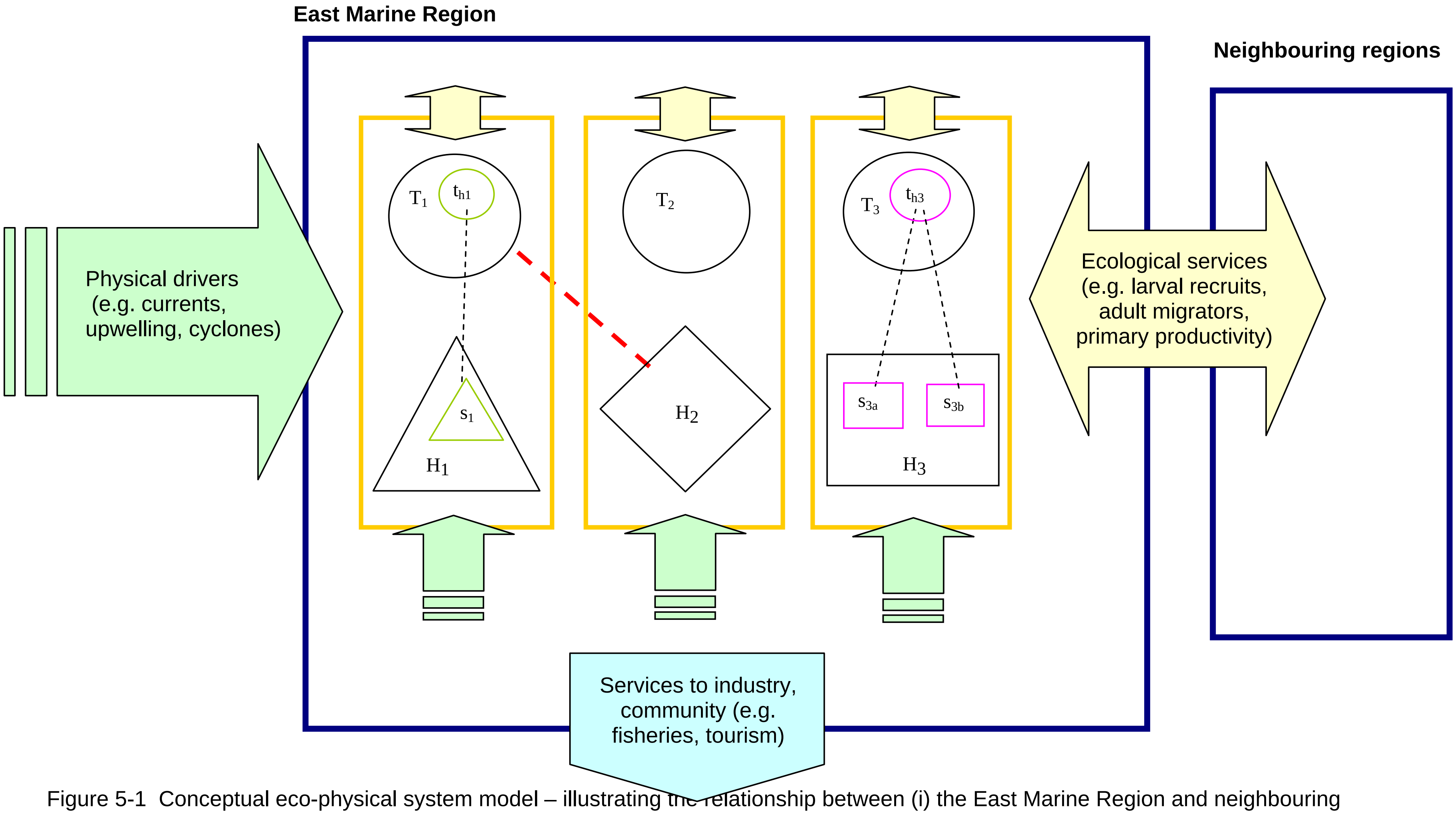


Figure 5-1 Conceptual eco-physical system model – illustrating the relationship between (i) the East Marine Region and neighbouring regions and (ii) three sub-regions, each comprising a major habitat type (H) and associated trophic system (T). Key sub-habitats (s) and their associated eco-physical systems (t) are also shown. The influence of physical drivers and flow of ecological services is also shown at the regional and sub-regional level.

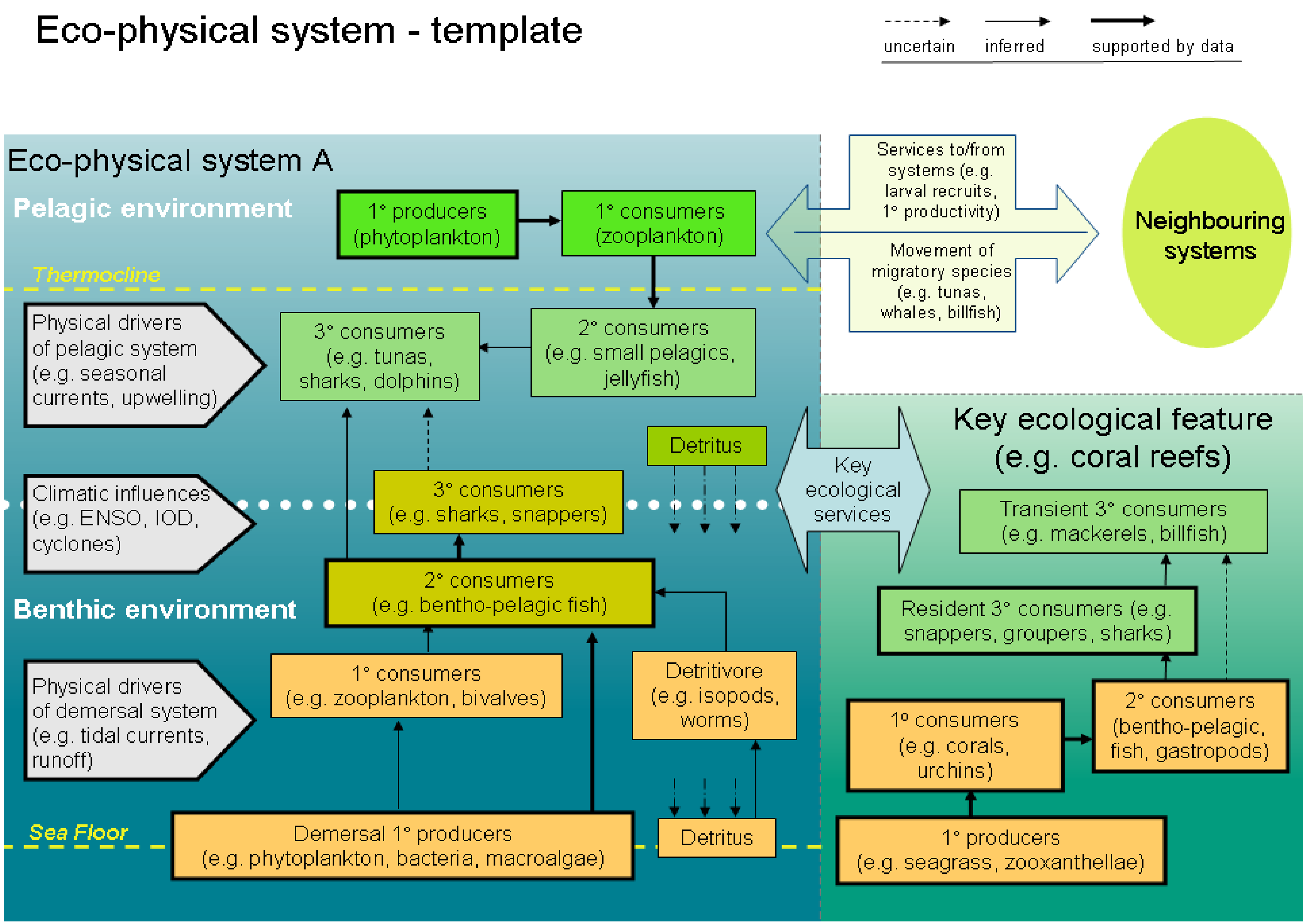


Figure 5-2 Template for conceptual models of the eco-physical systems in the East Marine Region, showing the main functional species groups, different environments, a key ecological feature of the sub-region, physical drivers and influences and biological linkages and services between systems.

6. DESCRIPTION OF THE REGION AND IT'S MAJOR ECOLOGICAL SUB-SYSTEMS

6.1 General description of East Marine Region

6.1.1 Oceanographic currents

The western flow of the South Equatorial Current (SEC) brings subsurface currents through the Coral Sea to the northeastern coast of Australia (Lyne and Hayes, 2005) (Figure 6-1). As they progress through the various reef complexes and islands in the south-west Pacific region, the westerly flow of the SEC arrives at Australian continental shelf as a series of 'jets' in the region of approximately 15 to 19°S depending on the season (an area spanning approximately between Cairns and Townsville) (K. Ridgway, *pers. comm.*). The surface waters of the tropical South Equatorial Current are generally oligotrophic and warm (surface temperatures averaging around 27 °C) (Hayes *et al.*, 2004).

At a latitude of approximately 17-19°S, the South Equatorial Current hits the continental shelf and bifurcates. This bifurcation creates the north-flowing Hiri Current which continues north to create the Gulf of Papua Gyre (Figure 6-1). The southern part of the bifurcation creates the East Australian Current (EAC) which is a principal physical driver of the entire East Region. Generally, deeper layers of the SEC arrive on the continental shelf and bifurcate further to the south, at approximately 22°S (an area approximating Shoalwater Bay in central QLD).

South of the SEC bifurcation point, the EAC becomes the most prominent oceanographic feature of the region and its southerly flow interacts with various topographic features to form various gyres and eddies. The warm waters of the EAC are the primary avenue by which species of ecological, recreational and commercial significance migrate into southern waters. Tuna fisheries in mid- to southern-New South Wales, for example, are centred on predictable water temperature and current features that contribute to aggregating tuna schools off the NSW coast.

The EAC follows the coast to its southern boundary (32° -34°S) where the main component separates eastwards traversing the Tasman Sea (Figure 6-1). This behaviour has been attributed to coastline curvature (Denham & Cook, 1976). Poleward of this separation point, a portion of the current remains connected to the coast and continues southward past the east coast of Tasmania (Ridgway and Dunn, 2003).

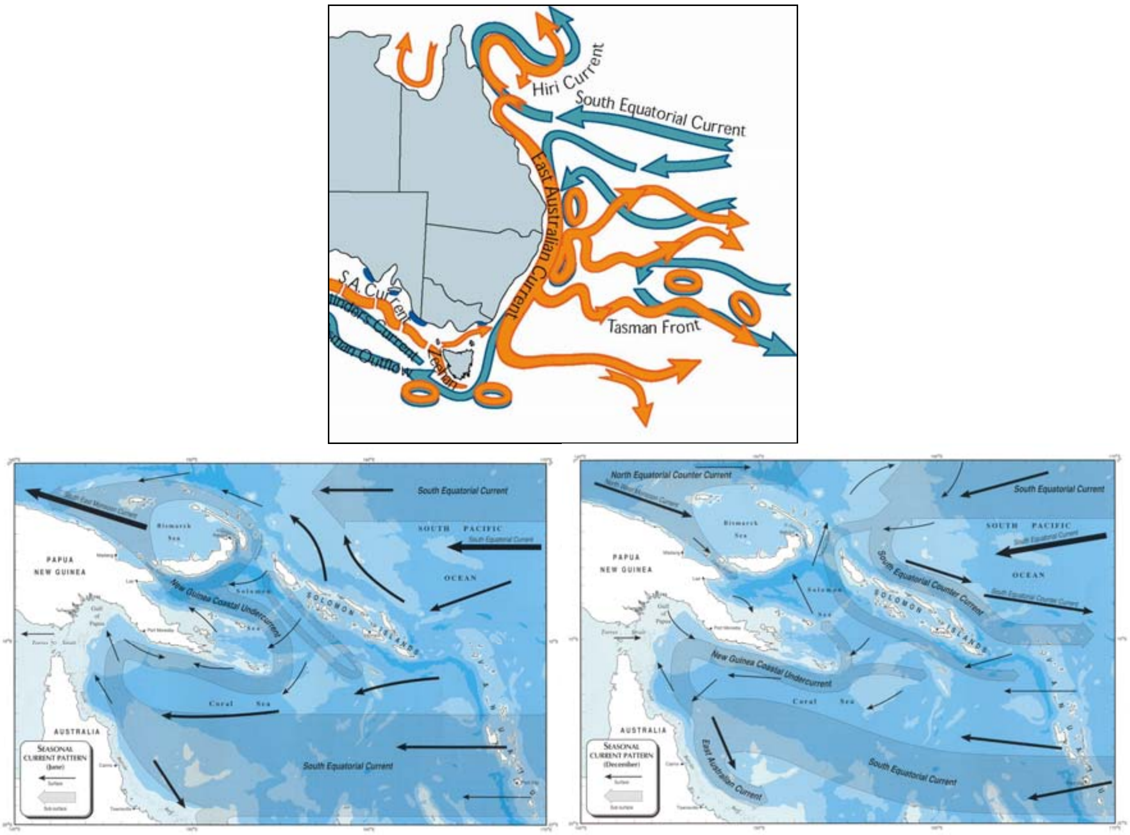


Figure 6-1 Schematic diagram of main eastern Australian currents, showing (a) the major current patterns (modified from Lyne and Hayes 2005), and seasonal differences in the South Equatorial Current between (b) June and (c) December (after Williams 2007).

After it leaves the coast, the eastward flow of the EAC occurs as a series of jets, each following different paths across the Tasman Sea, between 22° and 40°S (Figure 6-2). The main component of the eastward flow, known as the Tasman Front, occurs between 33°and 35°S (current B in Figure 6-2) and passes through the south of the New Caledonia Basin, while a relatively smaller jet, called the North Tasman flow (current C in Figure 6-2), passes through the north (Ridgway and Dunn, 2003). Once it has passed over the Lord Howe Rise, the Tasman Front flow enters the deep waters of the New Caledonia Basin and proceeds unchecked until it impinges on the irregular topography of the Norfolk Ridge.

The path of the EAC between Australia and New Zealand separates the cooler waters of the Tasman Sea and the warmer, more saline waters of the Coral Sea. Frontal features such as this may dictate the distribution of predator and prey species. Norse and Crowder (2005) describe three possible reasons for this effect on faunal distribution, (1) steep temperature or water clarity gradients are barriers to movement, (2) convergence flow at fronts aggregates buoyant or weakly swimming prey, or (3) temperature gradients allow epipelagic species to feed in food-rich cooler waters and then accelerate digestion and growth in warmer waters.

The Tasman Front is characterised by strong thermal gradients that produce significant velocities at the frontal zone between the subtropical waters of the Coral Sea and the temperate waters of the Tasman Sea. In general, the temperature changes across the front from 19°C in the Coral Sea waters to 17°C in the Tasman Sea waters over a distance of approximately 10 km. Mixing processes at the interface between the two water masses results in a zone of convergence that acts to maintain the distinct frontal character of the Tasman Front. Surface fronts such as the Tasman Front engender significant patterns in the habitat of marine organisms (Bakun, 2006). The concentration of food particles and weakly-swimming zooplankton leads to multi-trophic-level blooming of productivity, ultimately attracting larger nektonic predators such as squid, fish (e.g. redfish, *Centroberyx affinis*), sharks (*Galeorhinus galeus*) and killer whales. Convergence zones such as the Tasman Front are often visible as surface drift lines which may contain detached seaweeds, logs, and flotsam collect, providing hard substrates for the attachment of invertebrates and attracting small fishes and other animals such as turtles, followed by larger predators such as dolphinfish (*Coryphaena hippurus*), tunas and sharks.

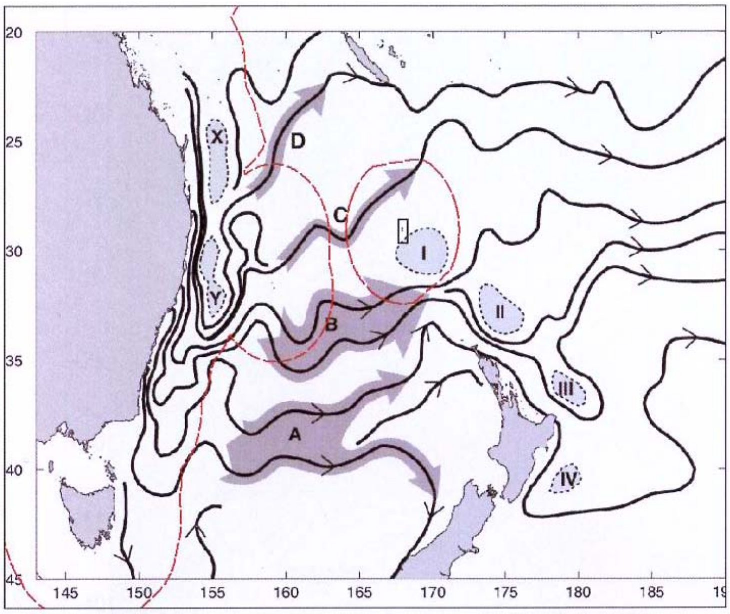


Figure 6-2 Schematic summary of the individual surface currents within the Tasman Sea. A, B, C and D represent four components of the separating EAC. B = Tasman Front, C = North Tasman Flow. I – IV represent four quasi-permanent eddies surrounding New Zealand including I, Norfolk Eddy and IV East Cape Eddy. X and Y are two anticyclonic recirculation cells associated with the EAC flow within the Tasman Abyssal basin (Ridgway and Dunn, 2003). Overlaid with the Australian EEZ (Australian Maritime Boundaries Information System, AMBIS) and the Norfolk Inshore Fishery Box (Australian Fisheries Management Association, AFMA).

Frontal features may be semi-permanent, seasonally predictable, or unpredictably episodic. Even those that are permanent can, in some instances in other ocean basins, move hundreds of kilometers throughout the year or on an annual basis (Hyrenbach *et al.*, 2000). Large oceanic species, including blue whales (*Balaenoptera musculus*), leatherback and loggerhead sea turtles, albacore tuna (*Thunnus alalunga*), bluefin tunas, and mako sharks (*Isurus spp.*), have been known to divide their lives between feeding in such areas with elevated chlorophyll concentrations (Block *et al.*, 2002; Hyrenbach *et al.*, 2002; Polovina *et al.*, 2000) and moving quickly across expanses of oligotrophic (food-poor) waters. Food-rich patches are often transitory, disappearing when frontal discontinuities break down or through prey reduction by predators. Many large oceanic species spawn, nest, or calve only in certain places, perhaps where they can optimize the balance between food availability and predation risk for their young. To reach breeding areas they journey hundreds or even thousands of kilometres, seamounts are therefore ideal 'stepping stones' within the barren open ocean (Gad and Schminke, 2002).

Eddies

While the EAC remains relatively stable along the east coast, sea level data (Figure 6-3) and thermal data (Figure 6-4) suggest that the current in its southern parts is at times dominated by a series of eddies (Ridgway and Dunn, 2003). One relatively predictable eddy system occurs in the open ocean offshore of Fraser Island in southern QLD, a feature that may be related to the interaction of the EAC with seamounts (Figure 6-5).

The EAC generally spawns warm-core anticyclonic eddies (Lyne and Hayes, 2005) which feature this convergent flow pattern in the surface layer within the interior of the eddy. As these eddies approach the slope region nutrient upwelling occurs and these nutrient inputs are then concentrated within the eddy cores creating chlorophyll hotspots (Bakun, 2006). Initial enrichment is directly followed by convergence and concentration of the products of that enrichment, which are then retained within the eddy along with any fish larvae that may have been spawned within the eddy by opportunistically feeding nektonic adults (Bakun, 2006). These eddy motions are therefore able to produce peaks in biological productivity and reproductive success.

Various fauna are dependent on seasonal mixing and the interaction of the eddy with the slope and shelf. Pelagic tunicates and coelenterates are drawn to these blooms which are themselves prey for a wide array of species including albatrosses and crustaceans , as well as fish such as the blue grenadier, blue warehou and banded whiptail (Prince, 2001). Previous studies have shown that southern bluefin tuna migration is timed to coincide with the autumn blooms of phytoplankton along the shelf and upper slope (Young et al., 1997). The tuna principally feed on jack mackerak, pilchard Sardinops neopilchardus and juvenile squid Nototodarus gouldi, which feed within the blooms. Through the winter months, as the blooms decline and prey fish disperse, southern bluefin tuna move offshore to prey on alternative prey species such as gelatinous zooplankton and squid.

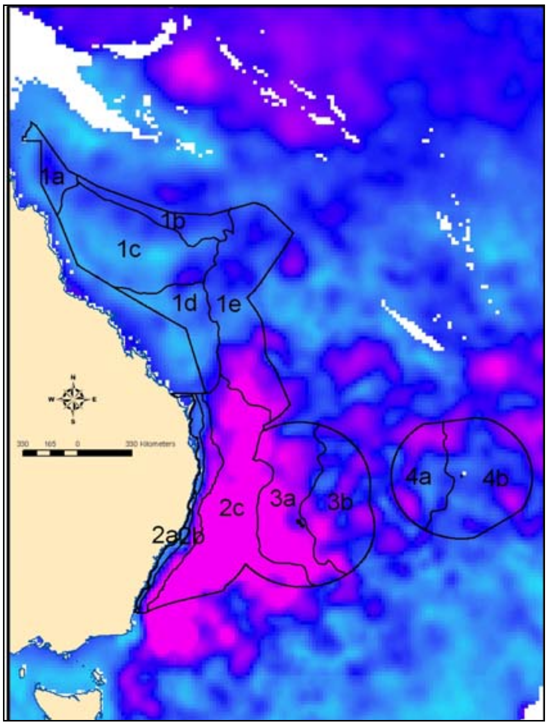
The separation of the EAC from the coastline leads to the formation of an eddy field that is an iconic and ecologically significant feature of the offshore East Marine Region. Two large stationary eddies occur close to the coast known as eddy J (34°S) and eddy K (32°S) (Figure 6-5). The EAC's eastern divergence is related to the north most eddy K. These larger eddies are semi-permanent features that migrate eastwards and have the effect of trapping and transporting plankton and creating transient fronts and conditions that can then attract pelagic predators. The extent of the southerly intrusion of the EAC and thus the latitude spanned by the eddy field is dependent on season, with the EAC extending further south in summer than winter. On the eastern side of the eddy, part of its flow branches off and moves eastward in a series of meanders that forms the Tasman Front.

During their lifespan, the eddies have strong marginal currents of 2 - 4 knots with central isothermal layers up to 300 m deep, termed 'warm-cores'. While, EAC eddies may remain as independent bodies of water (Lyne and Hayes, 2005), a variety of hydrodynamic behaviour patterns have also been observed including the reabsorption of eddies into the EAC, overlying and coalescing of eddies, escape paths to the south leading to loss of energy and eventual decay.

EAC eddies have been studied since 1976 with respect to their physical dynamics and biological properties (Jeffrey and Hallegraeff, 1987). Both the tropical origin of the EAC warm-core eddies, which in winter are approximately 2°C warmer than the surrounding seas, and their existence as separate or partially separate bodies contribute to the unique biological characteristics of each eddy (Jeffrey and Hallegraeff, 1987), specifically the relatively high biomass of plankton and micronekton.

At a structural level, eddy features have been identified as having an influence on biological distributions due to the relative distributions of trapped nutrients, notably, upwelling-downwelling at the eddy core leads to nitrate enrichment and high phytoplankton concentrations. Temperate differentials associated with the EAC eddies have been observed to extend from the surface down to approximately 4000 m water depth, making contact with the seafloor, although the differential at these depths is very small (Ridgeway, pers. comm.).

Associated with the vertical motions in the eddy core are patterns of divergence and convergence, in the horizontal flow field (Figure 6-6), which can concentrate nutrients and planktonic organisms, similar to frontal convergences (Bakun, 2006). Therefore, the eddies, by their nature are an important food source for tertiary consumers such as tuna and swordfish which aggregate around them (Young *et al.*, 2001; Young *et al.*, 2003; Landsell and Young, 2007).



Note: variation from low (light blue - 0.02 m) to high (pink – 0.4 m).
Source: National Bioregionalisationof Australia. GIS DVD, Geoscience 2005

Figure 6-3 Annual sea surface height variance

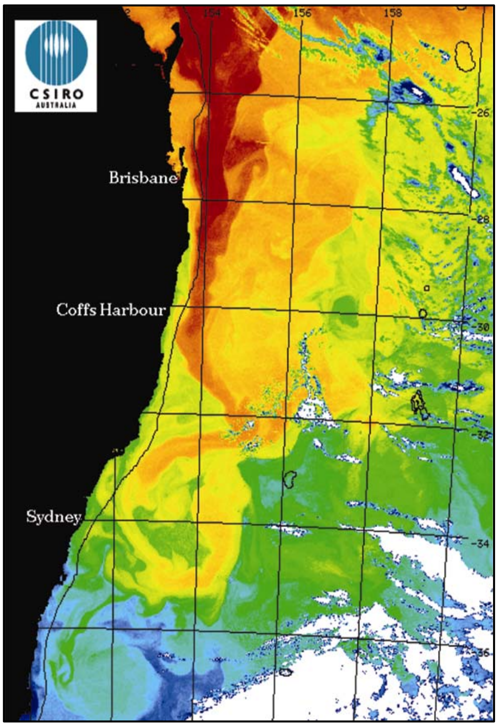
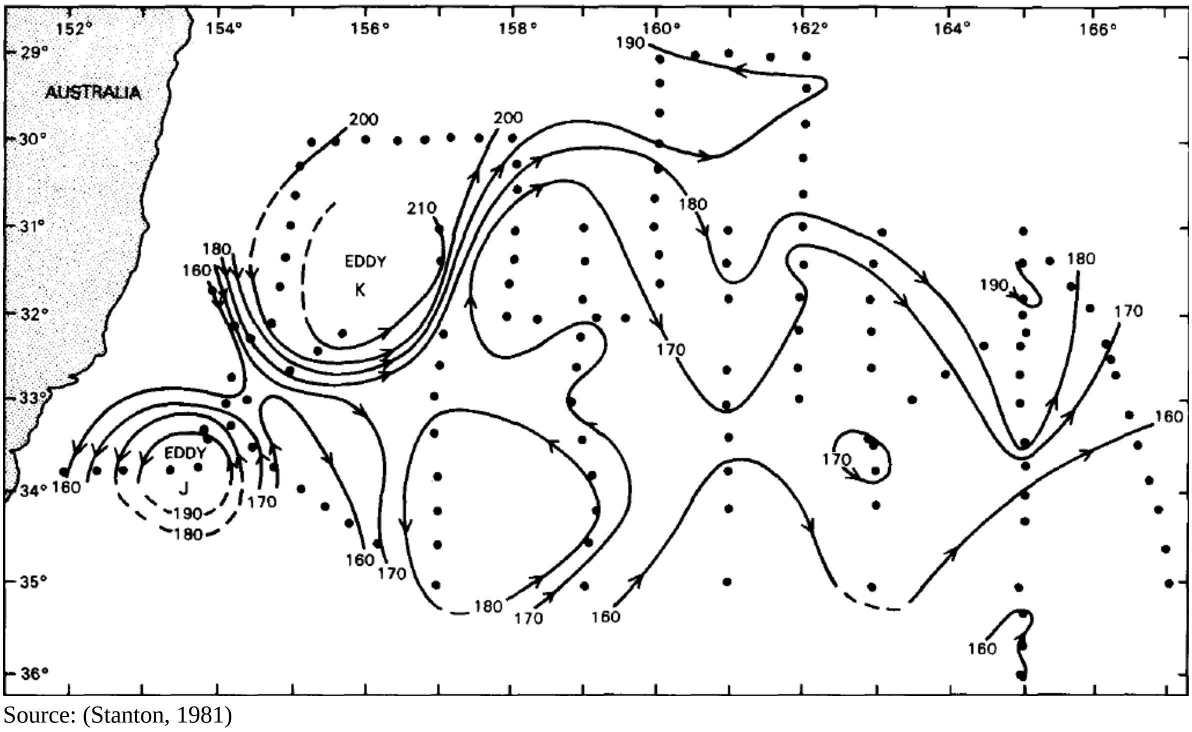


Figure 6-4 Sea-surface temperature image of the EAC



Source: (Stanton, 1981)

Figure 6-5 Surface currents at the East Australian Current/Tasman Front divergence

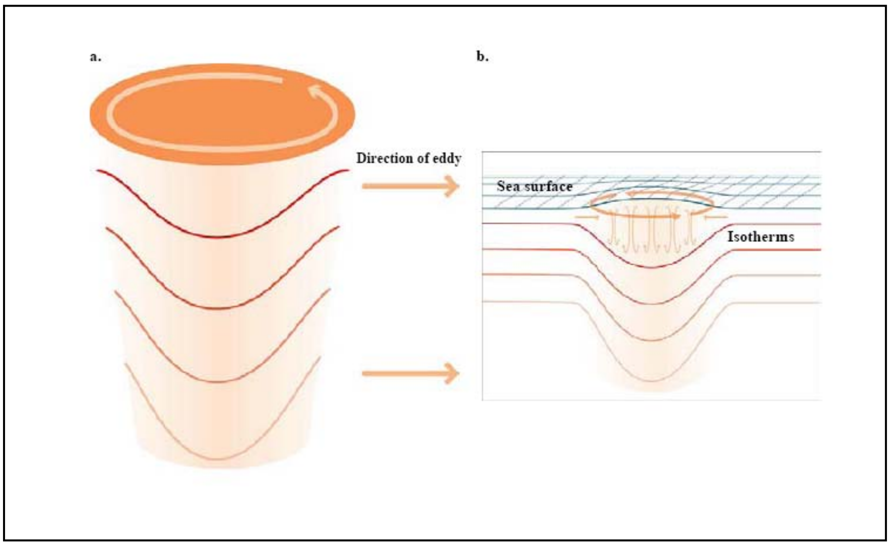
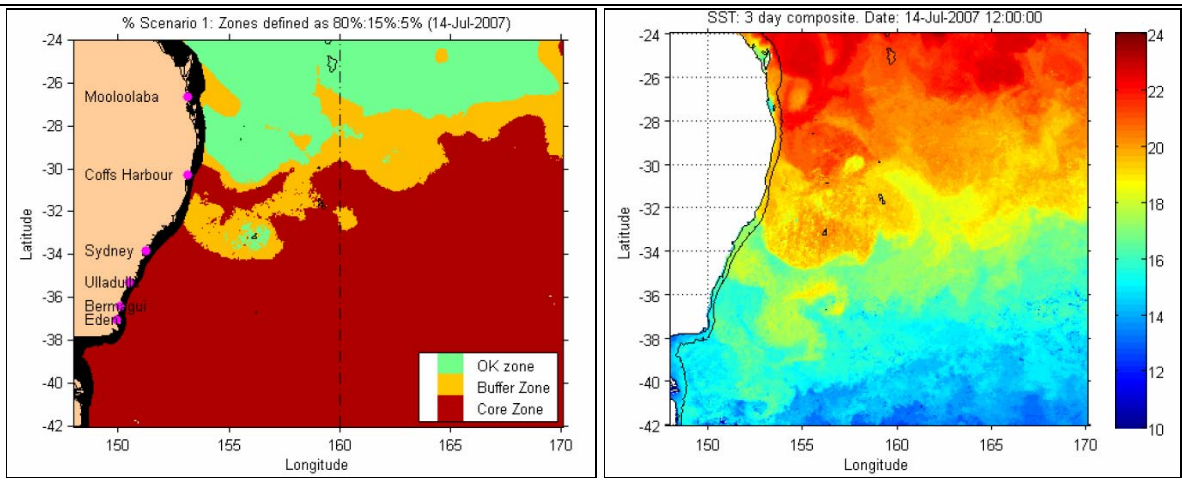


Figure 6-6 Eddy detail a) Individual eddy and b) internal structure (Lyne and Hayes, 2005)

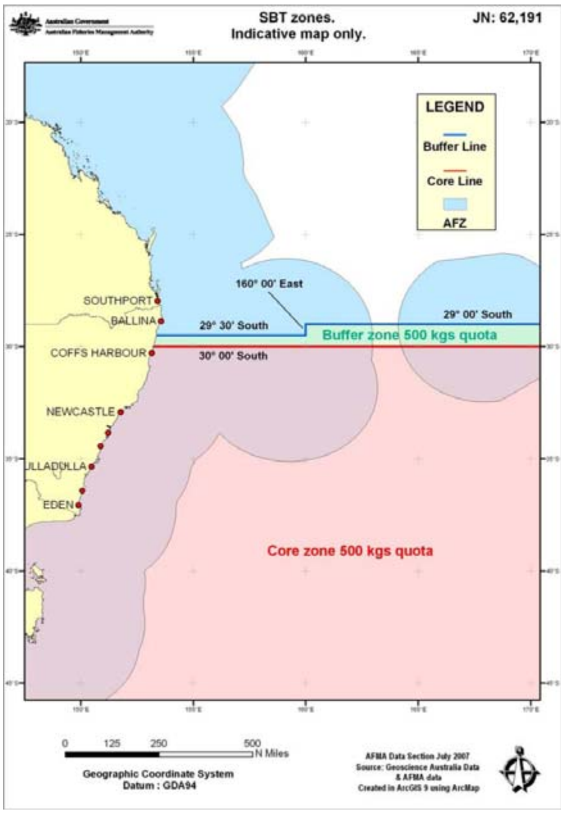
The influence of variation in EAC southerly penetration and eddy creation and extent on the pelagic environment is illustrated by the Southern bluefin tuna (SBT) prediction modelling that is undertaken by CSIRO at regular intervals. Data from pop-up tags are used, in conjunction with sea surface temperature data, to model the likely occurrence of SBT and set restrictions on the Eastern Tuna and Billfish Fishery. Figure 6-7 illustrates the potential for transient pelagic populations to span wide areas and the core zone of SBT occurrence across a broad area of the East Marine Regions (Figure 6-8).



a) SBT modelled occurrence *b). 3-day composite SST for the model*

Source: AMFA online document accessed at http://www.afma.gov.au/fisheries/tuna/etbf/mgt/zones.htm on 27 July 2007.

Figure 6-7 a). Distribution of core SBT habitat (red), 2007 and b). 3-day composite SST image used in the model



Source: AMFA online document accessed at http://www.afma.gov.au/fisheries/tuna/etbf/mgt/zones.htm on 27 July 2007.

Figure 6-8 Core SBT zone for Eastern Tuna and Billfish Fishery longline operations

Other processes driven by the EAC include true shelf-upwelling, where the combined effect of the eddy field and the EAC current along and away from the shelf causes upwell nutrient-rich, cool water onto the shelf which drives increased phytoplankton growth and primary production (Figure 6-9) to create periods of increased primary production which leads to increased consumer abundance (zooplankton, fishes and other predators).

Furthermore, as oceanographic currents are forced around the contours of the seamounts and ridges, counter- rotating vortices can form on the upstream and downstream flanks. This action can lead to the formation of an eddy on the slope of the seamount or one directly above the seamount, known as a Taylor Column. These eddies can generate upwellings and downwellings which have direct implications on the productivity of the adjacent waters and indeed the distribution of associated communities of pelagic fish which including kingfish, *Seriola lalandi*, redfish, *Centroberyx sp.*, and rosy jobfish, *Pristipomoides multidens* (Koslow, 2007).

Increased plankton biomass over the seamounts also attracts dense shoals of lantern fish, mysid shrimps and squid vertically migrate at night to feed on the organisms. In turn, they become a food source for larger pelagic species including shark species such as the smooth hammerhead shark, *Sphyrna zygaena*, and the Galapagos whaler shark, *Carcharhinus galapagensis* (Rogers, 2004).

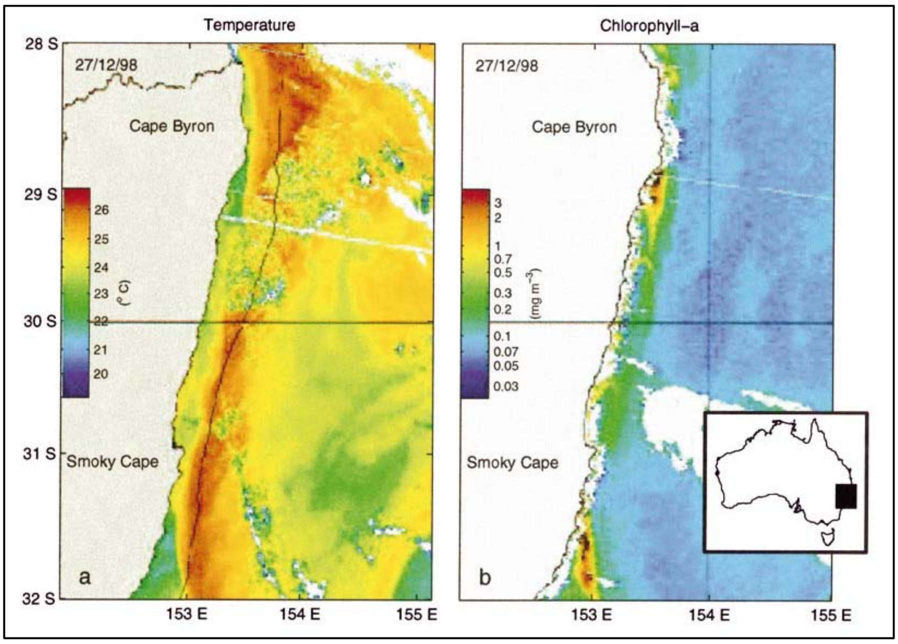


Figure 6-9 EAC-driven upwelling on the northern NSW coast

6.1.2 Influence on primary productivity

The waters of the northern tropics, and of the South Equatorial Current and the East Australian Current, at least at a surface-level, generally have a low primary productivity and are nutrient-limited based on satellite interpretation of surface waters. However, research has shown that there is potential for enhanced primary productivity in sub-surface waters that is not captured by satellites. Lyne and Hayes (2005) noted that the tropical waters of the Coral Sea, in general, have the highest concentration of phytoplankton in a deep chlorophyll-maximum layer in a nutricline at about 60-140 m, within which chlorophyll levels (and primary production) peak from June – August, which may be attributable to the increase in southeast trade winds during this time.

The south-east trades causes convective overturn and wind-induced upwelling currents that recharges nutrient levels in the surface waters. Surface waters tend to cool during winter and increase in density, causing them to sink. The resulting convective currents break down the shelf-edge fronts and bring deeper nutrient-rich water up into the euphotic zone, promoting phytoplankton blooms. This provides enhanced opportunities for feeding, which supports breeding aggregations and provides the enriched conditions critical for enhancing larval survival (Prince, 2001). In summer, increased solar radiation causes an increase in phytoplankton growth rate in the shallow mixed layers.

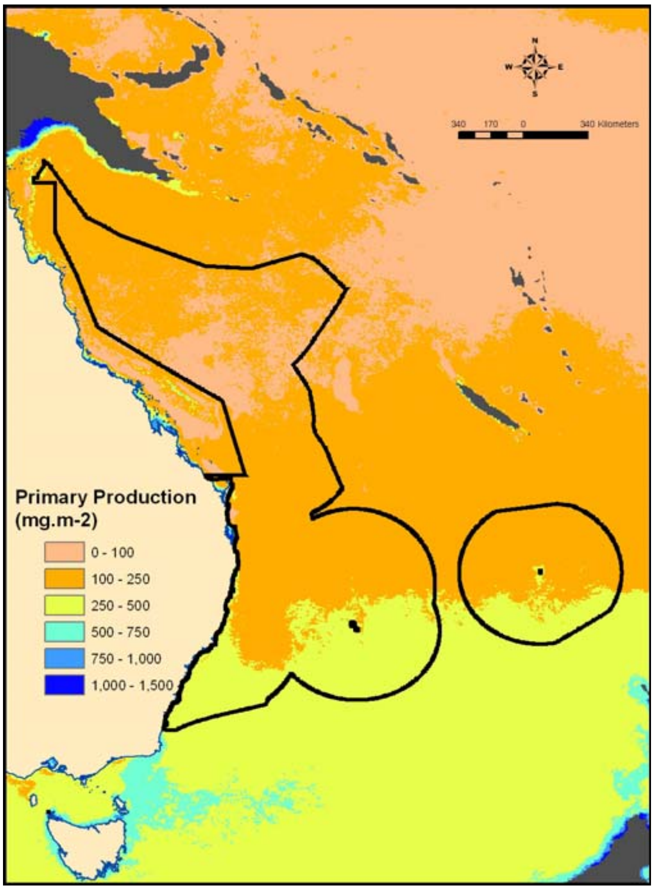


Figure 6-10 Spring primary production in the East Marine Region

In the southerly-most extent of the East Marine Region, seasonal productivity also occurs and features such as spring phytoplankton blooms or winter nutrient upwelling can create temporary increases in biomass in the pelagic environment.
As the EAC moves along and away from the continental shelf and slope, upwelling draws nutrient-rich, cool water over the slope and onto the shelf, which also results in increased phytoplankton activity and increased primary production. In Spring, phytoplankton blooms occur resulting from EAC-mediated intrusion of nutrient-rich slope water onto the continental shelf, as indicated by chlorophyll peaks over the continental shelf and slope (Figure 6-11), and possibly enhanced by northerly winds (Bax *et al.*, 2001).

The eddies associated with the EAC and the Tasman Front also influence productivity. The main biological influence of the eddies is to increase the vertical mixing within the upper ocean layers in the western Tasman Sea, effectively extending the mixed-layer depth and suppressing the winter phytoplankton and zooplankton populations through limiting light conditions (Hayes *et al.*, 2004). These conditions then allow for spring and autumn blooms of phytoplankton. The upwelling associated with the frontal-region around eddies also supplies more nutrients to the surface layers once the bloom has begun, initiating increases in phytoplankton biomass and thus prolonging the duration of the blooms.

Within the waters of the Tasman Sea, patterns of phytoplankton growth and primary production are very seasonal and operate in a latitudinal band about 10° wide (Figure 6-11). In July, there is a region of low chlorophyll (0.15–0.2 mg Chl-a m-3) between about 20°S and 30°S. In October, the southern edge of the low-chlorophyll region is still at about 30°S, but there is a marked increase south of this. This increase progresses southward as a front and is quite dynamic. Production is low (100-250 mg C m-3 d-1) over much of the region between 20°S and 40°S in July, but it doubles in October between 30°S and 40°S. By January, the high production region has moved further south, into the Subtropical Convergence and Subantarctic waters, but production in the 30°S to 40°S band has dropped back to < 250 mg C m-3 d-1 (Lyne and Hayes, 2005).

A constant background biomass of nanoplankton flagellates are present throughout the year (10 – 20% of the total chlorophyll during diatom peaks; 50 – 80% for most of the year; Lyne and Hayes, 2005). The Coral Sea phytoplankton communities include diatoms, cyanobacteria, and a great diversity of tropical dinoflagellates. Cell concentrations are generally very low and nanoplankton and picoplankton form a high percentage of total chlorophyll (70–95%), consistent with the oligotrophic nature of the environment. Ocean-colour imagery suggests higher chlorophylls are present in the Coral Sea region from April to August when the south-east trade winds are blowing. While surface values generally remain low for the remainder of the year, deep chlorophyll maxima within the seasonal pycnocline (down to 150 m depth) are probably present throughout the year (Hayes et al., 2004). In the, northern Tasman Sea surface chlorophylls are highest in winter (May–October), but drop rapidly to quite low levels from November to April.

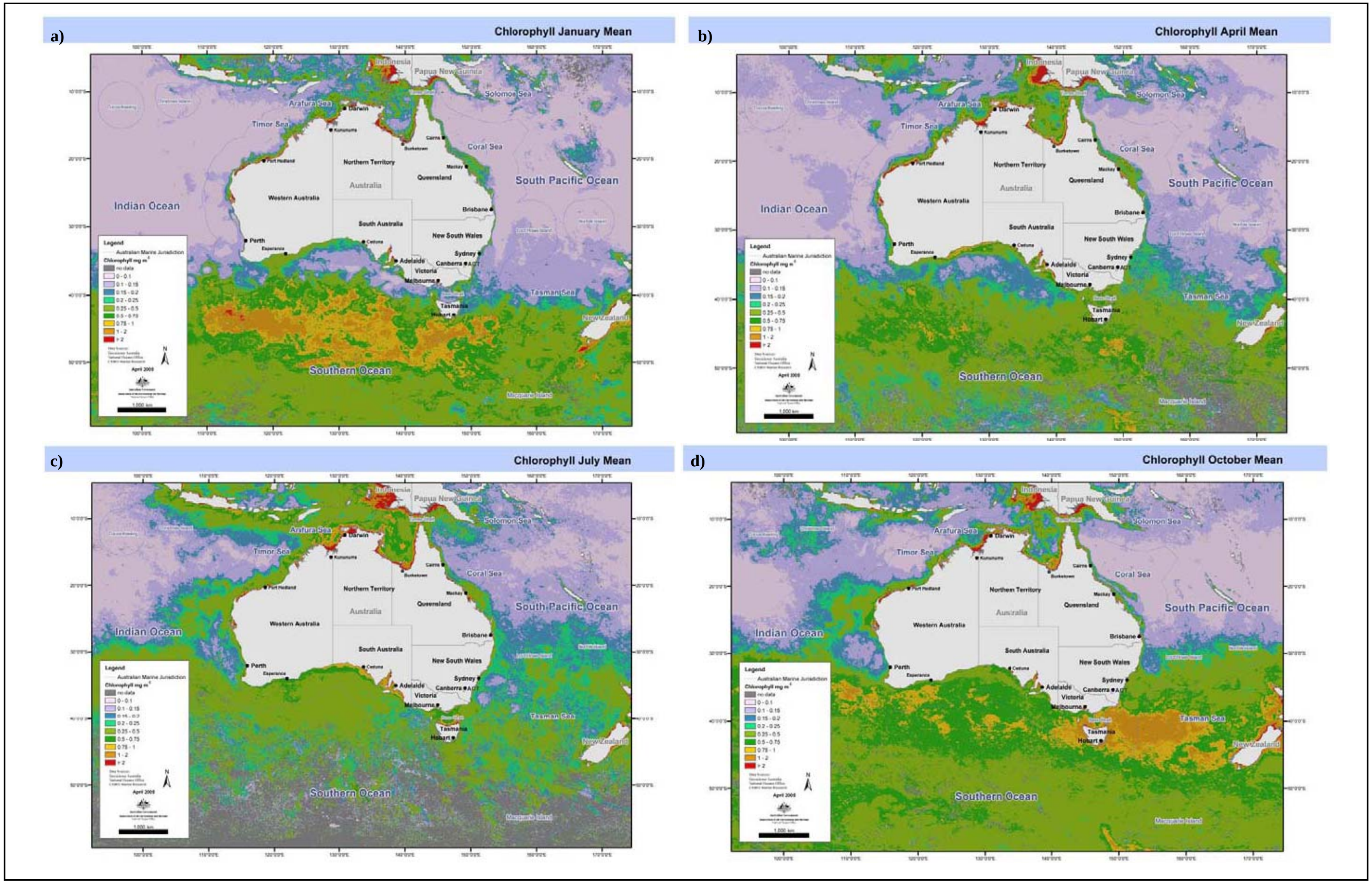
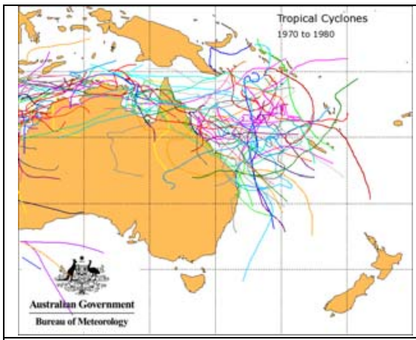


Figure 6-11 Monthly means for chlorophyll for (a) January, (b) April, (c) July, (d) October (Hayes *et al*., 2005).

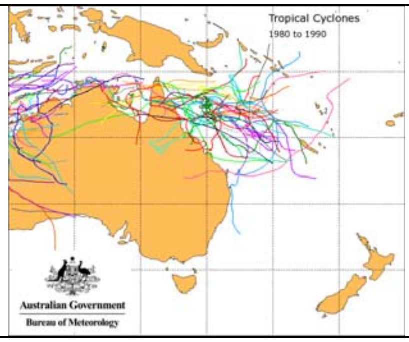
6.1.3 Winds

The northern tropical regions are influenced by seasonal wind variation and the dominant winds are southeast trending trade winds (June to October) and northwest monsoonal winds (November to May). This is an over-simplification of the wind scenarios as the northwest monsoon generally extends in a southerly direction over a number of months from its onset and there are periods of relative calm (often referred to as the 'doldrums') typically from December to April (Lyne and Hayes 2005).

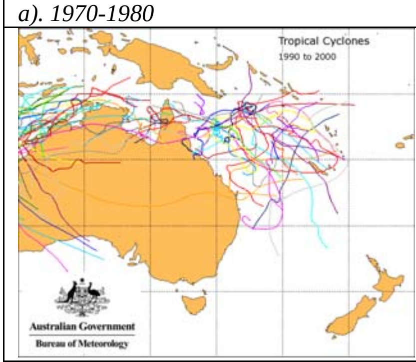
The tropics is also characterised by the regular occurrence of cyclones although, as shown in Figure 6-12, the potential influence of cyclones is highly variable (BOM 2007).



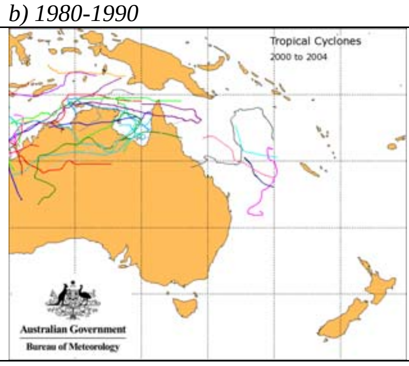
a). 1970-1980



b) 1980-1990



c). 1990-2000



d). 2000-2004

Figure 6-12 Cyclone paths 1970 - 2004 (Source: Australian Bureau of Meteorology 2007)

6.1.4 Geomorphology

The East Marine Region spans a vast range of bathymetry and geomorphic features, two major drivers of demersal ecology (Figure 6-13). Depths of over 5000 m are reached in the region. The geomorphology of the region consists of a mosaic that is a combination of 'patches' or 'complexes' (such as the Queensland plateau and the Norfolk Complex) and 'linear' features such as the north-south trending Eastern Slope and the Tasmantid Seamount chain.

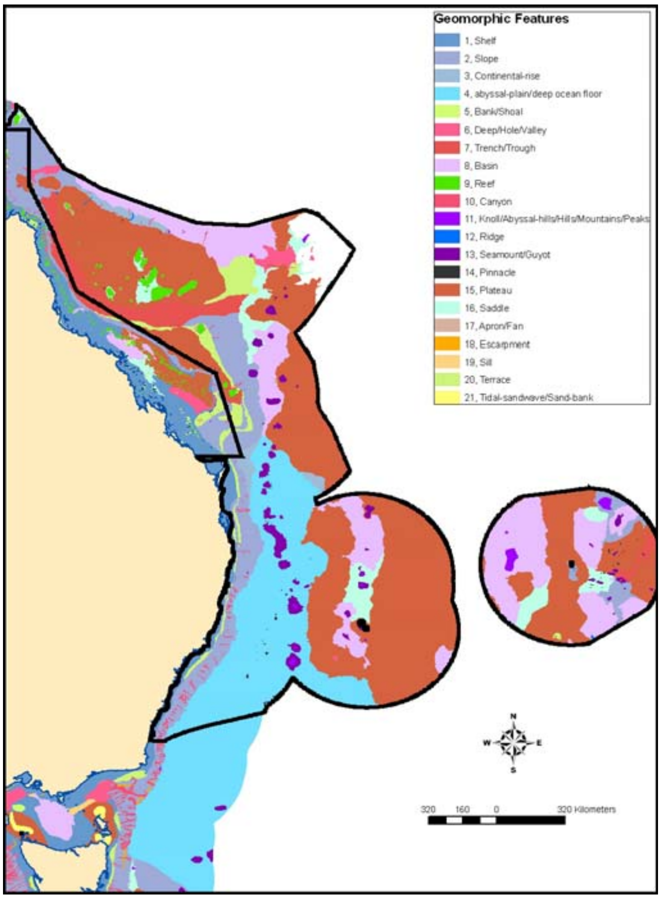


Figure 6-13 Geomorphic features of the East Marine Region

The benthic communities of the East Marine Region are not well studied in all areas and, for some areas, assumptions must be made based on bathymetry and seabed facie (seabed facie itself is not well known for the vast majority of the East Marine Region). There are topographic features that are expected to represent centres of biodiversity or endemicity. These include seamounts, slope habitats at the extent of plateaux (Queensland, Kenn and Lord Howe plateaux in particular, see below) and canyons on the Eastern Slope. Other demersal habitats in the East Region are noteworthy because of their unique representativeness within the region, their distinctiveness from similar neighbouring systems or because of their strong linkage to species and fisheries. The reefs in the far north of the region, the Coral Sea reefs, the Townsville Trench, the Marion and Kenn reef areas, Lord Howe Island and Norfolk Island fall into this category.

In deep water, the pelagic and demersal systems are somewhat separate, with few direct trophic linkages. However, it is clear that there are indirect linkages between these two environments in deep water and the processes that connect the two systems include vertical migration of zooplankton, topographically-induced upwelling, true oceanographic upwelling, planktonic fall-out and fall-out of megafauna such as whales and larges fishes. These processes provide an avenue whereby nutrients can move between the pelagic and demersal systems that are separated by a vertically stratified water column (i.e., typically not mixed below the surface mixed layer). In shallower waters, the pelagic and demersal environments come into closer association and food-webs become linked through the water column.

The interaction between bathymetry and seabed facie in driving benthic assemblages can be illustrated by examples where, at a given depth, a hard-substrate habitat would likely harbour a different assemblage to that inhabiting soft sediment in similar depths. This principle, in addition to the interactions with bottom-currents and topographically-induced upwelling is considered to influence the ability for filter-feeder dominated benthic assemblages in areas such as canyons and seamounts. Deep abyssal plains and basins, dominated by fine sediments, are known to be very sparsely populated environments, with benthic communities dominated by detritivorous in-fauna and epi-fauna that rely primarily on benthic cycling of organic matter or pelagic fall-out.

6.2 Major eco-physical sub-regions

The initial compartmentalisation of the Eastern Marine Region (EMR) into appropriate eco-physical systems (sub-regions) was done based on the influence of the major watermasses (Figure 6-14). This is in recognition of the principal influence of the major watermasses on the ecologic systems of the area. In particular, the compartmentalisation process used the pelagic regionalisation by Lyne and Hayes (2005) (Figure 6-14) as the primary basis for defining the systems of the EMR. We could not accommodate the full three-dimensionality of the various depth-related pelagic water masses. We instead gave precedence to the structure of the near surface layers. The Lyne and Hayes, (2005) classification used offshore information on water masses and was less accurate on the shelf. Therefore on the shelf and slope, the regionalisation based on fish by Last *et al.* (2003) and the IMCRA demersal shelf regionalisation by Lyne and Last (1996) were used to guide the definition of the systems.

The northern most region of the study area is under the influence of the Pacific Tropical Warm Pool watermass. This watermass is warmer and more saline than water to the south of the Tasman Front. The higher salinity is due to convective evaporation when water is transported into the region by way of the Equatorial Current, which splits at the Australian coast. The northward arm feeds into the Solomon Sea and the southern arm becomes the East Australian Current, the western boundary current of the South Pacific Subtropical gyre. This is a highly seasonal watermass system with a monsoonal/tradewind influence. It also has some considerable interannual variation through ENSO related events.

South of the Tasman front, the region is under the influence of the Central-South Subtropical watermass. This Tasman Sea watermass is cooler and fresher in comparison to the northern waters of the region.

The sub-region lies in the warm-temperate waters of the Coral Sea Circulation (Water Mass P13; mean temp. - 19.15°C) with the tropical Coral Sea to the north (Water Mass P17, 25.62°C) and a temperate convergence to the south (Water Mass 12; 13.59°C) (Lyne and Hayes, 2005).

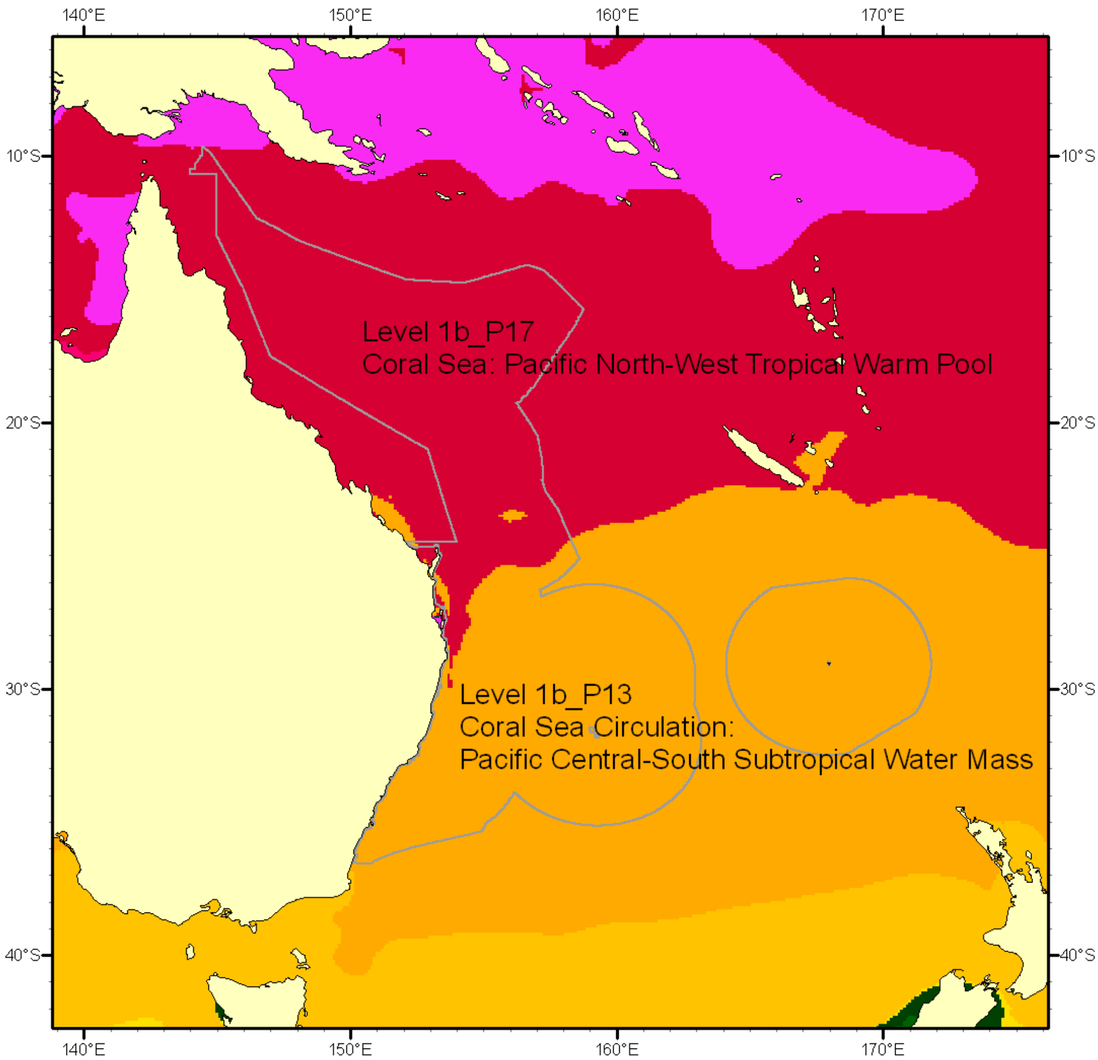


Figure 6-14. Location of major surface watermasses off the Australian east coast (from Lyne and Hayes, 2005).

The next level differentiation was done using depth. This is due to the dependence of a variety of processes, including mixing processes, the formation of the thermocline and depth-structured layering of the deep water masses (Lyne and Hayes, 2005) on the continental slope and deep ocean. Following the concepts embodied in the demersal regionalisation framework, the simplest classification of depth structures comprise three zones:

- The Shelf Zone subject to various mixing processes which in turn may be split into various depth bands (Lyne *et al*., 2006).

- The Slope Zone where many studies have found seasonally repeated patterns of circulation and nutrient flux, with an apparent disjunction at the shelf-break isobath. A number of demersal biomes, mostly depth related, have been documented within this zone (Last *et al*., 2003). The base of the continental slope zone in this region is usually at about the 4000 m isobath.

- The third zone is the Deep Ocean - Abyss zone beyond the 4000 m isobath. Above the deep ocean abyssal zone the pelagic ocean is structured into distinct depth bands and interactions within the water column characterised by the rain of particulate organic matter derived from surface production and various intrusions of water masses laterally.

At the next level of differentiation, various types of processes and features of the environment are discriminated. Often features and processes are associated in an intimate way within each system. Thus the deep abyssal plain and associated seamounts off the NSW coast are considered as a single system (albeit with the seamounts as important features within the system). Geomorphology also was an important driver for defining sub-regions in some areas, for example the two sub-regions in the Lord Howe EEZ area. The western sub-region (Lord Howe Complex, 3b) was defined geomorphically by the Lord Howe Rise whereas the eastern sub-region (Lord Howe Plateau, 3b) is characterised by the Lord Howe Plateau which has a relatively uniform topography and lies in depths of 1000 to 1500m.

Although there was scant information on species assemblages that could be used in the compartmentalisation process, sub-region boundaries were influenced by the analysis of finfish communities conducted during the demersal and pelagic shelf regionalisations by Lyne and Last (1996) and the demersal slope bioregionalisation by Last et al. (2003).

The compartmentalisation process resulted in the identification of 12 sub-regions within the EMR (Figure 6-15, Table 6-1). The physical derivation of the eco-physical systems was confirmed through the analysis of a wide range of available abiotic physical datasets (Appendix 1).

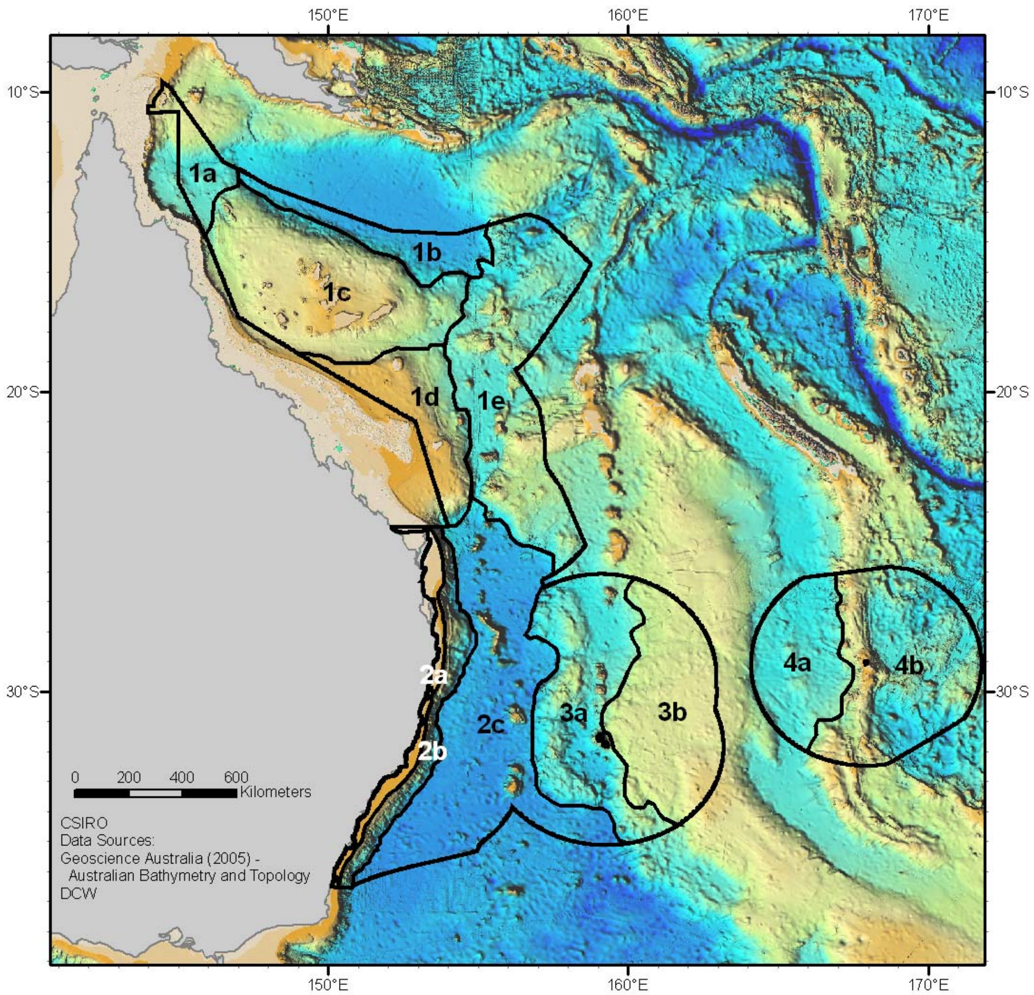


Figure 6-15 Map of Eastern Marine Region with eco-physical systems (subregions).

Table 6-1 Names for Primary and Secondary eco-physical systems for the Eastern Marine Region.

Primary system		Secondary eco-physical system	
1	Northern tropical	1a	Cape Province
		1b	Coral Sea Abyssal Basin
		1c	Queensland Plateau
		1d	Marion Plateau
		1e	Northern Seamounts Field
2	Southern temperate	2a	Eastern Shelf
		2b	Eastern Slope
		2c	Southern Seamounts Field
3	Lord Howe	3a	Lord Howe Complex
		3b	Lord Howe Plateau
4	Norfolk	4a	New Caledonia Basin
		4b	Norfolk Complex

6.3 Comparison with IMCRA provincial regionalisation

The eco-physical sub-regions formulated in this study, following the conceptual approach detailed above, showed considerable concordance with the IMCRA4 bioregions (Figure 6-16). The boundaries of several sub-regions are similar to IMCRA4 bioregions, for example, the Cape Province of IMCRA4 and sub-region 1a (Cape Province). This is not surprising given that we used similar information to drive the compartmentalisation as the IMCRA4 regionalisation – notably the original demersal and pelagic shelf regionalisations by Lyne and Last (1996); the demersal slope bioregionalisation by Last et al. (2003); the pelagic regionalisation by Lyne and Hayes (2005) and the National Bioregionalisation of Australia (NBA) 2005. These regionalisations provided structural components from which the sub-regions of the EMR are developed and described. As discussed previously, our approach in developing the sub-regions was to use the pelagic regions as the highest level (largest scale) for defining the different major types of systems. Within that structure, the depth-based structures from the demersal and the pelagic regionalisations were determined and then the smaller scale systems were defined around specific major features of the larger systems (Table 6-1).

With that as a background, the top level system boundaries closely follow the pelagic regionalisation boundaries in the offshore region (Figure 6-14). However, at the lower levels, there are some differences. Several of the IMCRA4 bioregions contain two or more sub-regions; for example the Norfolk Island Province and Lord Howe Province both have two sub-regions within them, based mostly on differences in geomorphology within those areas. Alternatively, some sub-regions contain several IMCRA4 bioregions; for example sub-region 2c (Southern Seamounts Field) contains two IMCRA4 provinces, and a transition zone. There are other differences, especially in the north, however, this is often where the boundaries between sub-regions are contained within IMCRA4 transition zones.

Another variation between the two regionalisations is the demarcation of the slope zone from the abyssal zone when constructing the eco-physical sub-regions. For example the sub-regions 2b (Eastern Slope) and 1b (Coral Sea Abyssal Basin) are not represented in the IMCRA4 bioregionalisation. This depth classification also means that the large IMCRA4 North East Province is split into three sub-regions, 1b, 1c and 1d (Figure 6-16), base mostly on depth and related geomorphology.

In keeping with the philosophy of the system definition approach adopted for this project, eco-physical sub-regions are embedded within their primary pelagic system (Table 6-1). Underlying this, the overriding criteria we applied was for a sub-region description where components were intimately tied by interrelationships with the environment and drivers, and were as self-contained as possible while being differentiated from neighbouring sub-regions. Thus, the IMCRA4 bioregions were seen as components to be integrated into the sub-regions, rather then driving their formulation.

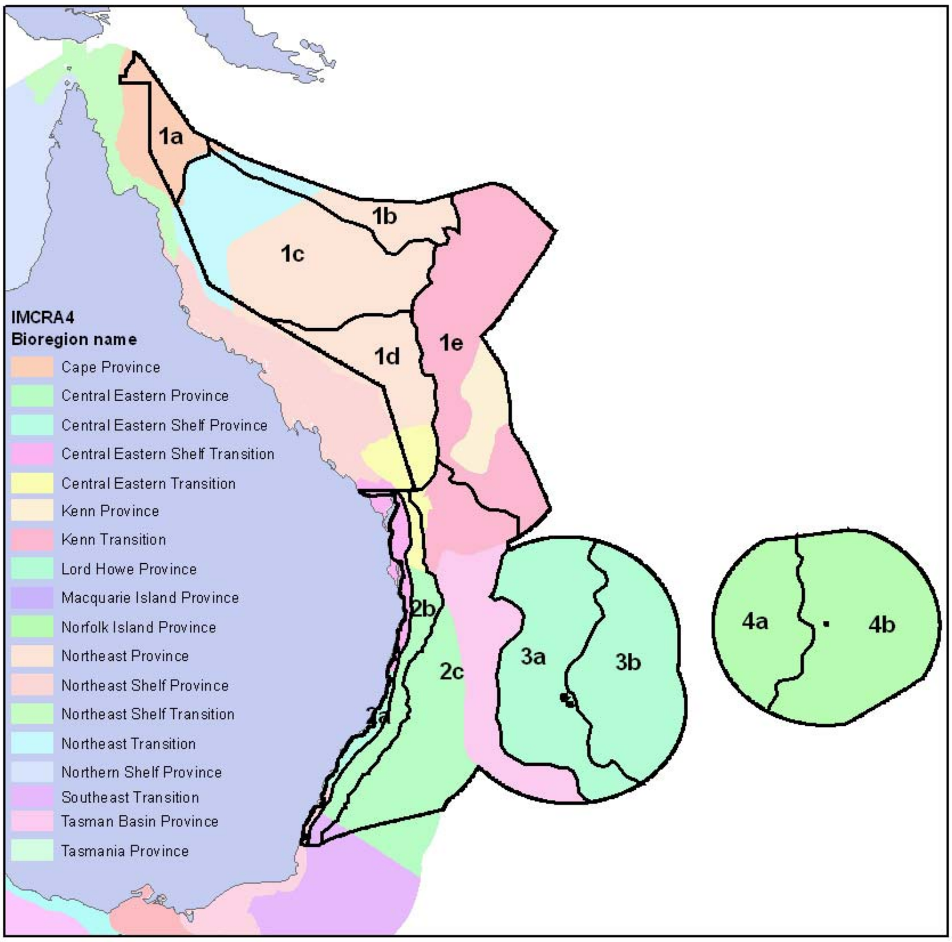


Figure 6-16 Map of East Marine Region and eco-physical sub-regions (black lines and labelled) and IMCRA4 bioregions (pastel zones associated with Figure legend).

7. DESCRIPTION OF SUB-REGIONS

7.1 Cape Province Sub-region (1a)

7.1.1 Description

The northern-most of the East Marine Region, the Cape Province sub-region (1a), lies in tropical waters and encompasses a large proportion of deep abyssal slope, incised by sparse, widely-spaced submarine canyons (Heap *et al*., 2005). This sub-region also includes Ashmore Reef[1] and Boot Reef in the far northern corner (Figure 7-1). The sub-region is bordered to the west by the Great Barrier Reef Marine Park and to the north and east by Australia's EEZ boundary. The Cape Province sub-region overlaps with the previous IMCRA4 Cape Province Bioregion (Figure 7-2).

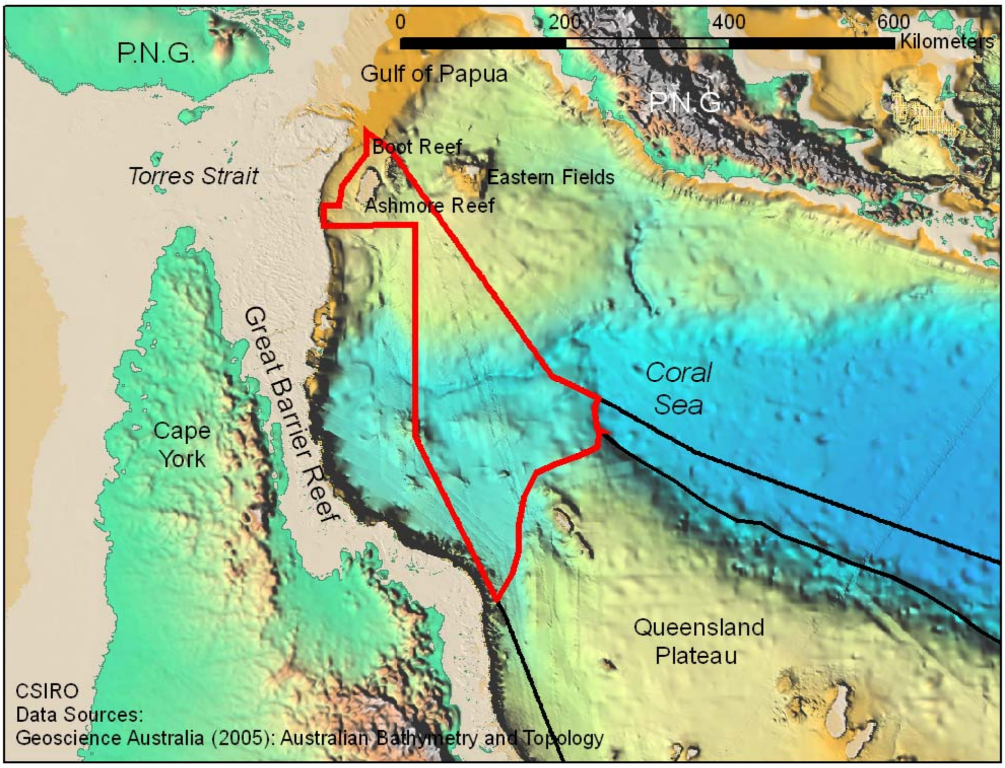
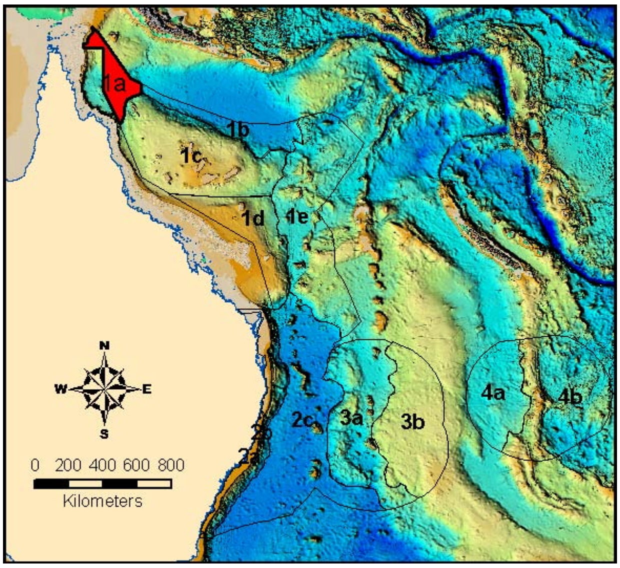
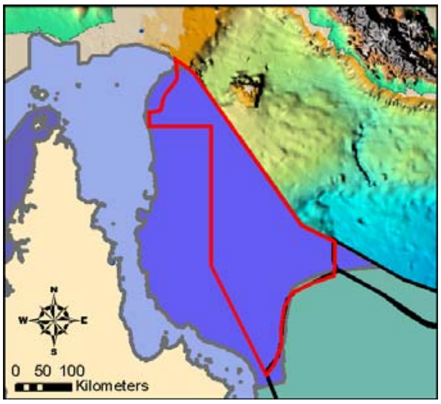


Figure 7-1 Cape Province sub-region (1a) showing locations of selected features

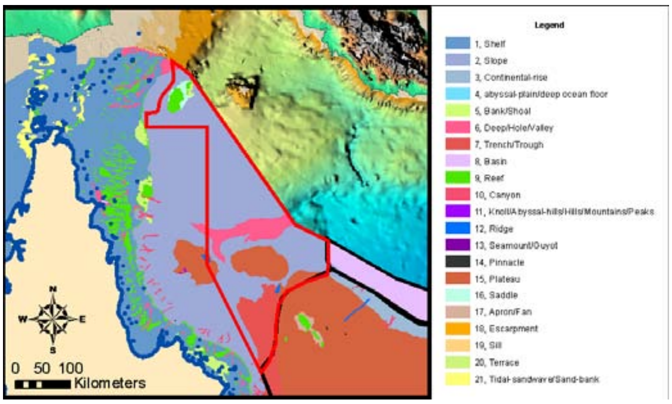
[1] Not to be confused with the Ashmore Reef off the coast of Western Australia.



a) Location of sub-region 1a



b) Sub-region 1a overlaid on IMCRA Bioregions



c) Sub-region 1a overlaid on Geomorphic Features

Figure 7-2 Cape Province sub-region (1a), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.1.2 Important Drivers and Ecological Features

Pelagic

Oceanic waters in this sub-region are characterised by generally low productivity, oligotrophic conditions and warm surface temperatures averaging around 27 °C (Hayes *et al.*, 2004).

The important ecological features of the pelagic zone of the Cape Province sub-region include transient populations of highly migratory pelagic species that are the secondary and tertiary consumers in an ecophysical system that is driven by oceanographic processes (Figure 7-3). While there may be some level of seasonal aggregation or transient attraction to certain areas, there are expected to be very few, if any, 'resident' populations. The possible exception to this is the shallow pelagic environment in the vicinity of Ashmore and Banks reefs which may have pelagic ecological features that are characterised by pelagic assemblages that range between reefs during life history cycles in a somewhat more predictable pattern.

Demersal

Some 302 species of demersal fish have been recorded from Cape Province Sub-system, 24 of which are believed to be endemic (Last *et al*., 2005). Last *et al*. (2005) indicated that the northern edge of the province was not able to be clearly distinguished on the basis of demersal fish assemblages. Sponge assemblages in this sub-region form a subset of the tropical east coast fauna that is recognised as a transition zone between eastern Cape York Peninsula and the Queensland Plateau assemblage (Hooper and Ekins, 2004).

Bathymetry and geomorphology (and the related seabed facie) is believed to be the primary driver of the demersal environment in the Cape Province Sub-system and the 'slope' biotope dominates this sub-system. This sub-region encompasses demersal habitats ranging from shallow coral reefs to >3000 m deep abyssal troughs and submarine canyons. There is some evidence to suggest that at least some shallow reef assemblages in this sub-region are biogeographically different from those of the Great Barrier Reef, potentially forming a group that has stronger affinities to Torres Strait and even as far west as the Arafura Sea and Timor Sea (Benzie 1998, Endean 1957).

A far greater proportion of the demersal environment is comprised of gently-sloping seafloor in excess of 1000 m deep (mean depth = 2,325 m). This area is expected to represent a matrix of sediment grain-sizes that would ultimately drive the seabed facies and, therefore, ecology on the deep sea floor.

The demersal ecophysical system in the deep sea is driven primarily by the distribution of particulate organic matter (POM) (in the form of marine snow, zooplankton faecal matter, whale falls etc.) and thus are linked in some way to pelagic processes (Figure 7-3). Near-bottom currents are believed to influence benthic standing crop (Gage and Tyler, 1991), probably by attracting filter-feeders. Particle size, which is independent of pelagic processes and linked to geomorphic processes such as down-slope transport of eroded shelf sediments and channelling of terrigenous sediments through deep submarine canyons and troughs, is also believed to be important for influencing patterns of deep benthic communities.

The primary ecological features in the abyssal benthic, soft-bottom environment are likely to be patchy distribution of mobile epibenthos that is typical of the deep seafloor. These organisms, including holothurians, ophiuroids, echinoderms, polychaetes, sea-pens and other mobile epifauna are typically supported by microbial processes at the sediment surface and infaunal assemblages including filter-feeders and detritivores. Larger grain sizes or concreted seabed facies may coincide with the appearance of established, more resident deep epibenthic communities. Although poorly studied, such habitats have been known to support eco-physical systems that are characterised by groups such as crabs, cephalopods, echinoderms and other suspension-feeding epibenthic organisms that may include deepwater corals (typically azooxanthellate).

Fishes and cephalopods are an ecological feature of the demersal environment of the abyssal zone. In the bathypelagic zone, assemblages would be expected to include small, bioluminescent species that may vertically migrate, including hatchetfish (*Argyropelecus spp.*), dragonfish (*Melacosteus spp.*), viperfish (*Chauliodus spp.*) and a number of squid and eel species. In addition, more bottom-attached species such as conger eels, macrourid cods and tripod fish would be expected to occur. These organisms are typically present is very low abundances (in the absence of some aggregating feature such as a hydrothermal vent) and are very patchily distributed. An eco-physical model for sub-region 1a is shown in Figure 7-3

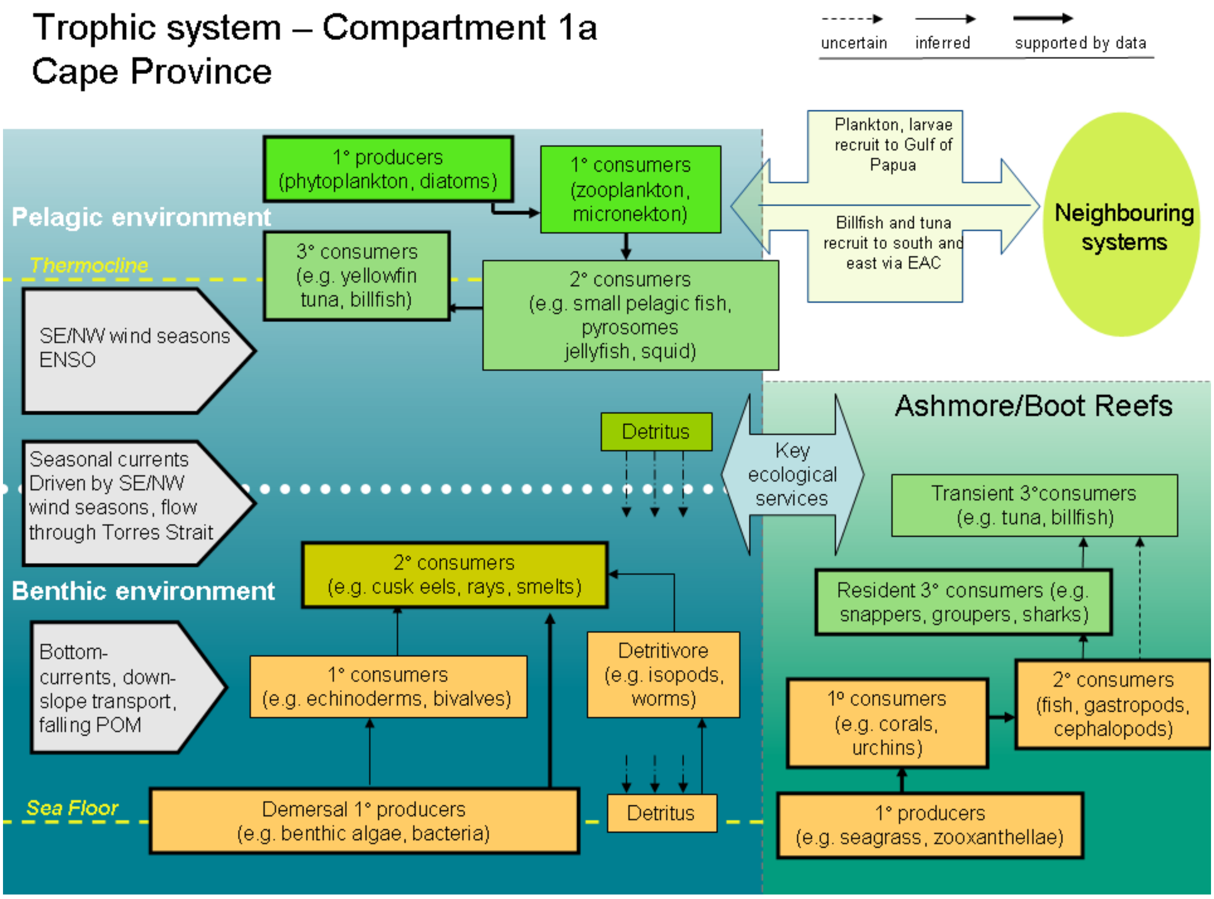


Figure 7-3 Eco-physical model for the Cape Province Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and

their trophic interactions. Ashmore and Boot reefs are important ecological features in this sub-region and are also described.

7.1.3 Productivity flows

Productivity flows in the benthic portion of the deep slope environment are expected to be dominated by down-slope transport of sediments/nutrients, cycling of particulate organic matter (such as marine snow and other falling organic matter and detritus) through bacterial detrital food webs and thus supporting sparsely populated epi-benthic communities of a range of trophic groups. These epi-benthic communities may support bentho-pelagic fish or invertebrate communities if they are suitable for providing habitat services (e.g. epi-benthic communities on concreted sediments may support deep slope sponge/coral habitat) or food resources (e.g. epi-benthic communities) on unconsolidated sediments may include filter-feeding worms/bivalves that in turn may support bentho-pelagic consumers. Indeed, Last *et al*. (2005) noted several species of bathydemersal fish species that were indicative of this region.

In the pelagic portion of the deep-sea environment, productivity flows are expected to be dominated by classical tropical pelagic processes of primary productivity (phytoplankton), to secondary production by vertically migrating zooplankton (such as crustaceans, larval molluscs, larval fishes). Primary consumers such as jellyfish and salps are known to occur in the Coral Sea and are prey for secondary consumers as such small schooling fishes, and cephalopods. The main tertiary consumers of interest in the deep sea environment are transient billfish and tuna and other pelagic predators such as sharks and marine mammal that either migrate seasonally or range through the sub-region following prey fish schools. Seabirds are expected to be included in the latter category.

Therefore, the productivity flows in the pelagic and demersal portions of the very deep sections of the sub-region are somewhat disconnected, with falling detritus from the pelagic environment or whale-falls, for example, providing the main avenue of linkage. However, in the shallower sections of the sub-system, the productivity flows between the pelagic and demersal environment are expected to be more closely linked as the distance between the two environments decreases and they become more inter-connected. For example, at Ashmore and Boot reefs, and in the slope habitat offshore of these isolated reefs, there are expected to be benthic organisms (including primary producers such as algae and coral) that provide direct habitat and food resources for primary consumers (fishes and invertebrates such as molluscs and crustaceans) which are subsequently preyed upon by reef-associated secondary consumers (e.g. reef fishes) and tertiary consumers that are likely to include resident reef-associated predators (e.g. cod and snappers) and transient predators such as mackerel, tunas, billfish and sharks.

7.1.4 Connectivity with other Sub-regions

This sub-region is connected strongly with the southern equatorial current and the northern bifurcation of that current. Planktonic organisms entering the sub-region are likely to be connected to the Torres Strait and perhaps, ultimately, the Gulf of Papua (Figure 7-3). However, mobile billfish and tuna, for example, are likely to be connected to the sub-regions to the south (in particular, sub-region 1c). The westerly and then southern movement of adult and juvenile billfish, through the Coral Sea and into Australian waters is reported to be important to the recruitment of billfish into the Queensland Plateau region (and the Cairns billfish fishery in particular) (Campbell and Hobday, 2003; Bromhead *et al.*, 2004).

Early research indicated that there are faunal affinities, at least in shallow-water echinoderms that have planktonic larvae, between this area and the Arafura Sea and Indian Ocean through Torres Strait (Endean, 1957). Therefore, connectivity in communities of some reef organisms with planktonic larvae may be inter-regional.

7.1.5 Interactions with important species and habitats

Movements of larval and adult billfish from the Coral Sea, westwards into Australian waters, and southwards into neighbouring sub-systems, have been identified, as has seasonal variation in this pattern driven by the northwest-southeast monsoonal systems (Bromhead *et al*., 2004).

Deep slope habitat that dominates this sub-region is not replicated in immediately adjacent sub-regions and is replicated further south in sub-region 1d, which lies in the same ocean water mass but under different oceanographic regimes. Therefore, it is possible that the slope habitat in the Cape Province Sub-system has some ecological features that are unique to this sub-system.

Data available for demersal fish populations (>40 m) indicate some differences from more southerly areas and other data suggest that the shallow reef environments of Ashmore and Boot reefs may support communities that have closer affinities to Torres Strait that the more southerly sub-regions near the GBR and so may represent an important habitat that is not replicated elsewhere in the East Region

7.1.6 Vulnerability to impacts and change

Climatic influence of the northwest-southeast wind seasons and oceanographic processes of the bifurcation of the Southern Equatorial Current are important in this sub-system. Therefore, the ecophysical system is vulnerable to impacts from these physical features and sea surface temperature. Ecophysical systems associated with Ashmore and Boot reefs, particularly coral reefs, are vulnerable to impacts of sea surface temperature increase. Shallow environments are also vulnerable to cyclone damage in this sub-system, but these are less frequent in this sub-region than more southerly sub-regions (Furnas, 2003). Coastal agriculture and terrigenous inputs are minimal in this sub-region and reefs in the sub-region are generally not subject to riverine sediment plumes (Furnas, 2003).

7.1.7 Information gaps

- Details of abyssal trophic systems in the sub-system;
- Linkages between pelagic and demersal systems in the open ocean;
- Details of biogeography of Ashmore and Boot reefs.

7.2 Coral Sea Abyssal Basin Sub-region (1b)

7.2.1 Description

The Coral Sea Abyssal Basin sub-region (1b) lies in tropical waters and encompasses a portion of the large deep abyssal basin lying between Papua New Guinea and the Australian EEZ (Figure 7-4). This deep water eco-physical system is characterised by the deep (>4,000 m) abyssal plain, a habitat type that is among the Earth's flattest and smoothest regions, and the least explored. Deep abyssal plains cover approximately 40% of the ocean floor. They are typically covered by silt, much of it deposited from turbidity from the continental margins and planktonic remains which sink from the upper pelagic waters. There may also be some scattered regions of hard bottom particularly on the margins.

The Coral Sea Abyssal Basin is dominated by flat terrain, incised by very sparse canyons and is bordered to the south by the continental rise that rises to form the Queensland Plateau (Heap *et al*., 2005) (Figure 7-4). The Coral Sea Abyssal Basin sub-region encompasses two previously defined IMCRA bioregions; the Northeast Province in the eastern half of the sub-region and the Transitional Province in the western half of the sub-system (Figure 7-5).

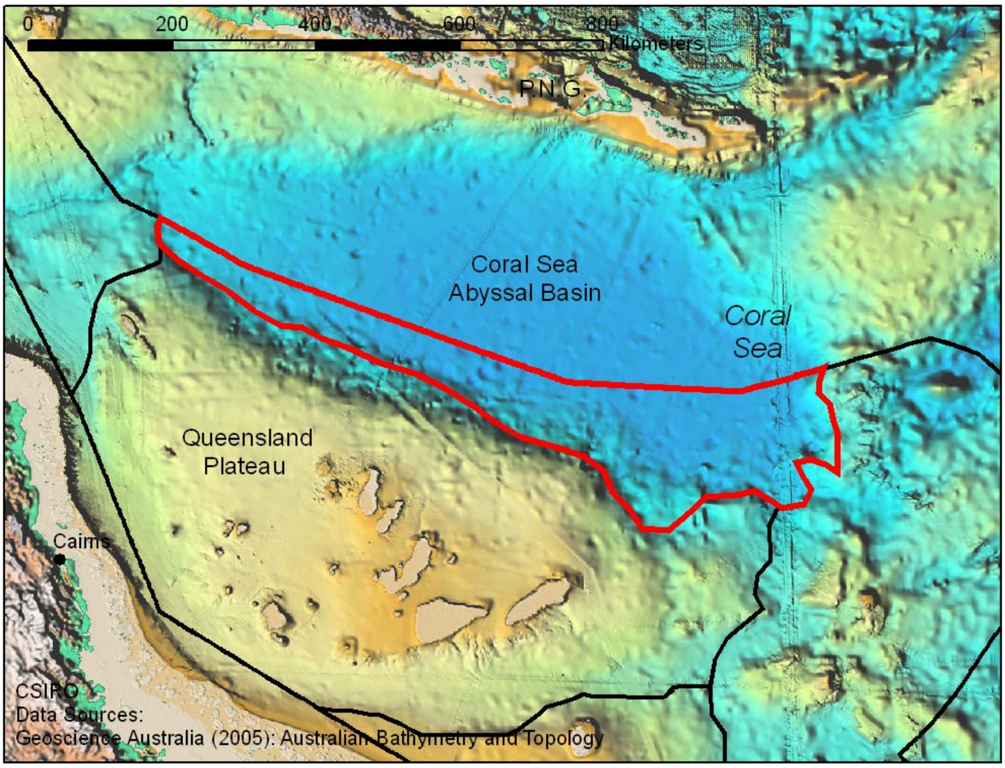


Figure 7-4 Coral Sea Abyssal Basin sub-region (1b) showing locations of selected features

7.2.2 Important Drivers and Ecological Features

Pelagic

The principal drivers of ecology in the pelagic environment are the oceanographic processes related to the westerly flow of the South Equatorial Current through the Coral Sea and the variation in this current brought about by the northwest-southeast monsoonal wind seasons. The waters in this sub-region are characterised by warm surface temperatures (averaging approximately 26 °C) and generally low productivity.

The important ecological features of the pelagic environment of this sub-region include transient populations of highly migratory pelagic species (notably schools of small fishes such as engraulids and pelagic predators such as billfish and tuna) that are the secondary and tertiary consumers in an ecophysical system that is driven by oceanographic processes (Figure 7-6). While there may be some level of seasonal aggregation or transient attraction to certain areas, there are expected to be very few, if any, 'resident' populations.

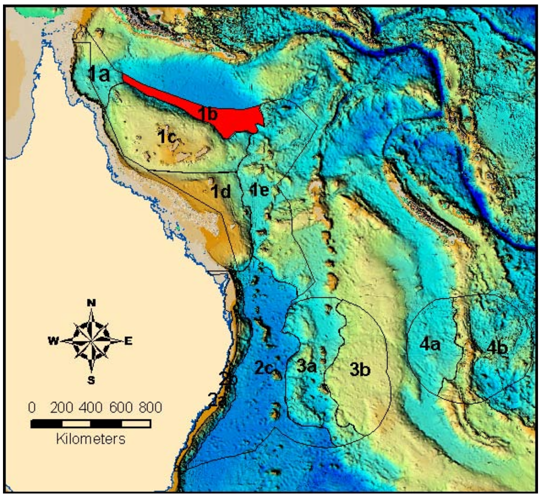
Demersal

The demersal environment of this sub-region consists of seafloor at depths in excess of 4000m. Existing data on demersal fish communities that was integrated into the IMCRA bioregionalisation is not directly applicable to this sub-region because the IMCRA bioregions included continental rise, shelf and deep slope habitats of the Queensland Plateau, while the Coral Sea Abyssal Basin Sub-system comprises only abyssal basin habitat.

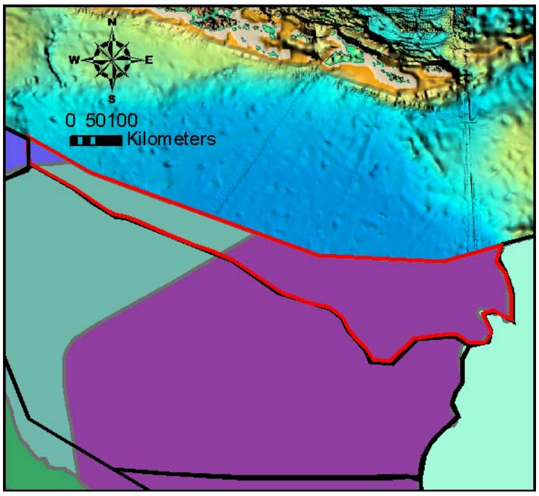
Bathymetry and geomorphology (and the related seabed facie) are believed to be the primary driver of the demersal environment in the Coral Sea Abyssal Basin Sub-system and the abyssal basin geomorphic habitat dominates this sub-system.

The deep demersal environment is reliant for its energy input on falling detritus or particulate organic matter (POM) (detritus, zooplankton faecal matter) and the occasional large carcass directly supplied by the pelagic environment (Figure 7-6). Much of the detrital energy is cycled through bacterial-detrital food webs. In this case, the relatively low nutrient/productivity of the pelagic environment is results in a low biomass in the benthic habitats supporting sparsely populated infaunal and epi-benthic communities of a range of trophic groups. There is likely to be a very sparse distribution of mobile epibenthos including holothurians, crabs and polychaetes. Any harder seabed facies that occur in the area may contain established, more resident deep epibenthic communities that may include crabs, cephalopods, echinoderms and other suspension-feeding epibenthic organisms including deepwater corals (typically azooxanthellate). Much of the benthic biomass will likely be made up of infauna (meiofauna and microfauna) including filter-feeders and detritivores.

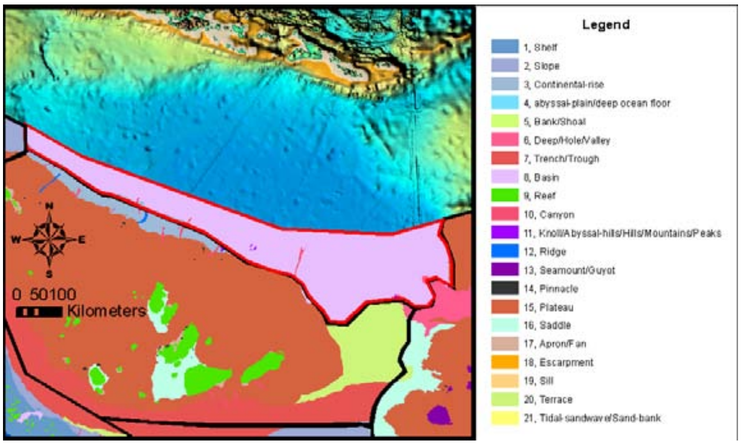
These epi-benthic communities may support a sparse population of bentho-pelagic fish and cephalopods may also be present in low densities. Fish assemblages would be expected to include Grenadiers or rattails (Macrouridae), hatchetfish (*Argyropelecus spp.*) and small, bioluminescent species that may vertically migrate. These organisms are typically present is very low abundances and are very patchily distributed.



a) Location of sub-region 1b



b) Sub-region 1b overlaid on IMCRA Bioregions



c) Sub-region 1b overlaid on Geomorphic Features

Figure 7-5 Coral Sea Abyssal Basin sub-region (1b), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.2.3 Productivity flows

Productivity flows in the benthic portion of the abyssal plain environment are expected to be dominated by down-slope transport of sediments/nutrients, cycling of particulate organic matter (such as marine snow and other falling organic matter and detritus) through bacterial detrital food webs and thus supporting sparsely populated epi-benthic communities of a range of trophic groups. These epi-benthic communities may support bentho-pelagic fish or invertebrate communities if they are suitable for providing habitat services (e.g. epi-benthic communities on concreted sediments may support deep slope sponge/coral habitat) or food resources (e.g. epi-benthic communities on unconsolidated sediments may include filter-feeding worms/bivalves that in turn may support bentho-pelagic consumers). Deep-sea canyons may support deep-reef habitats if conditions of seabed facie and bottom currents are sufficient to support, for example, filter-feeding epi-benthic communities on concreted substrates. Such introduction and flow of particulate organic matter may supplement benthic primary productivity and thus provide productivity flow to a particular community type that may be present in deep-sea canyons, but absent from the broad, relatively feature-less abyssal plain.

In the pelagic portion of the deep-sea environment, productivity flows are expected to be dominated by pelagic processes of primary productivity to primary consumers dominated by pelagic, vertically migrating zooplankton (such as crustaceans, larval molluscs, larval fishes, etc.). Pelagic secondary consumers such as jellyfish and salps are known to occur in the Coral Sea, as are nekton secondary consumers such as transient small-fish schools and squid (Figure 7-6). The main tertiary consumers of interest in the deep sea environment are transient billfish and tuna and other pelagic predators such as sharks and marine mammals that either migrate seasonally or range through the sub-region following prey (e.g. fish schools). Seabirds are expected to be included in the latter category.

Therefore, the productivity flows in the pelagic and demersal portions of the deep sea environment in this sub-region are somewhat disconnected, with falling detritus from the pelagic environment or whale-falls, for example, providing the main avenue of linkage.

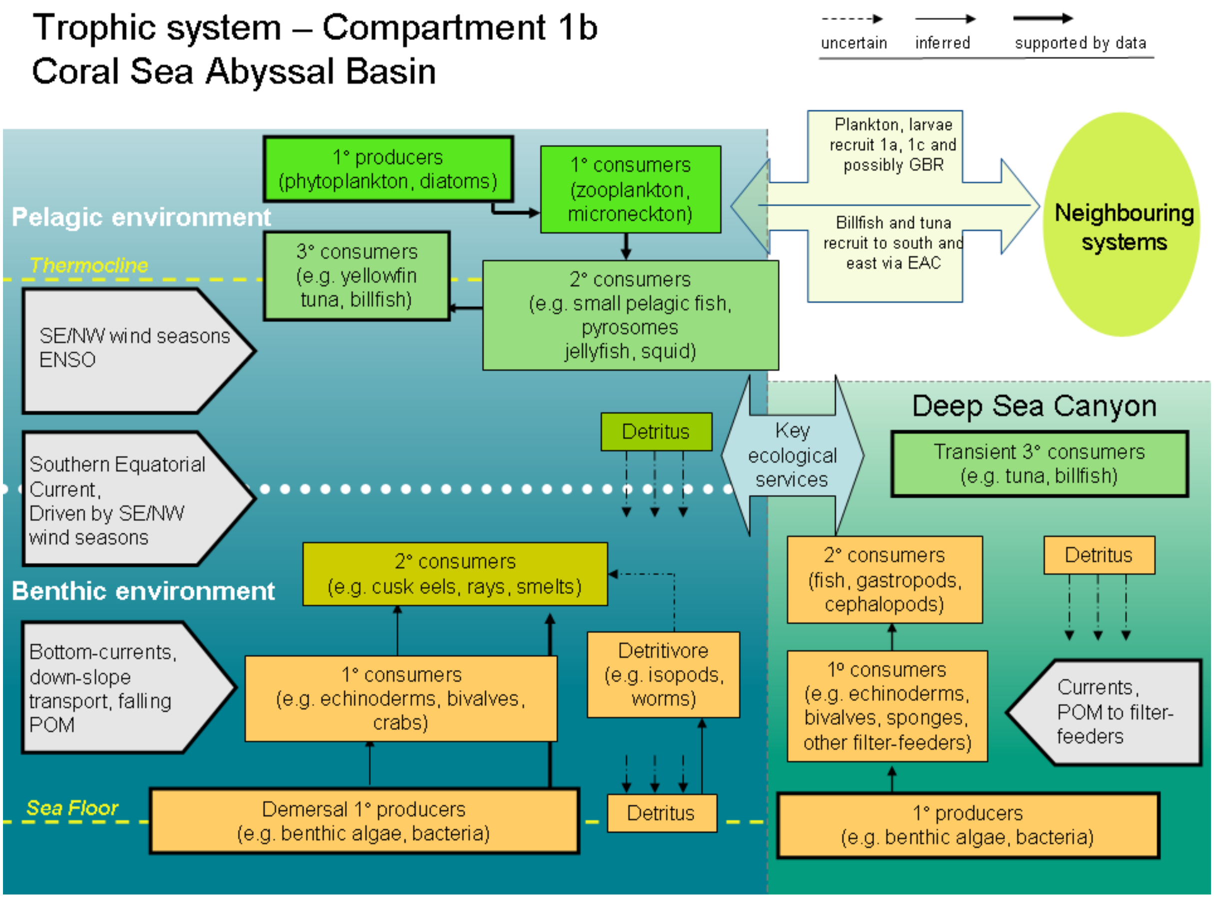


Figure 7-6 Eco-physical model for the Coral Sea Abyssal Basin Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Deep sea canyons are important ecological features in this sub-region and are also described.

7.2.4 Connectivity with other Sub-systems

This sub-region is connected strongly with the southern equatorial current. Planktonic organisms entering the sub-region are likely to be connected to the neighbouring sub-region 1a to the north and to 1c to the south (the Queensland Plateau) (each representing opposite directions of the bifurcation of the Southern Equatorial Current). Mobile predators such as billfish and tuna, for example, are likely to be connected to the sub-regions to the south (in particular, sub-region 1c). The westerly and then southern movement of adult and juvenile billfish, through the Coral Sea and into Australian waters is reported to be important to the recruitment of billfish into the Queensland Plateau region (and the Cairns billfish fishery in particular) (Campbell and Hobday, 2003; Bromhead *et al.*, 2004). In the benthic environment, particulate organic matter or sediment-derived nutrients in the southern border of this sub-region may be sourced from down-slope transport or bottom-current coming from the neighbouring sub-region 1c (Queensland Plateau).

7.2.5 Interactions with important species and habitats

Movements of larval and adult billfish from the Coral Sea, westwards into Australian waters, and southwards into neighbouring sub-systems, have been identified, as has seasonal variation in this pattern driven by the northwest-southeast monsoonal systems (Bromhead *et al*., 2004).

The deep abyssal plain is expected to be characterised by relatively featureless seabed, with sparsely-populated ecological communities, probably dominated by epi-benthic detritivores and filter-feeders. However, this sub-region does include some deep-sea canyon habitat, albeit very sparse. If appropriate conditions of concreted sediments and delivery of organic matter in bottom currents and other sources are met, these deep canyons may support deep-reef communities. While such communities are more typical of seamounts, deep canyon reefs are known to occur and if present, would be expected to be dominated by filter-feeding epi-fauna (i.e., sponges, bryozoans, azooxanthellate corals), which may in-turn support demersal consumers such as crustaceans, echinoderms, bivalves, cephalopods and fishes.

The deep-sea canyon habitat is replicated in the East Region further to the south in sub-regions 1d and 2b, where they occur more frequently. However, these canyons are considerably shallower than those that do occur in sub-region 1b.

7.2.6 Vulnerability to impacts and change

Climatic influence of the northwest-southeast wind seasons and oceanographic processes of the Southern Equatorial Current are important in this sub-system. Therefore, the ecophysical system is vulnerable to impacts to these physical features and sea surface temperature.

The deep-sea demersal communities are buffered somewhat from potential impacts in the pelagic environment and these communities are generally viewed as being less vulnerable to change. However, demersal communities may be vulnerable to alterations in delivery of detrital matter and other organic processes (e.g. down-slope sediment transport) and near-bottom oceanographic processes.

7.2.7 Information gaps

- Details of abyssal trophic systems in the sub-system;
- Linkages between pelagic and demersal systems in the open ocean;
- Occurrence of unique fauna in deep ocean canyons;
- Linkages with the Queensland Plateau.

7.3 Queensland Plateau Sub-region (1c)

7.3.1 Description

The Queensland Plateau sub-region (1c) lies in tropical waters and encompasses the distinct geomorphic feature of the Queensland Plateau that covers some 165,000 km^2 (Harris *et al.*, 2003) (Figure 7-7). Approximately half of the plateau surface lies in waters less than 1000 m deep and living reefs occur over about 10 to 50% of its surface (Davies *et al.*, 1989). The largest of the reef complexes are Tregrosse (contained within the Coringa-Herald NNR) and Lihou reef systems. Other reefs are associated with pinnacles rising from deep water to within 10 m of the surface and reefs associated with these structures include Flinders, Bougainville, Holmes and Osprey Reefs (Davies *et al.*, 1989) (Figure 7-7). The Queensland Plateau sub-region includes portions of the approximately NW-SE trending Queensland Trough that lies along the eastern boundary of the Great Barrier Reef zone and the sub-region also includes the E-W trending Townsville Trough at the southern margin of the sub-region (Figure 7-7). With the troughs included, the mean depth of the sub-region is 1496 m and the maximum depth is 4536 m. The mean water temperature is 26.2 °C.

The Coringa-Herald National Nature Reserve and the Lihou Reef National Nature Reserve (both declared in 1982), lie within this sub-region. The sub-region encompasses two previously defined IMCRA bioregions; the Northeast Province in the eastern half of the sub-region and the Transitional Province in the western half of the sub-region.

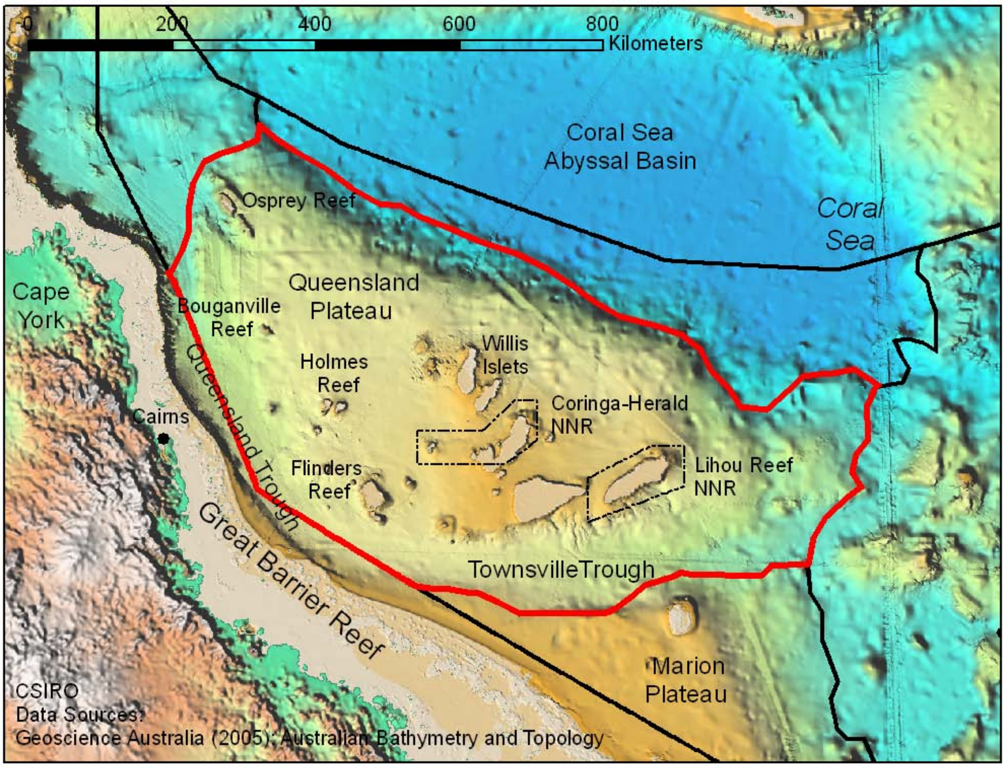
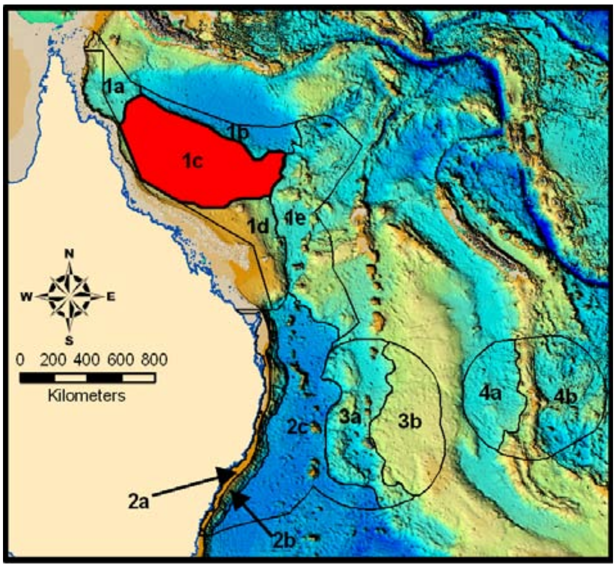
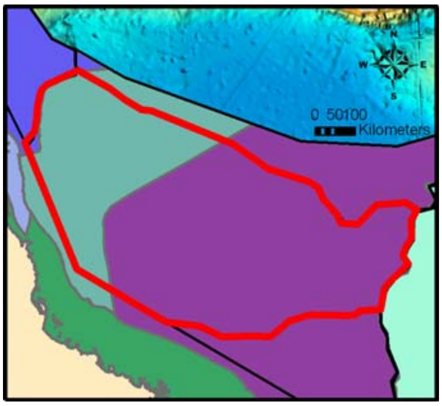


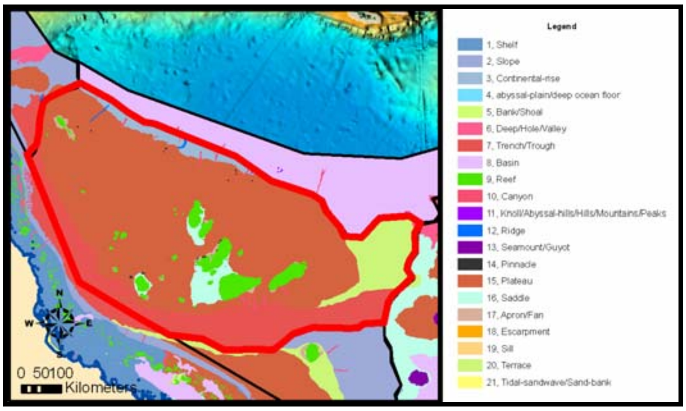
Figure 7-7 Queensland Plateau sub-region (1c) showing locations of selected features, including locations of National Nature Reserves (NNR)



a) Location of sub-region 1c



b) Sub-region 1c overlaid on IMCRA Bioregions



c) Sub-region 1c overlaid on Geomorphic Features

Figure 7-8 Queensland Plateau sub-region (1c), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.3.2 Important Drivers and Ecological Features

Pelagic

This sub-region has the highest occurrence (frequency and intensity) of cyclones of all the east region sub-regions (Appendix 1) although, as shown in Figure 6-12, the influence of cyclones is highly variable on annual and decadal timescales (BOM 2007).

Pelagic environment of the Queensland Plateau sub-region is complex with respect to currents. The sub-region receives westerly current flow that bifurcates generally in the region of 15°S to 16°S, which represents the northern part of the sub-region in the region of Osprey Reef. This bifurcation point is known to shift north and south. Although the driver for this shifting is not certain, ENSO cycles may be one factor.

The Queensland Plateau area is known to represent a 'formation phase' region for the East Australian Current (EAC), with the southern portion of the bifurcation generally trending south to form the EAC (Ridgway and Dunn 2003). However, surface currents are also known to form gyre systems in the Queensland Plateau region and early studies with drogues found northerly sub-surface currents and westerly currents up the slope to the Great Barrier Reef (GBR), such that drogues released in the Queensland Trough ran aground on the GBR (Church 1987). This gyre system in the Queensland Plateau region has been implicated as a possible driver of faunal endemicity on this sub-region (P. Last, *pers. comm.*).

As with the neighbouring open oceanic waters, those of the Queensland Plateau sub-region are characterised by oligotrophic conditions, although some isolated pockets of higher primary productivity do occur in the sub-region and these are generally associated with reefs or islands. However, as described by Lyne and Hayes (2005), surface primary productivity estimates probably under-estimate the overall productivity as significant primary productivity may occur in a deep chlorophyll maximum layer at the nutricline, which, in the Coral Sea, occurs at depths of 60 to 140 m. There is an increase in chlorophyll concentration in the sub-region in July, which may be related to the onset and peak of the southeast trade winds from April to July-August (Lyne and Hayes 2005).

The important ecological features of the pelagic environment of this sub-region include transient populations of highly migratory pelagic species (notably small fish schools and pelagic predators such as billfish, tuna and sharks) that are the secondary and tertiary consumers in an eco-physical system that is driven by oceanographic processes (Figure 7-10). While there may be some level of seasonal aggregation or transient attraction to certain areas, there are expected to be very few, if any, 'resident' populations. Cairns is the base for a significant recreational billfish fishery, and black marlin undergo seasonal movements into the Queensland Plateau region (Figure 7-9).

The Queensland and Townsville Troughs, both over 2000 m maximum depth, do not appear to represent hydrodynamic boundaries between the plateau and the GBR for species with broad larval dispersal which tend to occur in both areas (Benzie and Williams 2004, Benzie 2004). However, species with limited larval dispersal on at least some parts of the Queensland Plateau do appear to show genetic differentiation from those on the GBR, indicating separation of populations (Planes *et al* 2001, for a fish example). At the level of the 'assemblage', some differences in species composition are evident between reefs of the

Queensland Plateau and the GBR (Oxley *et al.,* 2003; Byron *et al.,* 2001). While the mechanism for this separation is not clearly defined, it would appear that ocean current systems and physical isolation of assemblages from the GBR are likely drivers.

Demersal

The influence of cyclones and wave conditions on shallow-water demersal environments was demonstrated by Oxley *et al*. (2003). These authors recorded significant wave damage to shallow coral communities on exposed reefs in the Coringa-Herald National Nature Reserve. The demersal environment in this sub-region covers an extremely wide depth range and beyond the influence of climatic conditions, the deep sea demersal environment is influenced by similar drivers to those described for the deep sea environments of sub-regions 1a and 1b (see Section 7-1 and 7-2 respectively).

The Queensland Plateau sub-region lies the same latitude as the Northeast Province of the demersal fish bioregionalisation (Last *et al.,* 2005). This province was characterised by the occurrence of 441 species and 70 endemics. This previous bioregionalisation was based on continental-slope fish assemblages and it is unclear how this relates to shelf environments of the Queensland Plateau. However, there are indications from the literature that demersal fish assemblages in this sub-region have a high degree of endemicity and are different from neighbouring GBR assemblages (Oxley *et al.,* 2003; Byron *et al.,* 2001).

Bathymetry and geomorphology (and the related seabed facie) are believed to be the primary driver of the demersal environment. Harris *et al*. (2003) indicate that there are some areas of concreted seabed in the Queensland and Townsville troughs and deep reefs may occur under such conditions.

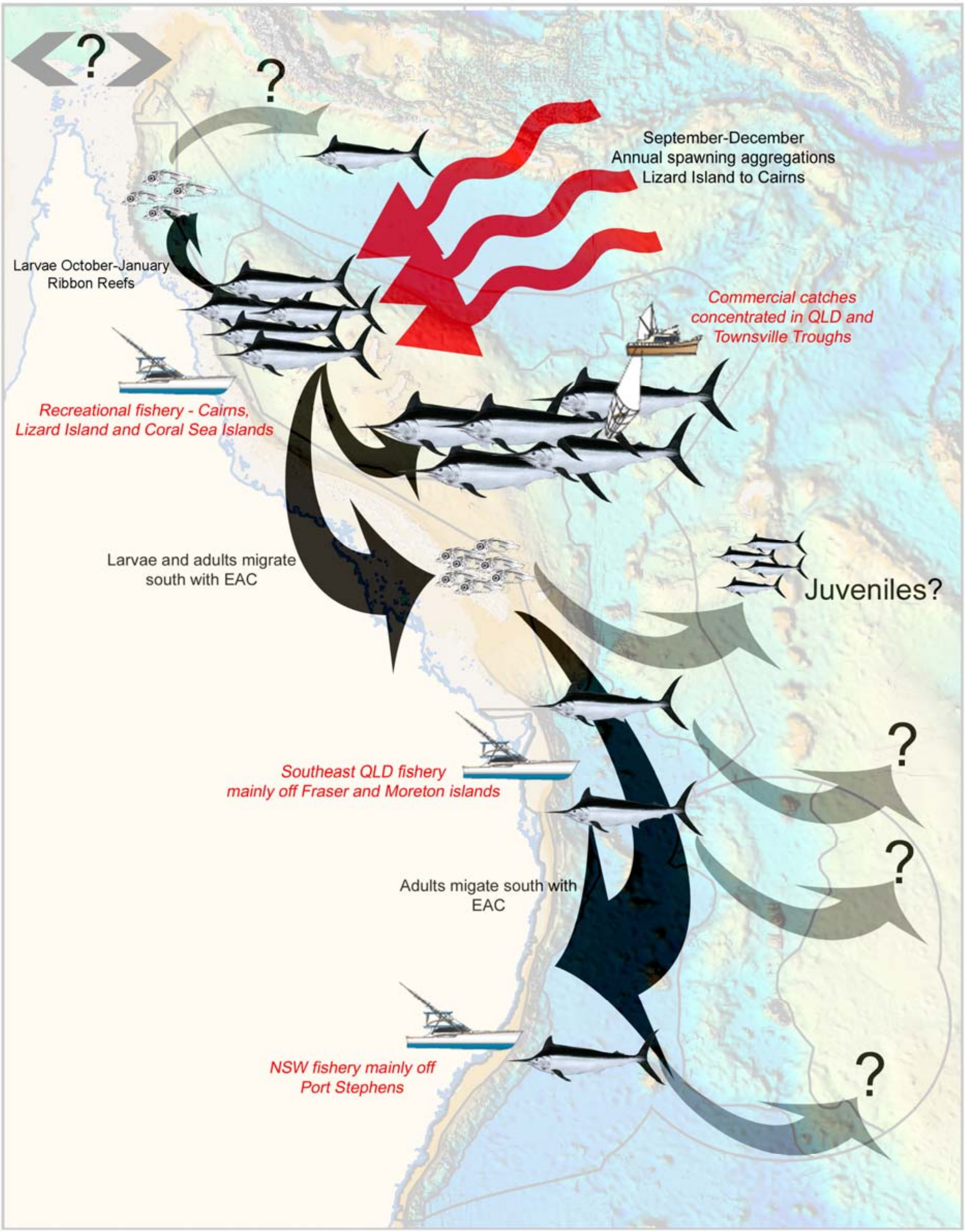


Figure 7-9 Spawning, movements and interactions of black marlin (*Makaira indica*) in the East Marine Region.

7.3.3 Productivity flows

Productivity flows in this sub-region are poorly understood and given the uniqueness of some assemblages in the Queensland Plateau, extrapolation from other sub-regions should be viewed with caution. The shallow reef environments within the sub-region, while comprising some endemic species, unique assemblages and being subject to unique physical drivers, are expected to have general productivity flows that are typical of tropical reef environments. The reef habitats and slope environments surrounding the plateau are expected to be the principal habitat of any resident populations.

In the pelagic environment, fronts of transient current systems are expected to drive transient aggregations of pelagic productivity and zooplankton which in turn may attract larger transient predators. Pelagic secondary consumers such as jellyfish and salps are known to occur in the Coral Sea, as are nekton secondary consumers such as transient small-fish schools and squid. The main tertiary consumers of interest in the deep sea environment are transient billfish and tuna and other pelagic predators such as sharks and marine mammals that either migrate seasonally or range through the sub-region following prey fish schools. Seabirds are expected to be included in the latter category.

The benthic environment of the Queensland and Townsville troughs is not well studied, but is expected to be dominated by down-slope transport of sediments/nutrients, cycling of particulate organic matter (such as marine snow and other falling organic matter and detritus) through bacterial detrital food webs and thus supporting sparsely populated epi-benthic communities of a range of trophic groups. These epi-benthic communities may support bentho-pelagic fish or invertebrate communities if they are suitable for providing habitat services (e.g. epi-benthic communities on concreted sediments may support deep slope sponge/coral habitat) or food resources (e.g. epi-benthic communities on unconsolidated sediments may include filter-feeding worms/bivalves that in turn may support bentho-pelagic consumers).

As mentioned for previous sub-region, the productivity flows in the pelagic and demersal habitats in the deep-sea portions of this sub-region are likely to be somewhat disconnected, with falling detritus from the pelagic environment or whale falls, for example, providing the main avenue of linkage. The pelagic and demersal environments are likely to interact more directly in shallower waters.

7.3.4 Connectivity with other Sub-regions

The sub-region represents a major formation area of the EAC and literature sources point to the connectivity of this region with areas further south in terms of a supply of planktonic larvae. The oceanographic and ecological connectivity between this sub-region and the GBR is more complex and poorly understood.

Clearly the EAC is a major avenue for connectivity between this sub-region and sub-regions to the south, particularly for mobile predators such as billfish and tuna. Immediately to the south of this sub-region is the Marion Plateau and the influence of the Townsville Trough separating these two sub-regions is not well understood.

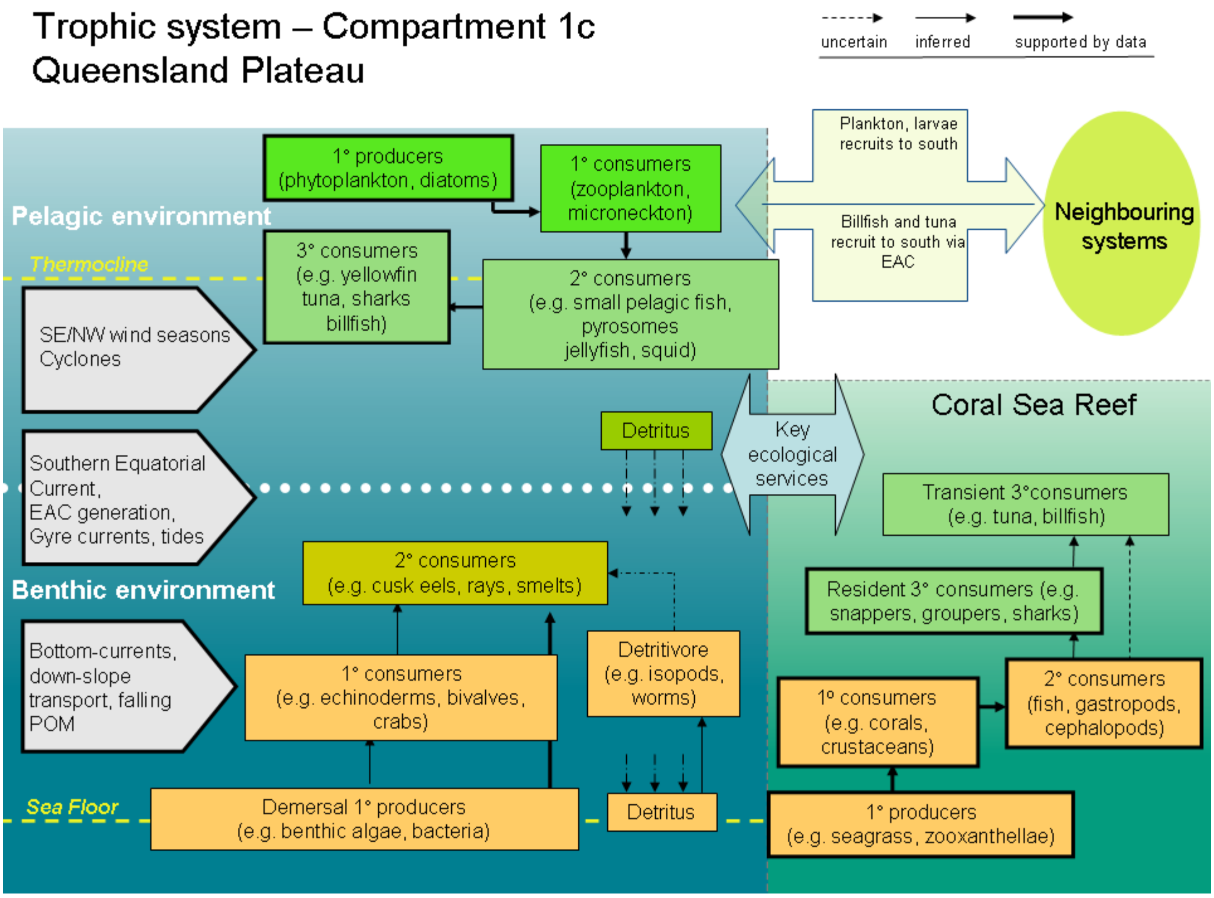


Figure 7-10 Eco-physical model for the Queensland Plateau Sub-region (1c), showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Coral sea reefs are important ecological features in this sub-region and are also described.

7.3.5 Interactions with important species and habitats

Seasonal increases in the abundance of pelagic predators, billfish in particular, forms the basis of a significant recreational (black marlin in particular) and commercial fishery in this sub-region. The apparent uniqueness of faunal assemblages of the reefs of the Queensland Plateau suggest that these are important habitats and while endemicity is not well known, Oxley *et al*. (2003) identified nine new species records for the Coral Sea and a high level of distinctiveness in fish assemblages among neighbouring reefs.

The Queensland and Townsville trough represent habitat that is not replicated elsewhere in the East Marine Region. The geomorphology of these troughs suggests that deep-reef communities may occur and thus represent important habitats.

Studies of demersal fish on the continental shelf off the mainland revealed highly distinct assemblages (Last *et al*., 2005). It is unknown whether the slope communities on the shelf skirting the Queensland Plateau would uncover similar endemicity or uniqueness.

7.3.6 Vulnerability to impacts and change

Climatic influence of cyclones and oceanographic processes of the Southern Equatorial Current and generation of the EAC and associated gyre-systems are important in this sub-region. Therefore, the ecophysical system is vulnerable to impacts to these physical features. The sub-region has shallow reef systems that are unique among the East Marine Region and have been shown to be susceptible to cyclone damage and bleaching (Oxley *et al.*, 2003). Theses ecophysical systems are therefore susceptible to changes to sea surface temperature and cyclone regimes.

The deep-sea demersal communities are buffered somewhat from potential impacts in the pelagic environment and these communities are generally viewed as being less vulnerable to change. However, demersal communities may be vulnerable to alterations in delivery of detrital matter and other organic processes (e.g. down-slope sediment transport) and near-bottom oceanographic processes. Benthic environments are vulnerable to activities relating to oil and gas resource exploitation.

7.3.7 Information gaps

- Faunal assemblages associated with slope habitats skirting the Queensland Plateau and relationship between these and the continental slope;
- Oceanographic gyre systems around the Queensland Plateau;
- The influence of these systems on faunal endemicity;
- Deep-sea faunal assemblages of the Queensland and Townsville troughs;
- Linkages with the Marion Plateau.

7.4 Marion Plateau Sub-region (1d)

7.4.1 Description

The Marion Plateau sub-region (1d) is situated off the central Queensland coast in the region of Mackay to Rockhampton (Figure 7-11). The sub-region encompasses the geomorphic structure of the Marion Plateau and the two major reefs of Marion Reef (in the north of the sub-region) and Saumarez Reef (in the south of the sub-region), which are the largest of the several small drowned reef-like features on the plateau (Symonds *et al.*, 1983). The plateau feature covers an area of 36,808 km^2 and lies in the warm tropical waters of the Coral Sea at depths of 100-600 m. The northern boundary is formed by a rift trough, the Townsville Trough, which separates it from the Queensland Plateau sub-region (1c). The eastern margin is created by the relatively steep slope leading to the Cato Trough, which is part of sub-region (1e). The western margin is demarcated by the border with the Great Barrier Reef Marine Park (Figure 7-11).

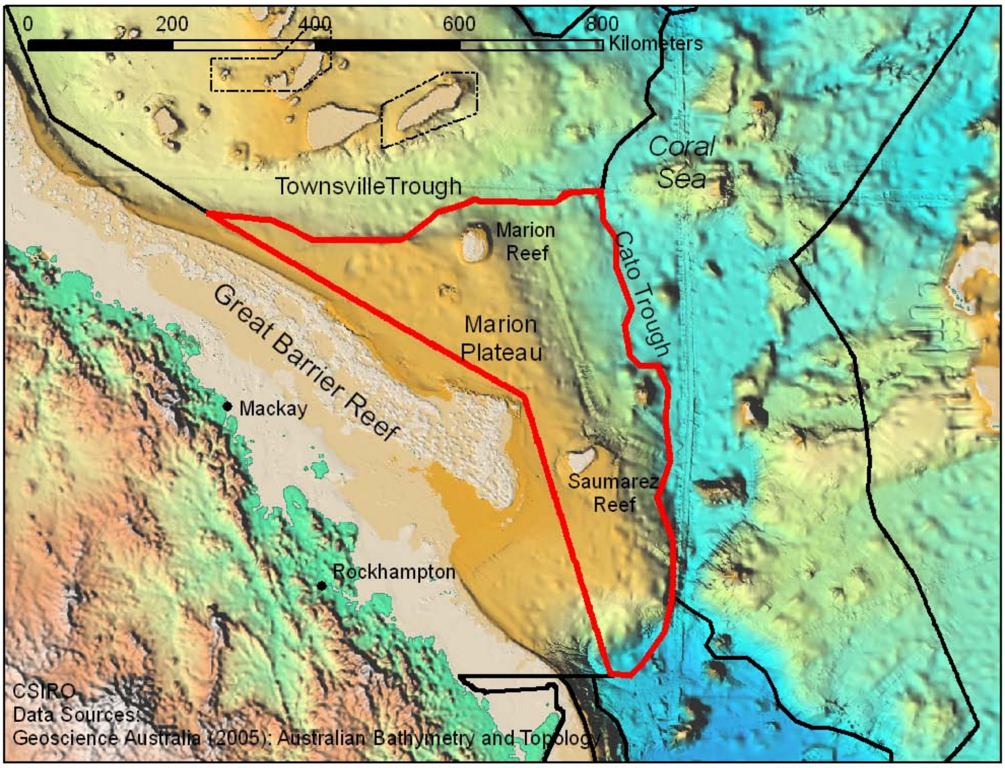
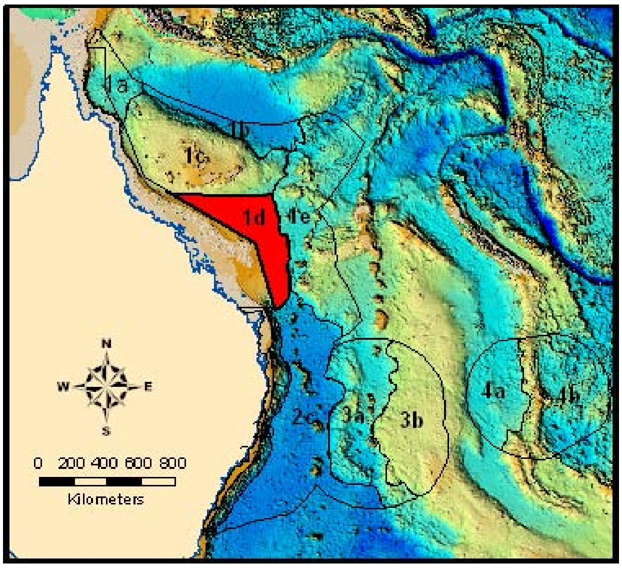
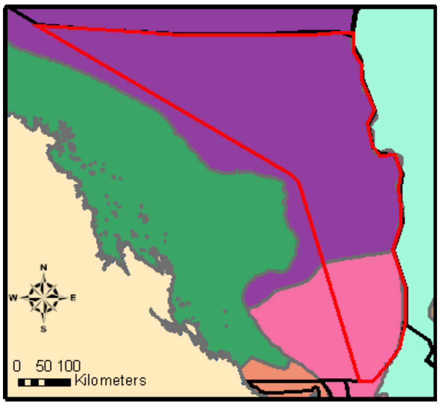


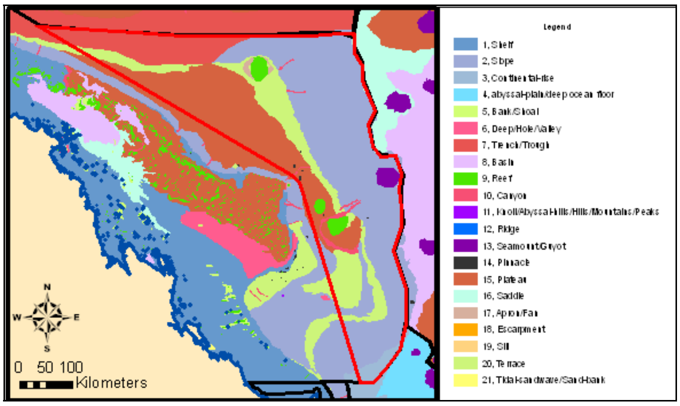
Figure 7-11 Marion Plateau sub-region (1d) showing locations of selected features



a) Location of sub-region 1d



b) Sub-region 1d overlaid on IMCRA Bioregions



c) Sub-region 1d overlaid on Geomorphic Features

Figure 7-12 Marion Plateau sub-region (1d), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.4.2 Important Drivers and Ecological Features

Pelagic

The regular passage of tropical cyclones also heavily influences the sub-region (Appendix 1, Figure 6-12). The effects of these climatic events are variable and have been known to generate wind-driven north-directed current flows in excess of 130 cm/s, which erode the seabed and dictate sediment deposition thus helping to determine community distribution (Larcombe & Carter, 2004). Wind-induced currents are among the strongest currents in the oceanic surface layer, although the platform architecture observed on the Marion Plateau is also strongly influenced by tidal processes (Isern *et al.*, 2002).

Contrary to most east coast sub-regions the strong southerly flow of the EAC, which originates over the Queensland Plateau, does not appear to directly impact upon the inner Marion Plateau. Rather, the EAC is directed around the Marion Plateau causing the formation of a slow flowing clockwise eddy around the structure. Tidal flooding is the principle mechanism for upwelling onto the inner plateau where mean current speed is low (Middleton *et al.*, 2004).

The waters in the Marion Plateau sub-region are oligotrophic, similar to the tropical open ocean waters to the east (Lyne and Hayes 2005). Some isolated pockets of higher surface primary productivity do occur in the sub-region and these are generally associated with reefs or islands.

The important ecological features of the pelagic environment of this sub-region include transient populations of highly migratory pelagic species (notably small fish schools and pelagic predators such as billfish, tuna and sharks) that are the secondary and tertiary consumers in an ecophysical system that is driven by oceanographic processes. While there may be some level of seasonal aggregation or transient attraction to certain areas, there are expected to be very few, if any, ‘resident’ populations. The sub-region is included in the Coral Sea fishery which targets a range of billfish and finfish species which are found over the plateau including; tropical snappers (Lethrinidae, Lutjanidae), surgeon fish (Acanthuridae), and wrasse (Labridae) (AFMA 2007).

Demersal

The Marion Plateau sub-region comprises significant expansive slope habitat (some 161,973 km^2) and several deep sea canyon features that do not appear to be well studied. The sub-region also encompasses one seamount near the eastern border (apparently un-named). These significant deep-sea demersal habitats remain poorly studied and may support deep reef communities. The main drivers of the demersal environment in this sub-region bathymetry, geomorphology (and the related seabed facie) and the supply of nutrient through bottom-currents or fall-out from the pelagic environment.

The shallow reefs of the Marion Plateau are also important ecological features in the sub-region and an important driver for this environment is cyclone activity. Cyclones and the intense winds they generate can create massive waves that break upon the reefs, removing the standing corals and breaking up the physical structure that forms the reef platform (Harmelin-Vivien, 1994).

The sub-region overlaps much of the Northeast Province bioregion and a smaller part of the Central Eastern Transition bioregion described in the IMCRA bioregionalisation (Figure 7-12). The Northeast Province extends from the Marion Plateau to the Queensland Plateau, indicating some connectivity between these two plateaux. The Northeast Province (PB18) was identified as having a high ration of endemic species (70 endemics out of a total of 441 demersal fish species in the bioregion) and indications from sponge data were that demersal sponge communities in this bioregion were distinct from those on the southern GBR (Hooper and Ekins, 2004). The Central Eastern Transition Province (PB15) represents a transitional area between the northern and southern regions and has some 518 demersal fish species and no endemics.

The Marion Plateau sub-region falls within Last *et al.*'s (2005) Northeast Province, a province that was 'strongly' defined based on slope and outer shelf fish assemblages. Of the 441 demersal fish species identified in this province, 243 occurred in depths greater than 200m.

7.4.3 Productivity flows

Productivity flows over the shallow reef areas of the Marion Plateau are poorly understood, however, while they may comprise some endemic species, and being subject to unique physical drivers, are expected to have general productivity flows that are typical of tropical reef environments.

Primary production in the pelagic environment is driven by large-scale oceanic circulation and climate. High levels of production attract transient aggregations of pelagic productivity and zooplankton which in turn may attract larger transient predators. Pelagic secondary consumers such as jellyfish and salps are known to occur in the Coral Sea, as are nektonic secondary consumers such as transient small-fish schools and squid. The main tertiary consumers of interest in the open ocean are transient billfish and tuna and other pelagic predators such as sharks, marine mammals and seabirds that either migrate seasonally or range through the sub-region following prey fish schools.

The benthic environment would be dominated by down-slope transport of sediments/nutrients from the continental shelf and cycling of particulate organic matter (such as marine snow and other falling organic matter and detritus) through bacterial detrital food webs, thus supporting sparsely populated epi-benthic communities of a range of trophic groups similar to those discussed in sub-region 1c. Again, there is expected to be little connectivity between productivity flows in the pelagic and demersal habitats in the deep-sea portions of this sub-region (Figure 7-13), with falling detritus from the pelagic environment (some of which represent falling phytoplankton and zooplankton which are obviously linked to pelagic processes) such as whale-falls, providing the main avenue of linkage. In shallower habitats, there would be expected to be a more direct link and interactions between pelagic and demersal environments. The productivity flows expected on the isolated seamount feature in this sub-region are described in Northern Seamounts Field sub-region.

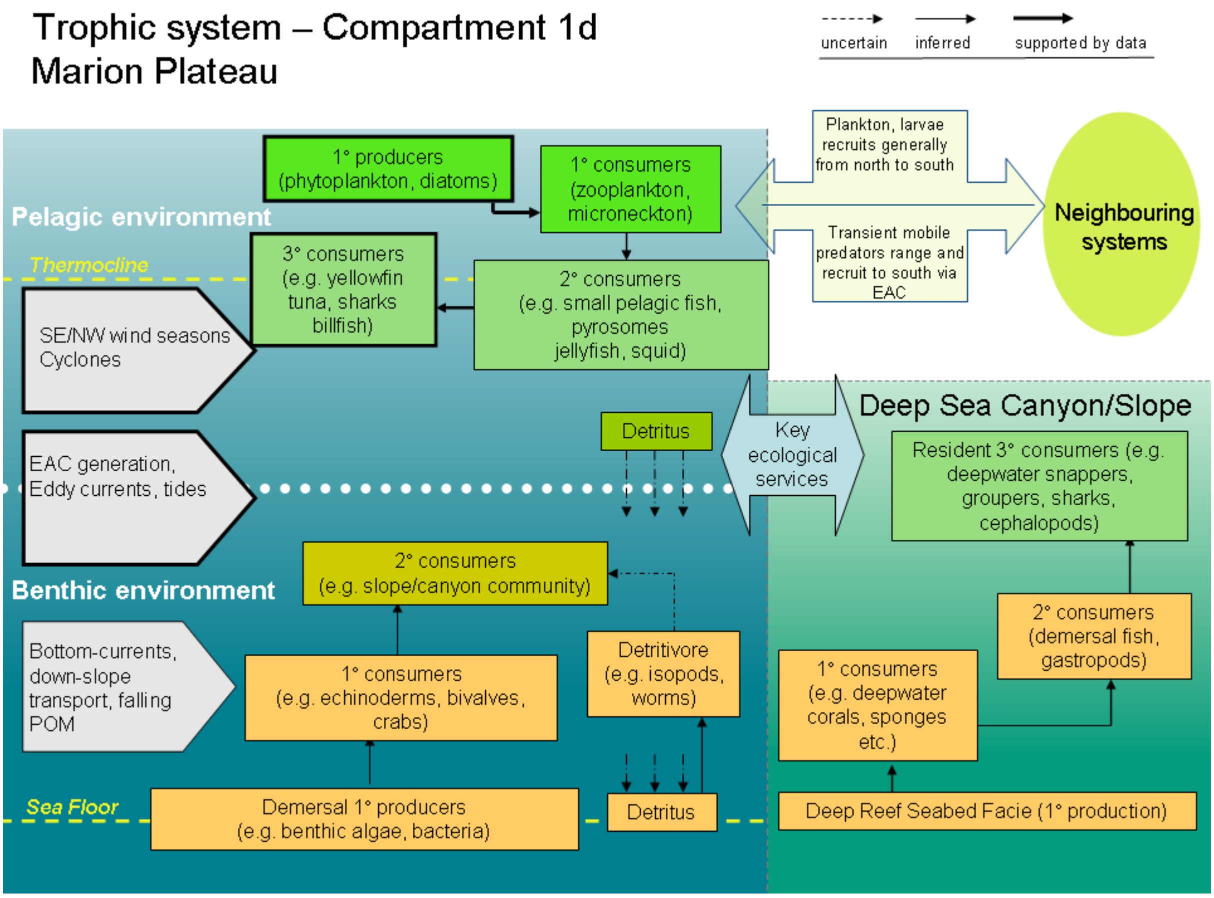


Figure 7-13 Eco-physical model for the Marion Plateau Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Deep sea canyons are important ecological features in this sub-region and are also described.

7.4.4 Connectivity with other Sub-regions

The southerly flow of the EAC is the main avenue of connection between the Marion Plateau and the sub-regions to the north and south. However, as mentioned above, there are large-scale gyre features in this sub-region and in the neighbouring sub-region 1e, possibly causing some faunal retention. The Townsville Trough which separates the Marion plateau and the Queensland plateau in the north may act as a physical barrier between the two plateaux for species with limited dispersal potential. However, previous bioregionalisation combined these two plateau and Last *et al*. (2005) also combined the two sites, suggesting linkages, at least for demersal fish. Connectivity and interactions between the seamount in this sub-region and those in the neighbouring sub-region (Northern Seamounts Field sub-region are unknown.

7.4.5 Interactions with important species and habitats

The Marion Plateau sub-region lies within the previously-identified larger bioregion that contains a high number of endemic species. The expansive slope environment, the occurrence of deeps-sea canyons, the occurrence of a seamount and the presence of isolated, relatively pristine reefs (that appear to be faunistically differentiated from the GBR) all combine to suggest that there is a high likelihood for important species and habitats to occur (Figure 7-13). The shallow reef and seamount environment represent potential areas that support resident, or at least small-home ranging species that are site-attached. Deep reefs, should they occur in the canyons or slope habitats, are known to be sites of high biodiversity and conservation value and potential fisheries focus. In the pelagic environment, the sub-region supports seasonal aggregations of migratory predators over the sub-region which attract a significant recreational fishery targeting black marlin and commercial fishery which targets mainly finfish species such as tuna and snapper (AFMA, 2007). The sub-region, while perhaps not as directly influenced by the EAC and other sub-regions to the south, clearly represents an additional link in the north-south connectivity along the coast.

7.4.6 Vulnerability to impacts and change

Climatic influence of cyclones and oceanographic processes of the EAC are important in this sub-region and subsequently the ecophysical system is vulnerable to impacts to these features. The shallow reef systems, that appear to have similarities with those on the Queensland Plateau but important distinctiveness from the GBR, are especially susceptible to cyclone damage and coral bleaching triggered by increased water temperature change (Oxley *et al.*, 2003). The deep-sea demersal communities lie below the direct influence of climate and current processes in the pelagic environment. These environments are likely to be influenced by interactions with the northward-flowing deep Sub-Antarctic Water Mass and are therefore vulnerable to alterations in this oceanographic feature. The deep benthic and pelagic environments are linked primarily via fall-out of detritus and other organic matter and this process is a crucial factor forcing the abundance and diversity of benthic communities. As such, the benthic environment may be vulnerable to alterations in delivery of pelagic organic matter in addition to purely demersal processes such as down-slope transport of sediments and nutrients and the delivery of nutrients in bottom-currents.

7.4.7 Information gaps

- Interactions between the plateau habitat and surrounding Cato Trough and Townsville Trough and the deep slope environment;
- Communities of the deep-slope, trough, seamount and canyon environments;
- Relationships between the plateau and the GBR;
- Relationships between the seamount in this sub-region with neighbouring seamounts;
- Faunal gyres associated with oceanographic gyres.

7.5 Northern Seamounts Field Sub-region (1e)

7.5.1 Description

The Northern Seamounts Field sub-region (1e) encompasses the northern extension of the generally north-south trending seamount chain (known as the Tasmantid Seamount Chain) (Figure 7-14), the southern extent of which is contained within the Southern Seamounts Field sub-region. This seamount chain lies to the west of another seamount chain that forms the Lord Howe Rise seamounts; the northern extent of which is beyond the Australian EEZ. The southern margin of the Northern Seamounts Field (mean depth = 2683 m) is delineated based on the bathymetric break between this and the deeper basin in which the Southern Seamounts Field lies (mean depth = 4563 m). This boundary between the Northern and Southern Seamounts fields also coincides roughly with the division of surface ocean water masses 1b_P17 in the north and 1b_P13 in the south (see Lyne and Hayes 2003). The Northern Seamounts Field sub-region is bordered to the west by the Marion Plateau (1d) and the Queensland Plateau (1c) sub-regions (Figure 7-15).

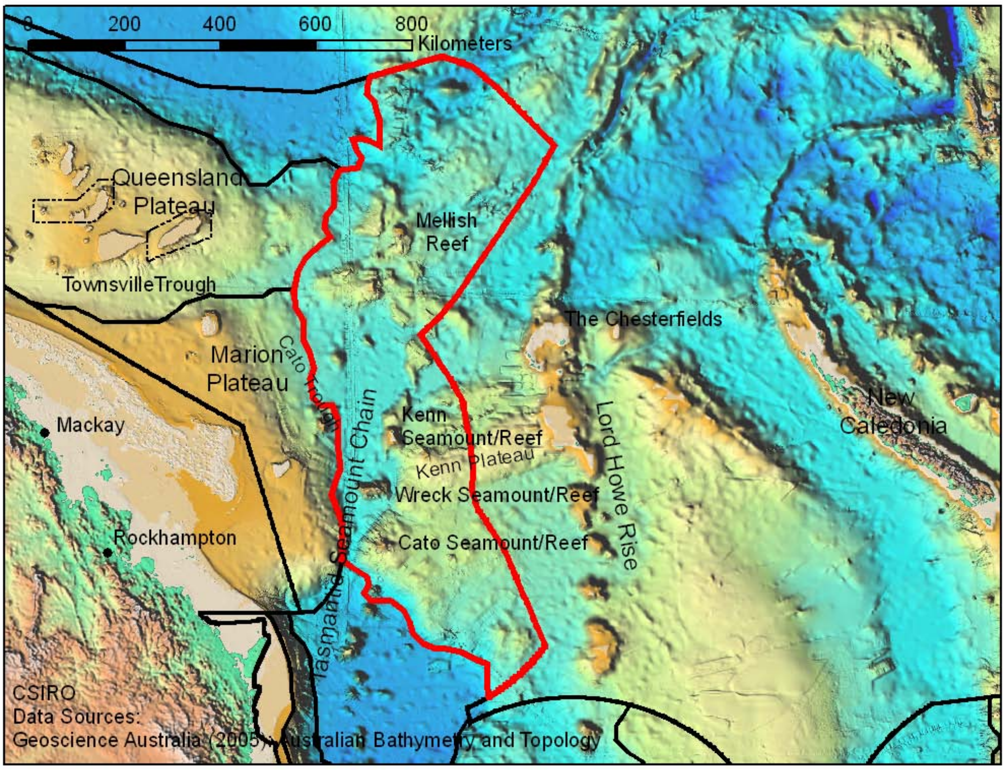
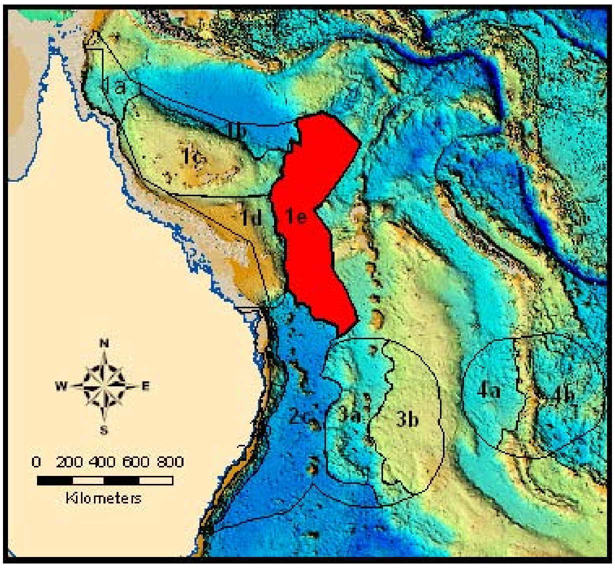
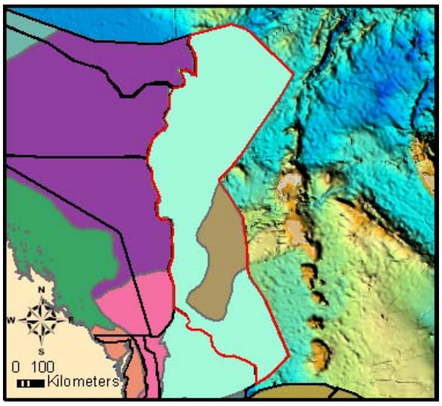


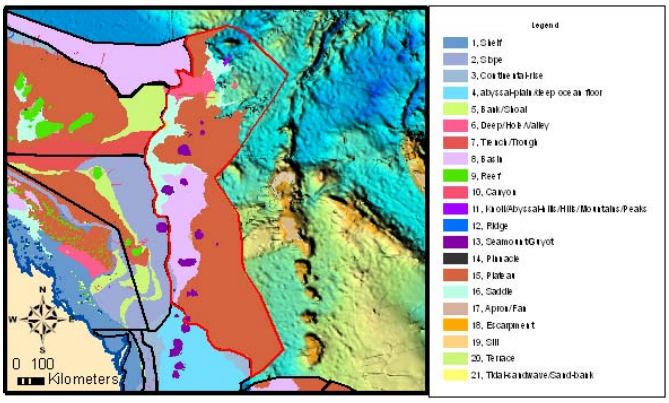
Figure 7-14 Northern Seamounts Field sub-region (1e) showing locations of selected features



a) Location of Sub-region 1e



b) Sub-region 1e overlaid on IMCRA bioregions



c) Sub-region 1e overlaid on geomorphic features

Figure 7-15 Northern Seamounts Field sub-region (1e), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it’s boundaries in relation to the geomorphic features map.

This sub-region overlaps with two existing IMCRA bioregions; Kenn Province (PB17) and Kenn Transition (PB16) (Heap *et al.*, 2005) (Figure 7-15). The plateau feature entering the sub-region at approximately 22°S latitude is known as the Kenn Plateau (Harris *et al.*, 2003). Approximately 100,000 km^2 of the Kenn Plateau occurs in Australian waters. Sub-region 1e encompasses Bird and Cato Islands, Kenn Reef, Wreck Reef and Mellish Reef. Some of these features are of volcanic seamount origin and the notable seamounts in the sub-region are Cato Seamount, the Wreck Seamount and the Kenn Seamount (Exon *et al.*, 2006) (Figure 7-14).

7.5.2 Important Drivers and Ecological Features

Pelagic

The Northern Seamounts Field sub-region lies mostly within tropical Coral Sea waters (Level 1 Water Mass P17) (Lyne and Hayes, 2005) with a mean surface temperature of 25.31°C. It also lies within the area of zonal westerly inflow of the Southern Equatorial Current. However, there is some indication that in the southern corner of this sub-region, near the border of the Southern Seamounts Field sub-region (2c) and the Marion Plateau sub-region (1d), there is some eddying or gyre feature that creates an area of sea surface height elevation (Figure 6-3). This coincides with the areas of Cato Island and Kenn Reef. Coarse-scale surface current data and bathymetry indicate that that this may be influenced by the principal factors:

- Southerly EAC flow coming off Marion plateau;
- Southerly EAC being supplemented by tidal flow from the Great Barrier Reef;
- Interaction between this southerly flow and the bathymetric break points at the junctions of the three sub-regions: southerly end of the Marion Plateau (1d), northern end of Southern Seamounts Field (2c) and southern end of Northern Seamounts Field (1e).

The interaction between this potential oceanographic gyre (or at least variable) feature and the seamounts off Fraser Island in the Southern Seamounts Field is believed to create conditions that are responsible for billfish aggregations around those seamounts (J. Young, *pers. comm.*) (see Southern Seamounts Field sub-region, 2c). While data for the Northern Seamounts Field are scarce, similar conditions may occur in sub-region 1e, and would be probably driven by the creation of temporary surface current fronts that may cause the aggregation on plankton which in turn aggregates transient secondary and tertiary consumers.

The interaction between currents and zooplankton abundance (and ultimately fish productivity) has been demonstrated for at least shallow areas adjacent to Cato Reef (Rissik *et al.,* 1997). Although surface-level primary productivity is generally low in this sub-region based on satellite interpretation of surface waters, and believed to be nutrient-limited, there is potential for enhanced primary productivity in sub-surface waters that is not captured by satellites. Rissik *et al* (1997) identified a nutricline and chlorophyll maximum at 80-100 m off Cato Reef, a feature that was believed to be related to the flow-disturbance effect of the island. Lyne and Hayes (2005) noted that the tropical waters of the Coral Sea, in general, have the highest concentration of phytoplankton in a deep chlorophyll-maximum layer in a nutricline at about 60-140 m, within which chlorophyll levels (and primary production) peak from June – August, which may be attributable to the increase in southeast trade winds during this time.

The chlorophyll concentrations in the flow-disturbed areas studied by Rissick *et al* (1997) were approximately 1.4 times greater than those in the non-disturbed current streams (which, interestingly, were northward). Peak zooplankton abundances were related to these maxima and calenoid copepods dominated (Rissik *et al.*, 1997), leading the authors to postulate that such current flow disturbance may drive nutrient uplift into surface waters which may be important to nutrient regime in the oligotrophic ocean, having a significant impact on zooplankton size structure and, in turn, fish productivity. However, Suthers *et al*. (2006) found that there were fewer reef fish larvae in the island-wake than the free-flowing stream, and suggested that reef settlement and/or predation may be the cause of this pattern. Non-reef-associated fish taxa dominated the larval fish assemblage in that study. In a further study at Cato Reef, Rissik and Suthers (2000) found that post-larvae and juveniles of two myctophid fishes (common pelagic species) fed more successfully in the island-wake region compared to the free-flowing stream. In the island-wake region, prey concentrations were up to 50% greater, and were centred around the thermocline (30-70 m). This lends support to the notion that island-induced disturbance and nutrient up-lifting (and therefore, possibly other current disturbance drivers), may an important driver of pelagic food webs.

Many of the observations of seamount pelagic systems come from studies in the Southern Seamounts Field and these are described in that sub-region section (2c). It is likely that many of the pelagic processes that drive, for example, billfish aggregations in the Southern Seamounts Field sub-region would also occur in the Northern Seamounts Field sub-region if the appropriate pre-conditions exist (e.g. depths at the tops of seamounts). Indeed, Kenn Reef and Wreck Reef are areas where game fishing charters target large pelagic predators such as billfish, tuna (with apparent large catches of dogtooth tuna, *Gymnosarda unicolor*) and giant trevally, *Caranx ignobilis*).

Demersal

The Northern Seamounts Field sub-region overlaps with the Kenn Province IMCRA bioregion and also includes the Kenn Transition Province. While no demersal fish community data were reported in the IMCRA bioregionalisation for these two bioregions, they were identified as encompassing areas that had close faunal affinities to New Caledonian fauna or represent zones of mixing between the two faunas (Heap *et al.*, 2005).

The IMCRA bioregionalisation indicated that seamounts in the north would be likely to have different faunal communities from those in the south and may also have endemic species, possibly because of the sharp bathymetric break between the two zones and the potential barrier effects of the Cato Trough, which runs in a north-south direction to the east of the Marion Plateau (Heap *et al.*, 2005). However, O'Hara (2007) found that brittle star fauna (Family Ophiuroidae) did not exhibit marked richness or endemism on Tasmantid Seamounts in both the northern and southern regions compared to neighbouring continental slope habitats. Attention in recent years has turned to genetic evidence for endemism and Samadi *et al*. (2006, in Poore and O'Hara, 2007), for example, suggest that seamounts may be 'oases' of high productivity rather than centres of endemism in some cases.

Much of the information available for the Tasmantid Seamounts originates from the southern region and this was described in Southern Seamounts Field (2c) - and the general demersal ecological features described in that section are expected to hold true for the northern seamounts.

Seamounts actually comprise a relatively small area in this sub-region which is actually dominated, in terms of area, by plateau habitat, which occupies some 180,000 km^2. This includes the Kenn Plateau. There is a paucity of data on demersal ecological features of this plateau, but, considering the mean depth of this plateau (approximately 1,500 m) is similar to that of the Queensland Plateau (albeit with fewer coral cays and islands), demersal ecological features may have some similarities.

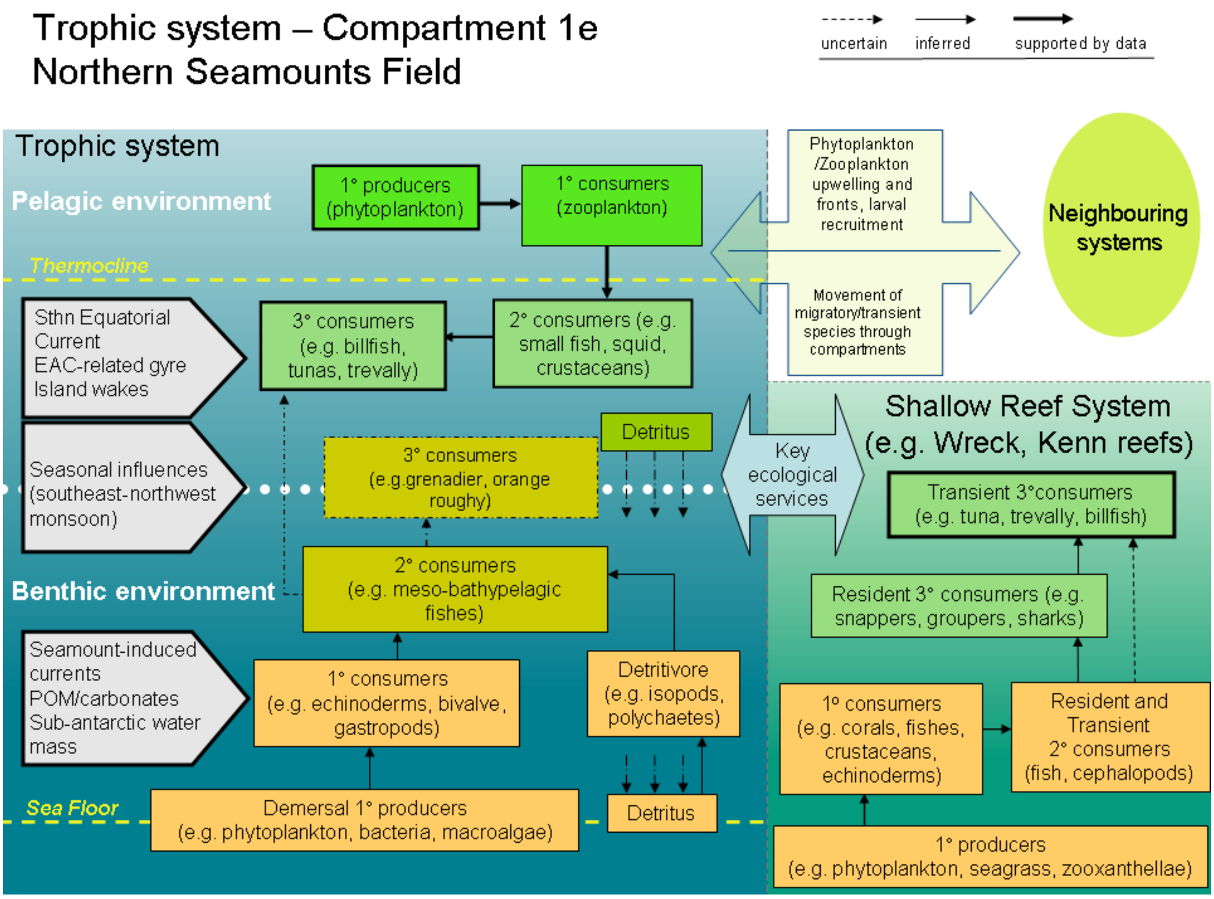


Figure 7-16 Eco-physical model for the Northern Seamounts Field Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Shallow reefs are important ecological features in this sub-region and are also described.

7.5.3 Productivity flows

In the pelagic environment, upwelling and island wakes have been found to influence primary productivity in the euphotic zone that in-turn can stimulate phytoplankton production above background values, leading to zooplankton aggregations, which attract planktivorous consumers including squids (Landsell and Young, 2007) and fishes such as anchovies (Engraulidae), lanternfishes, small carangids and, in-turn, transient pelagic predators such as billfish and tunas. This process, in sub-region 1e, appears to be influenced by seasonal variation in the Southern Equatorial Current that is the dominant oceanographic feature in the open Coral Sea. Lyne and Hayes (2005) describe the general pattern of increased productivity in June-August, possibly associated with increased mixing between surface waters and higher-productivity deep waters due to the onset of the southeast trade wind season. The upwelling or gyre features at the southern corner of sub-region 1e may also exert some influence on these productivity processes.

In the relatively featureless deep seafloor environment, seamounts, the hard substrates and topographically induced oceanographic phenomena provide refugia for prey species and consequently feeding locations for associated predators (Richer de Forges, 2000; Hixon and Beets, 1993; Norse and Crowder, 2005). The abundance of demersal seamount life and distinctive oceanographic phenomena attract highly migratory pelagic predators including cetaceans, seabirds, sharks, tunas (Young *et al.,* 2001) and billfishes (Young *et al.,* 2003; Norse and Crowder, 2005). Again, the vast majority of data available for seamounts comes from studies of seamounts located offshore of Fraser Island and further south, described in Southern Seamounts Field (2c). However, it is expected that at principal processes and ecological features in the southern areas would apply to the northern seamounts. One important difference between the southern and northern seamounts is that the most notable seamounts in the Northern Seamounts Field sub-region extend all the way to the surface and are capped by island or reefs. As such, these seamounts may act, effectively, as ‘slope’ environment at depth and ‘shallow reef’ habitat in the shallows and, therefore, may not have the some ecological features that occur at the ‘apex’ of the southern seamounts.

The supply of carbonates, principally of pelagic origin, appears to exert some control on the seabed facies of the deep sea floor environment of the Kenn Plateau (Exon *et al.,* 2006) and possibly other areas of the Northern Seamounts Field sub-region. The Cato Trough, which lies along the western edge of sub-region 1e, may be expected to have a benthic environment comprised of fine, soft-sediments and, if so, productivity flows in these very deep, isolated habitats, may be similar to those described for the Coral Sea Abyssal Basin (1b), that is, driven principally by particulate organic matter and infaunal/epifaunal detrital processes.

7.5.4 Connectivity with other Sub-regions

Implicit in the previous bioregionalistion of the sub-region (Kenn Province and Kenn Transition Province), was the notion that there is some connection between this area and New Caledonia. Within the Australian EEZ, given the position of this sub-region within the Coral Sea water mass (P17 and P20), the Northern Seamounts Field sub-region is likely to have connectivity with neighbouring sub-regions 1d, 1c and 1b in particular. The main avenue for this connectivity is through the movements of transient pelagic predators that are highly mobile and range through feeding areas with elevated chlorophyll concentrations (Block *et al.,* 2002; Hyrenbach *et al.,* 2002; Polovina *et al.,* 2000), moving quickly across expanses of oligotrophic waters. Food-rich patches are often transitory, disappearing when frontal discontinuities break down or prey reduction by predators. Such frontal discontinuities are often related to upwelling or mixing of water bodies and, as such, may occur less frequently in this sub-region that, for example, the more southern seamounts sub-region where interaction between the EAC and the Tasman front may set-up these conditions more often. However, in the Northern Seamounts Field sub-region, such conditions might be expected to occur where islands or seamounts interact with currents.

The other avenue for connectivity with other sub-regions is via dispersal of larvae in a westerly direction from the Queensland Plateau, Marion Plateau and, possibly, the Great Barrier Reef, providing a possible larval source to reefs in the sub-region. While current systems would appear to make such connection possible, the survival of larvae and subsequent colonisation on sub-region 1e reefs is unknown and is likely to be limited by the long-distances involved.

The potential for connectivity between seamounts in this northern sub-region and those in the southern sub-region, both for pelagic and demersal species, is uncertain. However, the lack of genetic differentiation between at least one group of demersal species (brittle stars) between these two areas suggests at least some possibility of connectivity (O'Hara 2007).

It is postulated here that the connectivity between this sub-region and other sub-regions may not be direct southern connection due to the EAC, because the southerly stream of the EAC at this latitude (and further south) is typically confined closer to the mainland. Rather, the connectivity may be based on westerly current flow off the Queensland and Marion plateaux and possibly, to a lesser extend, off the Great Barrier Reef. In addition, while oceanographic data are coarse-scale, northerly circulation of surface waters, related to possible gyre motions in the area of the southern corner of this sub-region (and northern corner of the Southern Seamounts Field sub-region), may also form the basis of some connectivity. In bottom-waters, northerly movement of the Sub-Antarctic Water Mass may also provide the basis of some connectivity between this sub-region with the Southern Seamounts Field sub-region.

7.5.5 Interactions with important species and habitats

Seamounts are known to be biomass hot spots because they often induce leeward plumes of elevated productivity due to localized upwelling (the island wake effect) (Norse and Crowder, 2005). Even in the absence of upwelling, seamounts might support high animal biomass because they offer a hard seabed facie and therefore, potentially a structurally complex habitat. This allows resident fishes both to feed on passing zooplankton and small fishes, such as lanternfishes and Myctophidae, in the water column and to take refuge amidst seamount structures. The level of endemism among the northern seamounts is unknown and the predictions of high endemism (e.g. Richer de Forges *et al.*, 2000) that often arise from limited ecological sampling and inferences from local eddying structures around seamounts, may or may not hold as genetic studies continue.

The shallow reef systems in the sub-region (Kenn Reef, Wreck Reef, Cato Reef) are remote and apparently, relatively pristine. Some recreational sport-fishing charters target these areas and they appear to have a reputation for large pelagic predators and pristine conditions. The remoteness of these reefs likely affords some protection of these areas from commercial fishing.

7.5.6 Vulnerability to impacts and change

The level of commercial fishing on seamounts in the Northern Seamounts Field sub-region appears to be lower than that in the Southern Seamounts Field and thus, potential impacts of commercial fishing on large pelagic species and trawl impacts on demersal habitats would appear to be lower. There is a Coral Sea Fishery (CSF), an exclusively demersal fishery, which encompasses Wreck, Kenn Cato and Mellish reefs, in which the methods of demersal longlines, trotlines, droplines, fishtraps, demersal otter trawls and sea cucumber harvesting are carried out. Fishing permits in the Coral Sea Fishery prohibit the taking of fishes in the Scombridae family (except genera *Scomberomorus*, *Scomber*, *Acanthocybium*, *Gymmatorcynnus* and *Rastrelliger*) (i.e. mackerels) and fishes in the families Istiophoridae and Xiphiidae (i.e. billfish). The Eastern Tuna and Billfish Fishery (ETBF) is a pelagic fishery that overlaps with the CSF in the Coral Sea. Therefore, some fisheries impacts are possible for some species.

The controlling physical factors described above indicate that the ecophysical processes in this sub-region are vulnerable to alterations in trade winds (timing, strength and duration). Oceanographic features such as island wakes, transient oceanographic fronts and gyre systems which may be generated by the formation and transport of the EAC are also important in this sub-region and therefore there is vulnerability to changes to these drivers. The influence of the northward-flowing Sub-Antarctic Water Mass is unclear, but is likely to interact significantly throughout this and neighbouring sub-regions and possibly exerting some influence on demersal habitats and ecology. Therefore, alterations to this oceanographic feature may have flow-on effects for ecophysical processes.

Hobday *et al*. (2006) outline the potential direct and indirect impacts of client change on a variety of marine organisms and systems and many of these relate to sub-region 1e, including coral reefs, deep-sea cold water reefs, zooplankton, phytoplankton etc.

Processes that maintain seabed facies are believed to be important in deep-sea environments, that are relatively stead-state and therefore, generally, vulnerable to change. Demersal ecophysical processes may be vulnerable to changes in, for example, supply of pelagic-derived carbonates and down-slope transport of particulate organic matter that forms the basis of some trophic systems.

7.5.7 Information gaps

The amount of knowledge regarding the physical and biological drivers of seamounts remains sparse in relation to continental shelf and slope communities and those in the Northern Seamounts Field appear to be less studied than those in the Southern Seamounts Field. The IMCRA bioregionalisation process identified data gaps in terms of demersal fish communities and other features and, probably due to its remoteness, the area remains largely under-studied.

The primary data gaps, as they relate to an understanding of the ecophysical processes, appear to be:

- Seamounts – ecology and fine-scale oceanography;
- Oceanographic connectivity;
- Resident fish assemblages – shallow- and deep-water;
- Potential endemicity of species with limited larval dispersal;
- Potential for unique shall- and deep-water habitats/biomes.

7.6 Eastern Shelf Sub-region (2a)

7.6.1 Description

The Eastern Shelf sub-region (2a), is located on the eastern Australian shelf and is demarcated by the southerly limit of the Great Barrier Reef Marine Park, the Central Eastern and South-east slope regions on its eastern edge and to the south the East Marine Region's southern boundary (Figure 7-17).

It overlaps the existing IMCRA bioregions PB37 (Southeast IMCRA Transition), PB38 (Central Eastern IMCRA Province) and PB39 (Central Eastern IMCRA Transition) (Figure 7-18). The sub-region lies in warm temperate waters (PB39) with transitional water masses to the north (tropical - warm temperate, PB39) and south (warm temperate – cold temperate, PB37) (Heap *et al.*, 2005). The Central Eastern IMCRA Transition (PB39) is defined by a region of numerous coral reefs and banks at the southern tip of the Great Barrier Reef (Figure 7-18).

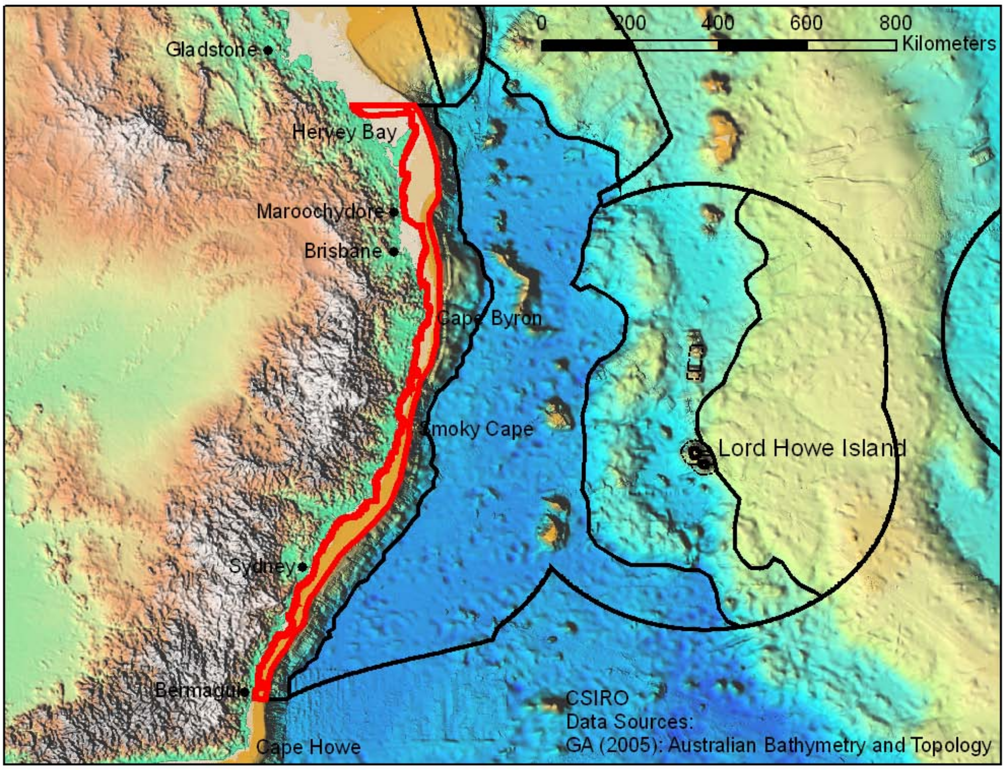


Figure 7-17 Eastern Shelf sub-region (2a) showing locations of selected features

7.6.2 Important Drivers and Ecological Features

Pelagic

The main driver of this sub-region is the Eastern Australian Current (EAC). While the EAC remains relatively stable along the east coast, nutrient enrichment can occur due to the EAC's movement along and away from the shelf causing upwelling of nutrient-rich, cool water onto the shelf, again resulting in phytoplankton growth and increased primary production. A region of relatively predictable upwelling is known to occur in the region between Cape Byron and Smokey Cape in NSW (Ridgway, *pers. comm.*).

The region is also subject to seasonal mixing patterns. In winter, convective overturn and wind mixing recharges nutrient levels in the surface waters which, along with increased solar radiation approaching summer, which causes an increase in phytoplankton growth rates in the shallow mixed layers.

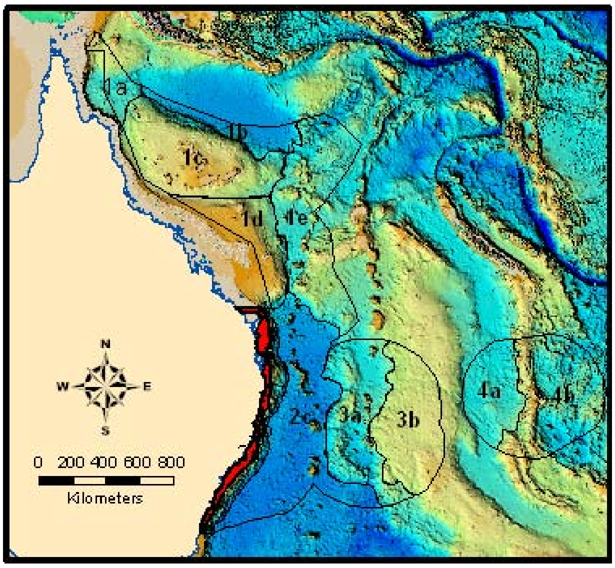
The sub-region overlaps with significant transitions zones (or biotones) which represent the major termination zone for many northern tropical and temperate species. Major pelagic species disjunctions have been identified just north of Brisbane (Maroochydore), near Byron Bay, Sydney, Bermagui and Cape Howe (IMCRA 3.3, 1998).

Demersal

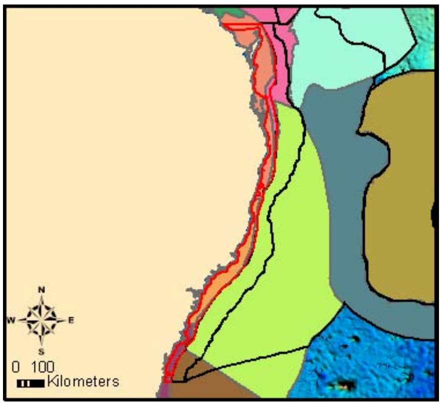
The northern sections of the subregion is characterised by a series of strong species 'disjunctions', forming the basis for the IMCRA4 Central East Shelf Transition bioregion. Principal internal disjunctions occur between Gladstone and Bundaberg where a suite of tropical species radiate southward. Another disjunction occurs between the region south of Hervey Bay to Maroochydore where the distributions of a suite of southern species ceases. The southern limit of this transition zone also coincides with a major disjunction between tropical and warm temperate species. The southern part of the sub-region overlaps with the Central East Shelf Province which contains indicator species as listed in Table 7-1.

7.6.3 Productivity flows

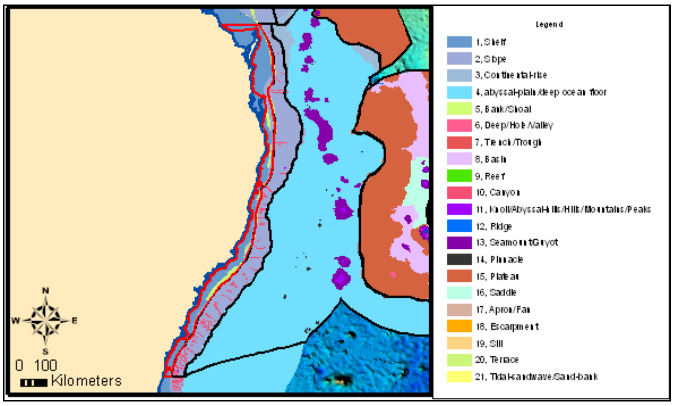
Phytoplankton biomass and primary production are nutrient-limited in this sub-region. South of the Tropic of Capricorn, down to the southern headland of Moreton Bay, subtropical water masses have distinctive seasonal growth and production patterns. Highest production occurs between August and November (Lyne and Hayes, 2005), peaking in October (Ridgway, *pers. comm.*), leading to eventual nutrient exhaustion in the euphotic zone and a reduction of primary production from November to February. Light may also be a limiting factor to phytoplankton growth in the southern end of the region in the winter.



a) Location of sub-region 2a



b) Sub-region 2a overlaid on IMCRA bioregions



c) Sub-region 2a overlaid on geomorphic features

Figure 7-18 Eastern Shelf sub-region (2a), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it’s boundaries in relation to the geomorphic features map.

Table 7-1 Indicator Species within Central Eastern Province (CEP) (IMCRA 3.3, 1998).

Species name	Common name	Authority
Urolophus sufflavus	Yellowback Stingaree	Whitley, 1929
Myxus petardi	Freshwater Mullet	Castelnau, 1875
Craterocephalus honoriae	Estuarine Hardyhead	Ogilby, 1912
Parma unifasciata	Girdled Parma	Steindachner, 1867
Trygonoptera testacea	Common Stingaree	Muller and Henle, 1841
Aptychotrema rostrata	Eastern Shovelnose Ray	Shaw and Nodder, 1794
Crinodus lophodon	Rock Cale	Gunther, 1859
Austrolabrus maculatus	Black-Spotted Wrasse	Macleay, 1881
Heteroclinus whiteleggii	Whitelegg's Weedfish	Ogilby, 1894
Brachaelurus waddi	Blind Shark	Bloch and Schneider, 1801
Hyporhamphus australis	Eastern Sea Garfish	Steindachner, 1866
Cochleoceps orientalis	Eastern Clinger-Cleanfish	Hutchins, 1991
Urolophus sp A	Sinclair's Stingaree	in Last and Stevens, 1994
Acanthistius cinctus	Yellowbinded Wirrah	Gunther, 1859
Scorpis violaceus	Blue Maomao	Hutton, 1873
Asymbolus analis	Australian Spotted Catshark	Ogilby, 1885
Acanthistius paxtoni	Striated Wirrah	Hutchins and Kuiter, 1982
Notolabrus inscriptus	Green Wrasse	Richardson, 1848

Planktonic communities in the regions experience species successions from small diatoms (*Asterionellopsis, Pseudonitzschia*, *Skeletonema, Thalassiosira*), to large diatoms (*Detonula, Ditylum*, *Eucampia*) to larger dinoflagellates (*Ceratium*, *Protoperidinium*) over spring and summer (Hallegraeff & Jeffrey, 1993; Hayes et al., 2004). Coastal upwelling results in short-lived diatom blooms (days to weeks) and associated zooplankton production, such as copepods and euphausiids, within the nutrient-rich euphotic zone which is critically important for larval recruitment of both pelagic and benthic fish (Bulman et al., 2006; Hayes et al., 2005). Bulman et al. (2006) describes the majority of the transfer between phytoplankton and fish occurring via a diatom to meso- and macrozooplankton to fish pathway.

The major commercial and quota fishes (tuna and billfish) feed largely on pelagic and benthopelagic prey, particularly fish but also a variety of invertebrates, e.g. copepods, euphausiids, ostracods, hyperiid amphipods, crab larvae, pelagic gastropods and gelatinous zooplankton (Bulman *et al*., 2001; Young and Blaber, 1986; Young *et al*., 1996). It is suggested that as a result of this transfer, the nutrient-rich shelf-break upwellings might have significant effects on fish distribution.

7.6.4 Connectivity with other Sub-systems

There is probably some connectivity between this subregion and the Eastern Slope sub-region (2b) on its eastern border due to adjective mixing processes such as the eddy systems associated with the EAC transporting water across the shelf edge. There is also most likely some movement of fish populations between waters of the continental slope (>40m depth) and outer shelf (Last *et al.*, 2005; Bulman *et al*., 2006). However, strong offshore environmental gradients caused by riverine input, water depth and upwelling processes, coupled with alongshore EAC mean the shelf subregion has a strongly unique biogeography from adjacent subregions.

As previously discussed, primary productivity and phytoplankton biomass drive secondary and tertiary consumers. Bulman *et al*. (2006) noted that small mesopelagic fishes that support the slope and shelf break fishes were imported into the area largely through the process of diel vertical migration causing them to be washed up from neighbouring sub-systems.

7.6.5 Interactions with important species and habitats

The subregion is penetrated by tropical eastern Australian species, many occurring at the limits of their known ranges as juveniles. It also contains the north-eastern limit of a large suite of widespread southern temperate species that extends from south east marine regions. Species within this province are also represented at Lord Howe Island and Norfolk Island.

This subregion contains the southernmost extent of true coral reefs, with the southernmost examples being in the Solitary Islands.

7.6.6 Vulnerability to impacts and change

The climatic influence of the northwest-southeast wind seasons and oceanographic processes resulting in the bifurcation of the Southern Equatorial Current are critical to driving the EAC/eddy field in this sub-region as described in studies of an area sometimes referred to as the 'Tasman Sea Box' (Ridgway, *pers. comm.*; Sprintall *et al*., 1995), .extending from Australia to New Zealand at 36° and 43°S. Therefore, the ecophysical system is vulnerable to impacts to these physical features and sea surface temperature.

In terms of impacts on the fishery in this region, Goldsworthy *et al*. (2003) notes the recovery of seals as an influence likely to shape the South East Fishery (SEF) ecosystem. While Bulman *et al*. (2006) suggests that current proposals to reduce or even eliminate discarding in the trawl fishery are also likely to have implications on the trophic dynamics of the SEF.

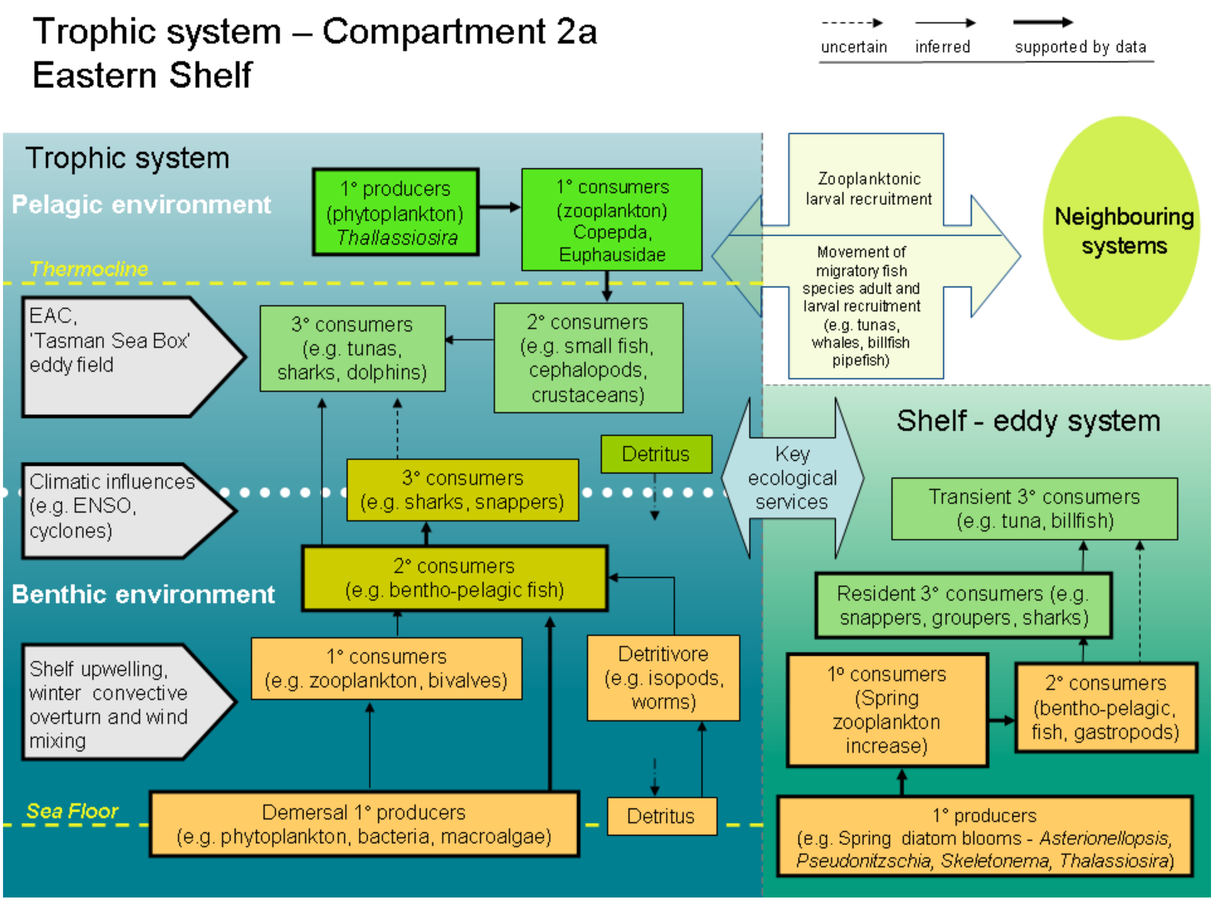


Figure 7-19 Eco-physical model for the Coral Sea Abyssal Basin Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Shelf eddies are important ecological features in this sub-region and are also described.

7.6.7 Information gaps

Studies on the dispersal range and effects of sewage outfalls may need to be addressed in order to verify whether increasing coastal populations are producing a knock-on effect within the EEZ.

7.7 Eastern Slope Sub-region (2b)

7.7.1 Description

The Eastern Slope subregion (2b), covering 81,691 km^2, is located on the eastern edge of the Eastern Shelf compartment (2a) and is bounded to the north by the southerly limit of the Great Barrier Reef Marine Park, the Southern Seamounts Field compartment (2c) to the east and to the south by the East Marine Region's southern boundary (Figure 7-20, Figure 7-21).

It overlaps the existing IMCRA4 Provincial Bioregions PB15 (Central Eastern Transition), PB12 (Central Eastern Province) and PB11 (Southeast Transition) (Figure 7-21). The majority of the Eastern Slope lies in warm temperate waters (PB12) with transitional water masses in the north (tropical - warm temperate, PB15) and south (warm temperate – cold temperate, PB11) (IMCRA4, 2006).

The upper slope is dominated by a series of submarine canyons including the Tweed and Richmond Canyons on the continental slope in northern NSW, between 28° and 29° S (Harris *et al.*, 2003; Figure 7-21).

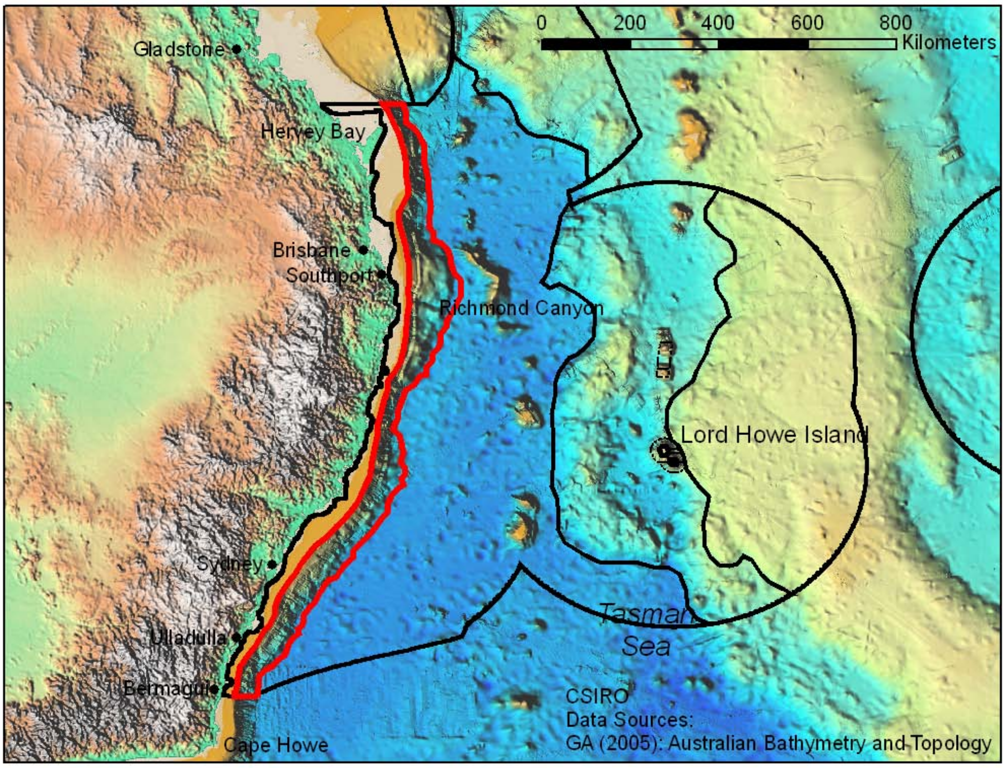
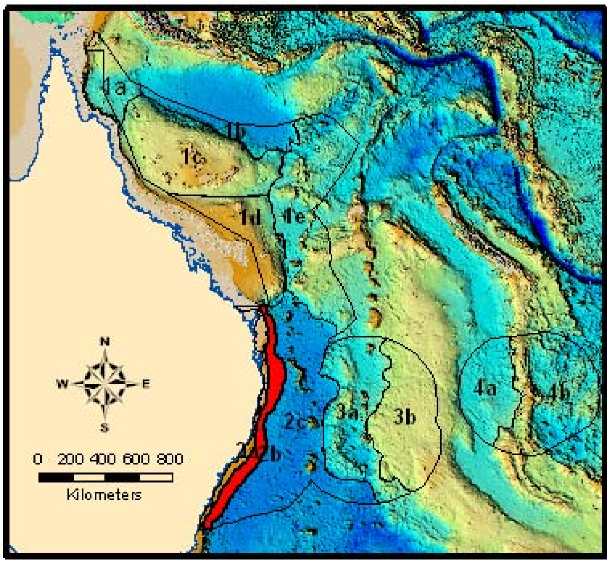
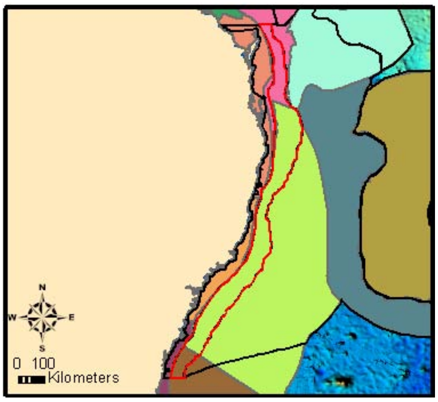


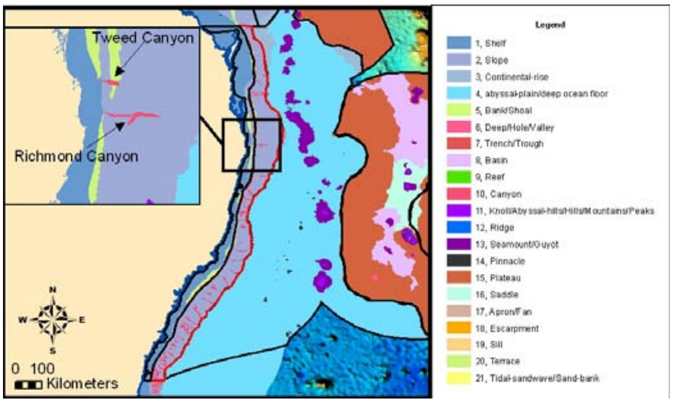
Figure 7-20 Eastern Slope subregion (2b) showing locations of selected features



a) Location of sub-region 2b



b) Sub-region 2b overlaid on IMCRA bioregions



c) Sub-region 2b overlaid on geomorphic features

Figure 7-21 Eastern Slope sub-region (2b), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.7.2 Important Drivers and Ecological Features

Pelagic

The Eastern Slope is situated within the Pacific Central-South Subtropical Water Mass 1b_P13 (Lyne and Hayes, 2005; Figure 6-14). The Coral Sea Circulation contains the Eastern Australian Current, the western boundary current in the South Pacific Ocean. The EAC follows the coast to its southern boundary (32° -34°S) in the southern section of this sub-region, where the main component separates eastwards traversing the Tasman Sea (Figure 6-1) to become the Tasman Front. Poleward of this separation point, a portion of the current remains connected to the coast and continues southward past the east coast of Tasmania (Ridgway and Dunn, 2003).

The sub-region is also influenced by Rossby speed eddies that are shed of the southern boundary of the Tasman Front. As these eddies travel southward they may be consumed and integrated within the EAC or remain as separate entities. Associated with the vertical motions in the eddy core are patterns of divergence and convergence, in the horizontal flow field (Figure 6-6), which can concentrate nutrients and planktonic organisms, similar to frontal convergences (Bakun, 2006). As these eddies approach the slope region nutrient upwelling occurs and these nutrient inputs are then concentrated within the eddy cores creating chlorophyll hotspots (Bakun, 2006). Initial enrichment is directly followed by convergence and concentration of the products of that enrichment, which are then retained within the eddy along with any fish larvae that may have been spawned within the eddy by opportunistically feeding nektonic adults (Bakun, 2006). These eddy motions are therefore able to produce peaks in biological productivity and reproductive success.

Nutrient cycling also occurs through seasonal mixing patterns. During winter, convective overturn and wind-induced upwelling currents recharges nutrient levels in the surface waters. Surface waters tend to cool during winter and increase in density, causing them to sink. The resulting convective currents break down the shelf-edge fronts and bring deeper nutrient-rich water up into the euphotic zone, promoting phytoplankton blooms. This provides enhanced opportunities for feeding, which supports breeding aggregations and provides the enriched conditions critical for enhancing larval survival (Prince, 2001). In summer, increased solar radiation causes an increase in phytoplankton growth rate in the shallow mixed layers. As the EAC moves along and away from the continental shelf and slope, upwelling draws nutrient-rich, cool water over the slope and onto the shelf, which also results in increased phytoplankton activity and increased primary production.

Demersal

Little is known of the drivers of the demersal ecosystem along the Eastern Slope. It may be assumed that the drivers within the pelagic system also have an effect upon the demersal environment, that is, the various nutrient enrichment and resultant peak productivity events caused by convective overturn, eddies and the southbound EAC flow lead to an eventual downward flow of energy, e.g. settling of detrital matter. In the IMCRA4 bioregionalisation, Last *et al*. (2005) identified strong distinctiveness in the structure of demersal outer shelf and slope fish assemblages (40 to 2000 m) and this distinctiveness implies evolutionary relatedness and some likelihood of endemism among the fish fauna. The Eastern Slope compartment of the current study is represented primarily by the Central Eastern Province of

Last *et al*. (2005), with inclusion of transitional zones to the north and south of this region. This province contained some 639 demersal species, 56 of which were endemic. Last *et al.* (2005) identified indicator species that were used to identify vertical separation of the slope into Upper Slope, Mid-upper Slope and the Mid Slope. In the Central Eastern Province (PB12) this categorisation resulted in the delineation of the eastern slope into the following levels:

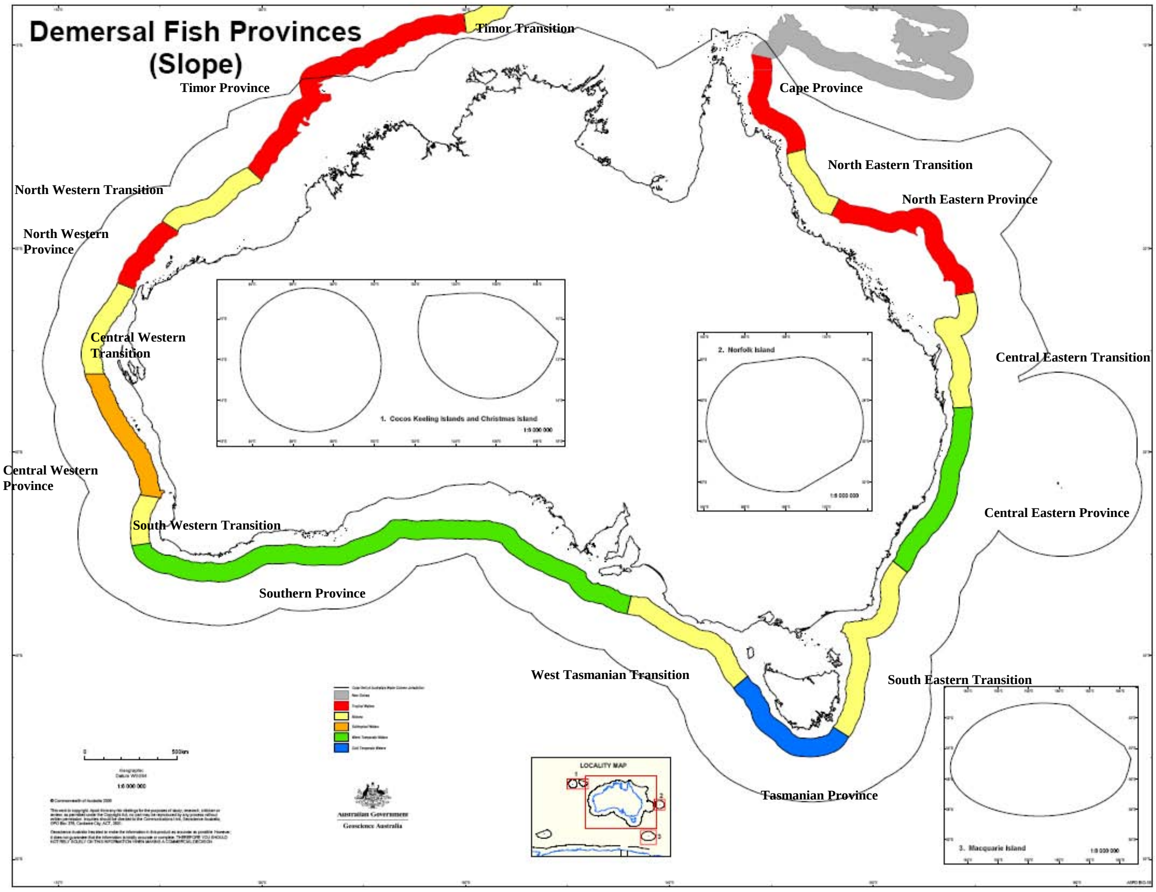
- The Upper Slope biome (280 – 490 m) (a biome characterised by longnose houndshark *Iago garricki*);
- The Mid – upper Slope biome (610 – 830 m) (a biome characterised by lined lanternshark *Etmopterus dislineatus*); and
- The Mid Slope (910 -1080 m) (a biome characterised by deep-sea lizardfish *Bathysaurus ferox*).

Last *et al*. (2005) identified 9 typically narrow-ranging, endemic, candidate indicator species within PB12, from Southport (QLD) to Ulladulla (NSW). The species identified were Flathead *Bembrops morelandi*, Sea toad *Chaunax sp*., Batfishes (*Halieutopsis sp*., *Solocisquama spp*.and *Malthopsis sp*.), Sea Bass *Lepidoperca magna*, Snailfish *Paraliparis eastami*, Grinner *Paraulopus okamurai* and Skate *Dipturus sp*.

7.7.3 Productivity Flows

In Spring, phytoplankton blooms occur resulting from EAC-mediated intrusion of nutrient-rich slope water onto the continental shelf, as indicated by chlorophyll peaks over the continental shelf and slope, and possibly enhanced by northerly winds (Bax et *al*., 2001). Bax *et al*. (2001) concluded that the eddy field within this area is the main cause of this uplifting of nutrient-rich water. The main biological influence of the eddies is to increase the vertical mixing within the upper ocean layers in the western Tasman Sea, effectively extending the mixed-layer depth and suppressing the winter phytoplankton and zooplankton populations through limiting light conditions (Hayes *et al*., 2004). These conditions then allow for spring and autumn blooms of chlorophyll-a. The upwelling associated with the frontal-region around eddies also supplies more nutrients to the surface layers once the bloom has begun, initiating increases in phytoplankton biomass and thus prolonging the duration of the blooms.

At a structural level, eddy features have been identified as having an influence on biological distributions due to the relative distributions of trapped nutrients, notably, upwelling-downwelling at the eddy core leads to nitrate enrichment and high phytoplankton concentrations. Various fauna are dependent on seasonal mixing and the interaction of the eddy with the slope and shelf. Pelagic tunicates and coelenterates are drawn to these blooms which are themselves prey for a wide array of species including albatrosses and crustaceans , as well as fish such as the blue grenadier, blue warehou and banded whiptail (Prince, 2001). Previous studies have shown that southern bluefin tuna migration is timed to coincide with the autumn blooms of phytoplankton along the shelf and upper slope (Young *et al*., 1997). The tuna principally feed on jack mackerak, pilchard *Sardinops neopilchardus* and juvenile squid *Nototodarus gouldi*, which feed within the blooms. Through the winter months, as the blooms decline and prey fish disperse, southern bluefin tuna move offshore to prey on alternative prey species such as gelatinous zooplankton and squid.



Source: Last *et al*. (2005)

Figure 7-22 Provincial structure based on demersal fish data

7.7.4 Connectivity with other Compartments

Warm-core eddies formed from the pinching off of the EAC carry myctophid, crustacean and squid communities characteristic of the compartment of formation which in this case tend to be from the northern compartments (1a – e) in the Coral Sea. Young *et al*. (2001) concluded that the presence of one of these warm-core eddies and associated, trapped, fauna provided a localised area of high productivity to which yellowfin tuna were attracted to. It is also suggested that without the presence of these EAC-derived eddies it would be unlikely for yellowfin tuna to be found in the southern Tasman Sea, which is well below the usual thermal range of this species.

This compartment overlaps with the Central Eastern Province as described by Last *et al.* (2005) in relation to demersal fish datasets. This report details fish populations in the waters of the Australian continental slope and outer shelf (>40m depth) and combined with a study by Bulman *et al.* (2006) supports the idea that fish travel between the shelf (compartment 2a) and the slope. Bulman *et al.* (2006) noted that small mesopelagic fishes that support the slope and shelf break fishes were imported into the area largely through the process of diel vertical migration causing them to be washed up from neighbouring compartments. Migratory fish such as the yellowfin tuna may also travel into this compartment from the eastern seamounts compartment (2c).

7.7.5 Eco-physical Model

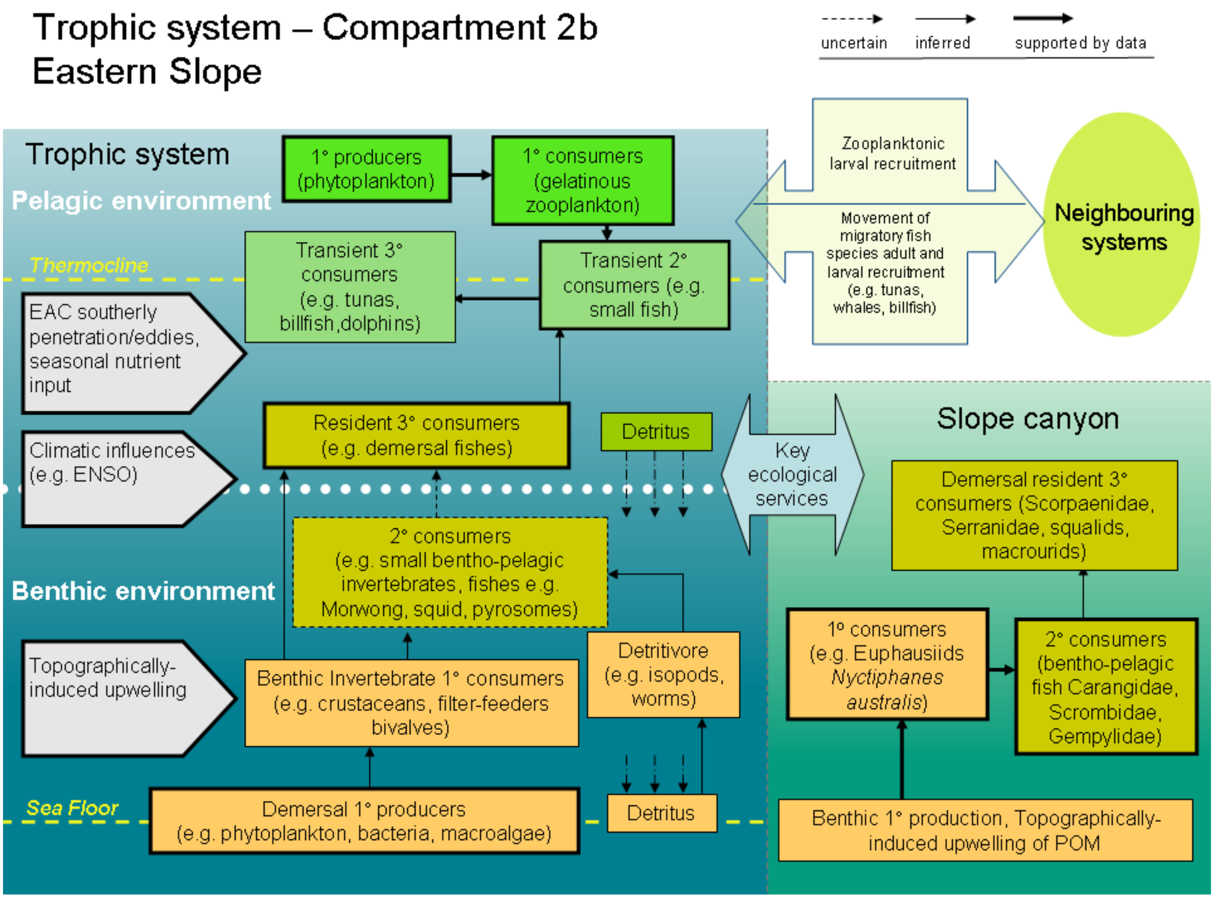


Figure 7-23 Eco-physical model for the Eastern Slope Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Slope canyons are important ecological features in this sub-region and are also described.

7.7.6 Interactions with important species and habitats

The previously described submarine canyons are important influences on the faunal abundances and composition within this compartment. The fisheries along the coast associate good fishing conditions with cold currents at depths, with the most productive grounds clustered around these abrupt topographical features such as these canyons, promontories, seamounts and bluffs. These canyons channel upwelling water over the slope and shelf, while downwelling flows may also seasonally reverse the flow through these structures (Prince, 2001). Winter cooling enhances the difference in density between the coastal and oceanic waters and produces pronounced downwelling in these topographic features, e.g. Tweed Canyon (Figure 7-21). Generally associated with low nutrient regimes, downwelling of coastal waters may play an important role in breaking down shelf-edge fronts, displacing deeper oceanic slope water and consequently pushing relatively nutrient-rich water towards the photic zone. These topographic features, therefore, create hotspots of fisheries productivity for the main commercial shelf-based fisheries (abalone, lobster, scallops, shark, squid, prawn and tuna).

7.7.7 Vulnerability to impacts and change

Fishers argue that because the main commercial species forage outside of their demersal environment they are relatively invulnerable to over exploitation with demersal fishing gear (Prince, 2001). Their feeding behaviours may make them less prone depending on the extent to which they forage in mid-water in which case demersal trawling would have little effect on highly pelagic oceanic species. However, commercially fished species such as the gemfish and orange roughy which spawn in the bottom layers of water pluming up the slope have been proven to be easily over-exploited because their obligation to breed repeatedly, making long-lived adults particularly vulnerable to fishing pressure. In addition, the persistence of demersal communities is likely to be linked to benthic habitat and seabed facies and so physical damage of potentially fragile canyon epi-benthic communities, for example, could have flow-on effects to demersal fishes.

The oceanographic processes described above are linked to the EAC. Further, phytoplankton processes have a seasonal cycle that supports pelagic (and demersal) ecosystems. Both of these processes are vulnerable to climate-change or other mechanisms whereby the EAC and seasonal cycles may be disturbed.

7.7.8 Information gaps

- Uniqueness of Eastern Slope canyons with respect to others to the south;
- Influence of topographically-induced upwelling and true oceanographic upwelling on nutrient cycling to the shelf and the pelagic/meso-pelagic environment. Importance to canyon and slope benthic assemblages;
- Understanding of local-scale topography on primary production.

7.8 Southern Seamounts Field Sub-region (2c)

7.8.1 Description

The Southern Seamounts sub-region (2c), covering the largest area of all the East Region sub-regions (408,866 km^2), is contained within the east Australian continental margin (Harris *et al*, 2003) and is bounded to the north by the Marion Plateau (Sub-region 1d) and Northern Seamounts Field sub-region (1e), to the east by the Lord Howe Complex (Sub-region 3a) and to the south by the East Marine Region boundary (Figure 7-24).

The sub-region lies in the warm-temperate waters of the Coral Sea Circulation (Water Mass P13; mean temp. - 19.15°C) with the tropical Coral Sea to the north (Water Mass P17, 25.62°C) and a temperate convergence to the south (Water Mass 12; 13.59°C) (Lyne and Hayes, 2005).

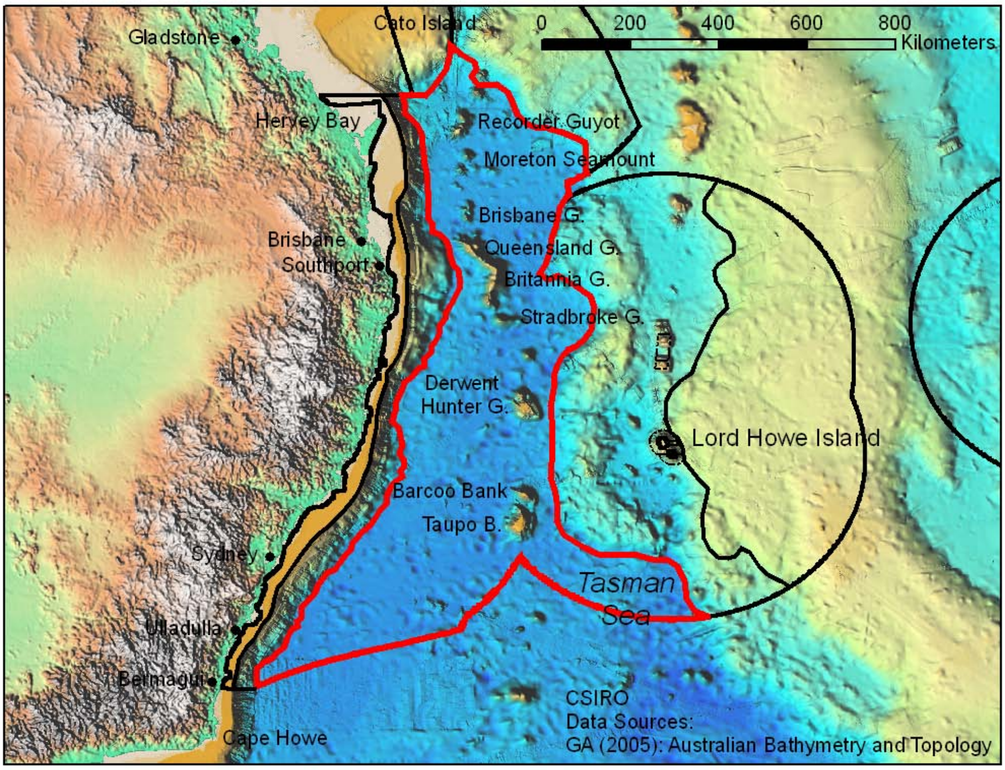
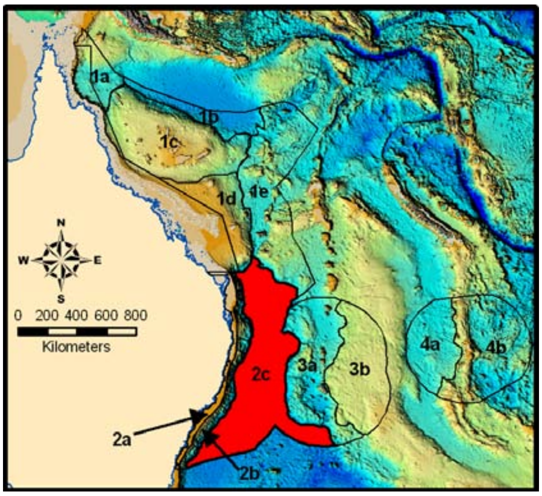
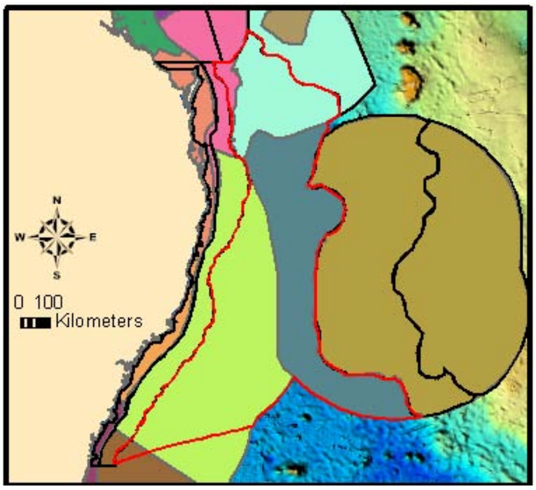


Figure 7-24 Southern Seamounts sub-region (2c) showing locations of selected features

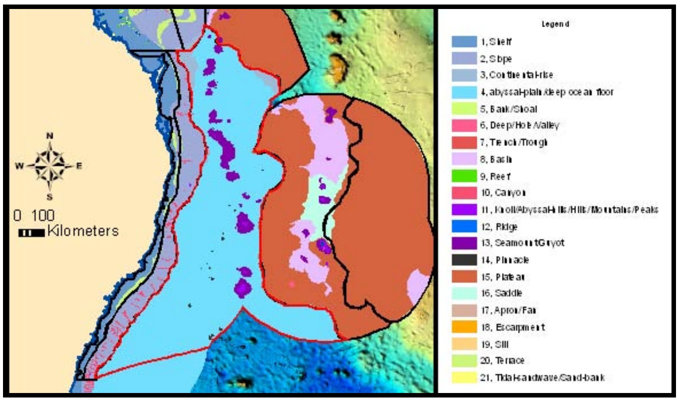
It overlaps the existing IMCRA bioregions PB11 (Southeast Transition), PB12 (Central Eastern Province), PB13 (Tasman Basin Province), PB15 (Central Eastern Transition) and PB16 (Kenn Transition) (Figure 7-25). The Central Eastern Transition (PB15) and Tasman Basin Province (PB13) cover the eastern margin's continental rise and abyssal plain (Harris *et al.*, 2003) in which lies the volcanic-origin Tasmantid Seamount chain, running north–south at approximately 155°E longitude. Included in this chain, moving southward, are Fraser Seamount, Recorder Seamount, Moreton Seamount, Brisbane Guyot and the Brittania Guyots, incorporating Queensland Guyot, Stradbroke Guyot, Stradbroke Seamount, Derwent-Hunter Guyot, Barcoo Bank and Taupo Bank (Figure 7-24). All these features are flat-topped, with the northern seamounts rising from the seabed to summit at water depths of 150-400 m (Harris *et al.*, 2003). The southern seamounts are deeper, Stradbroke Seamount rises to 900 m water depth, while Barcoo Bank rises to less than 1400m water depth (Harris *et al.*, 2003).



a) Location of Sub-region 2c



b) Sub-region 2c overlaid on IMCRA Bioregions



c) Sub-region 2c overlaid on Geomorphic Features

Figure 7-25 Southern Seamounts sub-region (2c), , showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.8.2 Important Drivers and Ecological Features

Pelagic

As with the other southern warm-temperate sub-regions, the main physical drivers are the Eastern Australian Current (EAC) eddy field and the Tasman Front (Figure 6-2; Hayes *et al.*, 2004), within water mass 1b_P13, the Pacific Central-South Subtropical Water Mass (Figure 6-14; Lyne and Hayes, 2005).

At the southern boundary, the EAC is highly variable and is associated with a highly energetic eddy field with the maximum surface-height variability is also indicative of the eddy and frontal activity in this sub-region (Figure 6-3, Figure 7-26). These eddies, which can be approximately 200-300 km in diameter, follow complex southward trajectories which are generally contained within the abyssal plain of the sub-region, between the steep continental wall in the west and the Dampier Ridge to the east.

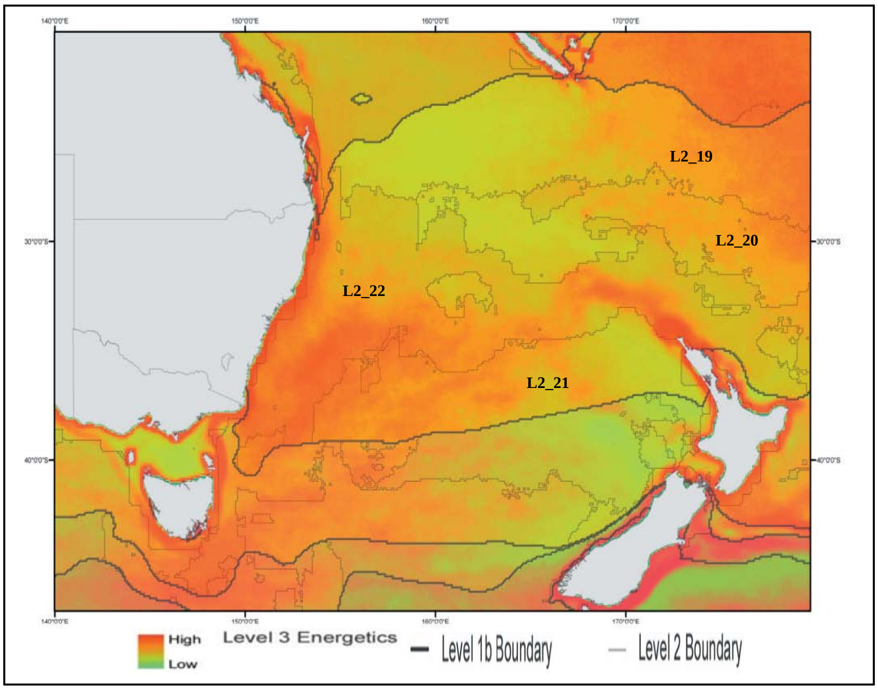


Figure 7-26 Pelagic regionalisation Level 2 (L2 – Circulation Regimes) and Level 3 (Energetics) map (from Lyne and Hayes, 2005)

Furthermore, as bottom and tidal currents are forced around the contours of the seamounts and ridges, counter- rotating vortices can form on the upstream and downstream flanks. This action can lead to the formation of an eddy on the slope of the seamount or one directly above the seamount, known as a Taylor column. During their lifespan, the eddies have strong marginal currents of 2 - 4 knots with central isothermal layers up to 300 m deep, termed 'warm-cores' that have a relatively high biomass of plankton and micronekton. Therefore, the eddies, by their nature are an important food source for tertiary consumers such as Yellowfin Tuna and Swordfish populations which aggregate around the Tasmantid Seamounts (Young *et al.*, 2001; Young *et al.*, 2003; Landsell and Young, 2007).

Demersal

The western boundary is defined by the foot of the continental slope and the upper surface of the abyssal plain, in water depths between 4,600 m and 4,850 m (Harris *et al.*, 2003). The upper surface of the abyssal plain is generally smooth, with patches of reflective sediment that appear to be ribbons of silt separated out by abyssal currents.

The Tasmantid Seamounts comprise a unique deep-sea environment, characterised by substantially enhanced currents and a fauna that is dominated by suspension feeders, such as corals (Richer de Forges *et al.*, 2000). Seamounts are an iconographic marine habitat which provide topographical structure across the continental slopes and abyssal plains of the deep sea, altering oceanic circulation patterns with local upwellings, turbulent mixing and closed circulation cells. Genin *et al.* (1986) stated that flow acceleration of local current regimes caused by seamount topography affected the coral distribution. Within a certain range of current speed, areas of flow acceleration are expected to be favourable for recruitment and growth of passive suspension feeders. This may be attributed to the 'settlement pathway' in which a site is colonised by relatively more recruits simply because more water, and hence more larvae, are flowing by per unit time, or the 'feeding pathway', in which an increase of water flow past suspension feeders results in increased feeding and growth rates. This may also be critical for the survival of small recruits. Both pathways can eventually lead to long-term integration of current conditions by the fauna as shown by the relatively high abundance of corals on seamount peak edges where periods of flow acceleration have been observed (Genin *et al.*, 1986).

Furthermore, seamounts have their own benthic depth zonation which does not ally with the vertical gradients and stratification of pelagic depth zonation (Norse and Crowder, 2005). For example, benthic algae have been recorded to depths exceeding 250 m (Littler *et al.*, 1985). The resuspension and removal of fine sediments from slopes, facilitates recruitment and settlement of fauna without risk of clogging and burial. Currents also deliver food to and remove wastes from their sessile, sedentary, and resident inhabitants. Indicative of this is the presence of structurally complex communities of suspension-feeding sponges, corals, crinoids, and ascidians (Rogers, 1994) that are rare or absent from surrounding abyssal plains dominated by deposit-feeders.

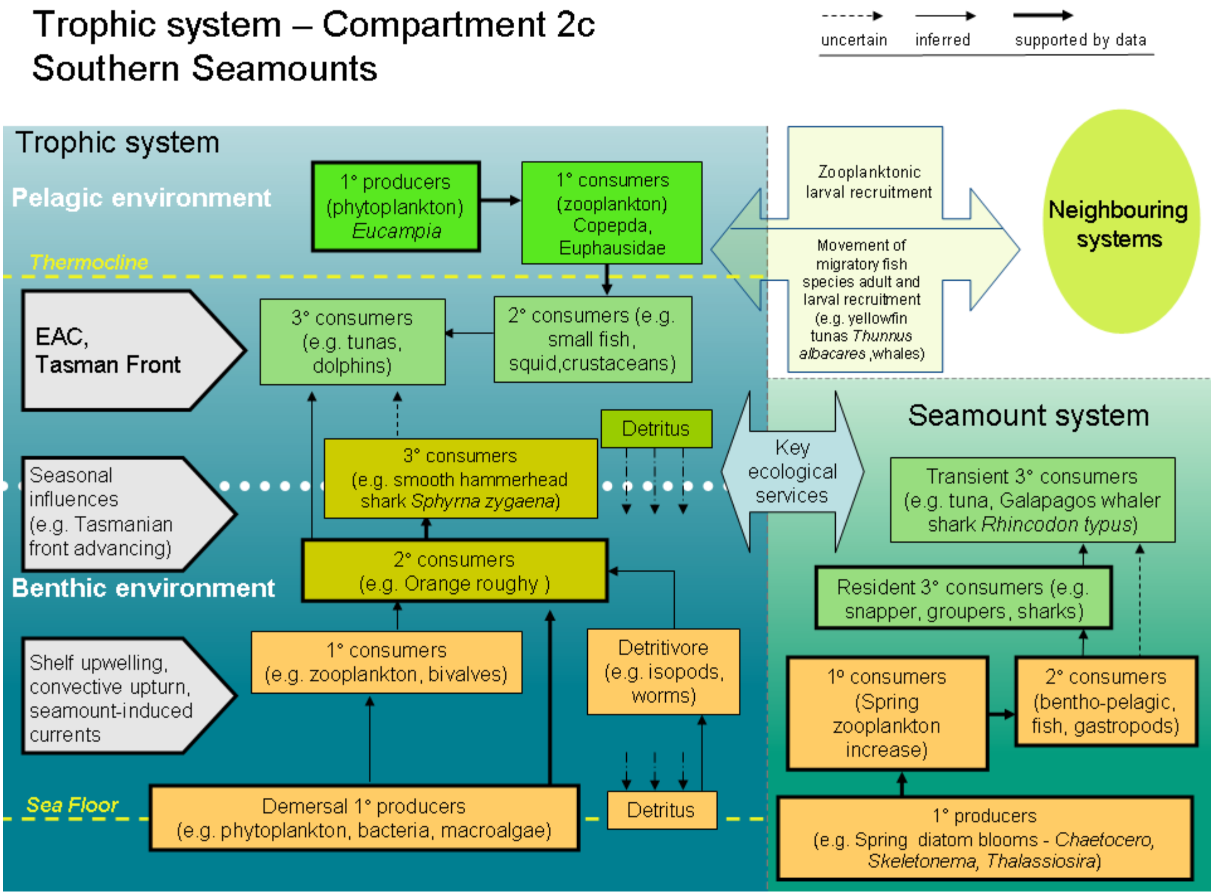


Figure 7-27 Eco-physical model for the Southern Seamounts Field Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Seamount systems are important ecological features in this sub-region and are also described.

7.8.3 Productivity flows

The EAC eddies are important for nutrient cycling and biological productivity as described in phytoplankton studies of eddy systems Eddy Mario (Jeffrey and Hallegraeff, 1987) and Eddy F (Tranter *et al.*, 1980, 1981, 1983). As previously described, each eddy has distinct characteristics, specifically; Eddy F is 'discrete', while Eddy Mario is a coalescing eddy, renamed Eddy Nicola after its engulfment by the EAC. Phytoplankton species within the warm-core eddies are an intermediary between the tropical Coral Sea, from where the eddies derive, and the sub-tropical to temperate Tasman Sea with which the eddies interact. Coral Sea phytoplankton is characterised by low cell numbers (102 – 104 diatoms l-1), mainly comprised of *Nitzschia spp.*, high proportions of nanoplankton (70 – 95% of total chlorophyll) and a high species diversity of dinoflagellates (Jeffrey and Hallegraeff, 1987). Tasman Sea waters are characterised by a series of short- lived diatom blooms (up to 106 cells l-1) over the spring, summer and early autumn months which include *Asterionella*, *Chaetocero*, *Detonula*, *Eucampia*, *Leptocylindrus*, *Nitzschia* and *Skeletonema* species. A constant background biomass of nanoplankton flagellates are present throughout the year (10

– 20% of the total chlorophyll during diatom peaks; 50 – 80% for most of the year; Hallegraeff, 1981). This capacity to generate diatom blooms is a key component of these EAC warm-core eddies which drives the productivity flow within this sub-region.

In the relatively sparse abyssal plain, the seamounts, the hard substrates and topographically induced ocean phenomena provide refugia for prey species and consequently feeding locations for associated predators (Richer de Forges, 2000; Hixon and Beets, 1993; Norse and Crowder, 2005). The abundance of demersal seamount life and distinctive oceanographic phenomena attract highly migratory pelagic predators including cetaceans, seabirds, sharks, tunas (Young *et al*, 2001) and billfishes (Young *et al*, 2003; Norse and Crowder, 2005). Seamounts also serve as rendezvous points where some epipelagic (scalloped hammerhead sharks, *Sphyrna lewini*; Klimley, 1995) and deep-sea fishes (orange roughy, *Hoplostethus atlanticus*; Bull *et al.,* 2001) converge to mate or spawn. Upwelling brings nutrients from deeper waters into the euphotic zone. This stimulates phytoplankton production above background values, leading to zooplankton blooms, which attract planktivorous squids (Landsell and Young, 2007) and fishes such as anchovies (*Engraulidae*), lanternfishes, small carangids and their predators such as common dolphins (*Delphinus delphis*), Cory's shearwaters (*Calonectris diomedea*), broadbill swordfish (*Xiphias gladius*; Young *et al*, 2003), bigeye thresher sharks (*Alopias superciliosus*), and Humboldt squid (*Dosidicus gigas*).

7.8.4 Connectivity with other Sub-regions

As previously discussed, the sub-region lies in the warm-temperate waters of the Coral Sea Circulation, Water Mass 1b-P13, with the tropical Coral Sea Water Mass 1b-P17 to the north, and a Temperate Convergence Water Mass 1b-12 to the south (Figure 6-14) (Lyne and Hayes, 2005). Frontal features between these water masses, such as the Tasman Front (Figure 6-2), may dictate the distribution of predator and prey species. Norse and Crowder (2005) describe three possible reasons for this effect on faunal distribution, (1) steep temperature or water clarity gradients are barriers to movement, (2) convergence flow at fronts aggregates buoyant or weakly swimming prey, or (3) temperature gradients allow epipelagic species to feed in food-rich cooler waters and then accelerate digestion and growth in warmer waters.

Convergence zones between water masses are often visible as surface drift lines which may contain detached seaweeds, logs, and flotsam collect, providing hard substrates for the attachment of invertebrates and attracting small fishes and other animals such as turtles, followed by larger predators such as dolphinfish (*Coryphaena hippurus*), tunas and sharks. Frontal features may be semi-permanent, seasonally predictable, or unpredictably episodic. Even those that are permanent can, in some instances in other ocean basins, move hundreds of kilometers throughout the year or on an annual basis (Hyrenbach *et al.*, 2000). Large oceanic species, including blue whales (*Balaenoptera musculus*), leatherback and loggerhead sea turtles, albacore tuna (*Thunnus alalunga*), bluefin tunas, and mako sharks (*Isurus spp.*), have been known to divide their lives between feeding in such areas with elevated chlorophyll concentrations (Block *et al.*, 2002; Hyrenbach *et al.*, 2002; Polovina *et al.*, 2000) and moving quickly across expanses of oligotrophic (food-poor) waters. Food-rich patches are often transitory, disappearing when frontal discontinuities break down or through prey reduction by predators. Many large oceanic species spawn, nest, or calve only in certain places, perhaps where they can optimize the balance between food availability and predation risk for their young. To reach breeding areas they journey hundreds or even thousands of kilometres, seamounts are therefore ideal ‘stepping stones’ within the barren open ocean (Gad and Schminke, 2002).

7.8.5 Interactions with important species and habitats

Seamounts are also biomass hot spots because they often induce leeward plumes of elevated productivity due to localized upwelling, a phenomenon called the island wake effect (Norse and Crowder, 2005). Even in the absence of upwelling, seamounts might support high animal biomass because they offer a combination of strong currents and structurally complex seafloor habitat. This allows resident fishes both to feed on passing zooplankton and small fishes in the water column and to take refuge from tertiary predators such as pelagic sharks and tunas.

The fishes and other animals that feed on passing organisms and detritus effectively increase the seamounts’ filtering capacity, providing more food to benthic communities than might otherwise occur. Seamount surveys have found extremely high (>30 percent) levels of apparent endemism (Richer de Forges *et al.*, 2000), that may be attributed to the eddy effects. Localised stationary eddies, or Taylor columns, increase the residence time of overlying waters. Taylor columns allow eggs and larvae to stay within waters above a seamount until individuals can settle. Being essentially closed populations with negligible gene flow favours seamount animals that may eventually become reproductively isolated endemics. Altered life histories have been observed whereby the initial adaptations to this isolation effect are manifested through shortened larval duration or behaviours that would retain larvae within Taylor columns (Norse and Crowder, 2005). While certain factors would suggest seamount endemism is relatively high, it is yet to be substantiated on a genetic basis and is currently subject to further investigation (O’Hara, 2007).

7.8.6 Vulnerability to impacts and change

Benthic and demersal seamount species, subject to fisheries targeting include billfish, tuna, and orange roughy. These species are generally long-lived, late-maturing species (e.g. orange roughy, maximum age >100 years, maturity at 22–40 years), making them especially vulnerable to overexploitation (Roberts, 2002). While some fishes are taken with bottom longlines, the more commonly utilised bottom trawling method causes a greater degree of damage to seafloor communities (Chuenpagdee *et al.*, 2003). Habitat-forming corals and sponges are both vulnerable to trawl damage and may take years to recover, similar to recovery periods following forest clear-cutting (Watling and Norse, 1998). Depletion of fish populations associated with seamounts is an indication of possible shortfalls within today’s fisheries management plans for conserving oceanic species (Koslow *et al.*, 2000).

7.8.7 Information gaps

The amount of knowledge regarding the physical and biological drivers of abyssal seamounts remains sparse in relation to continental shelf and slope communities. Understanding of these unique ecosystems is key to ensuring that the critical components are addressed within any zonal management plan.

7.9 Lord Howe Complex Sub-region (3a)

7.9.1 Description

The Lord Howe Complex sub-region (3a) lies within the Lord Howe IMCRA bioregion and is positioned in the Tasman Sea off the East coast of Australia. Adjacent to its western border lays the Southern Seamounts sub-region (3a) and on its eastern border, the Lord Howe Plateau subregion (3b). The Lord Howe Complex sub-region is characterised by the Dampier Ridge and the Lord Howe seamount chain which extends to the north as shallow banks and reefs and to the south as several small seamounts (Figure 7-28). The chain includes Lord Howe Island, an eroded basaltic volcano, at its southern end. The submerged mountains were most likely formed as the result of the Indo-Australian Plate moving northward over a static hotspot of volcanic activity (Figure 7-30) (Speare *et al.*, 2004).

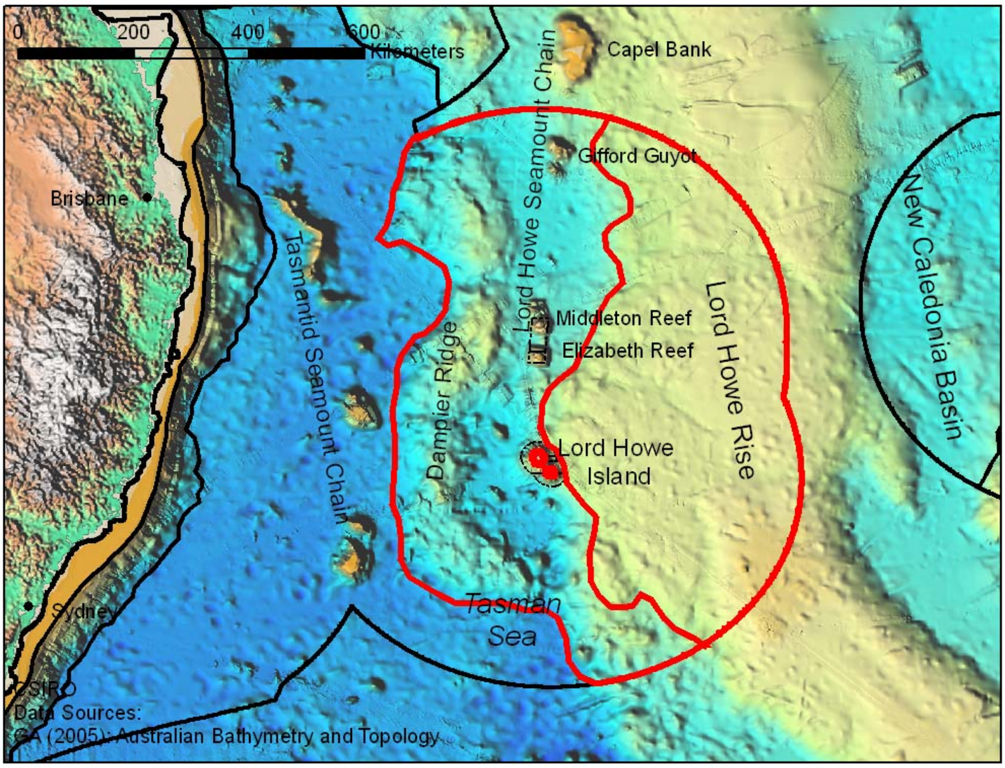
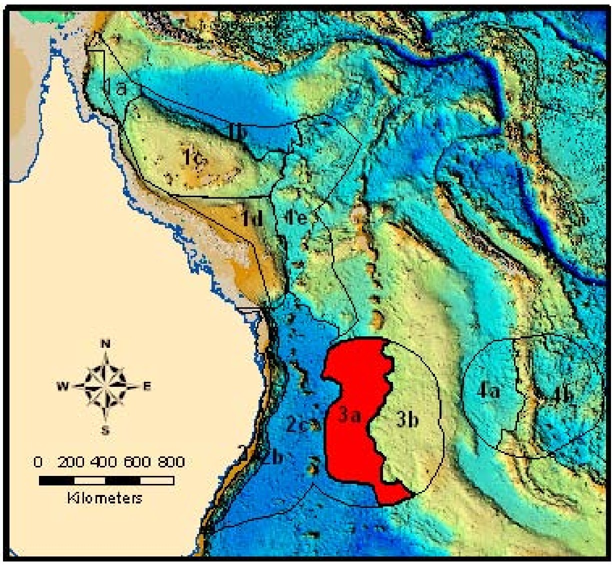
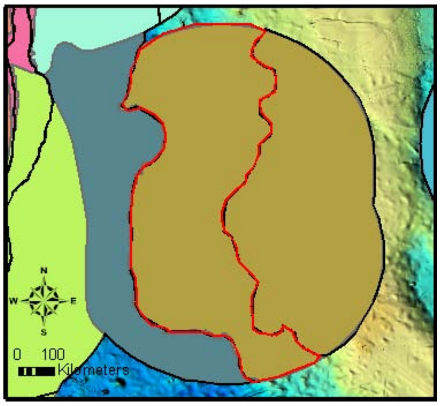


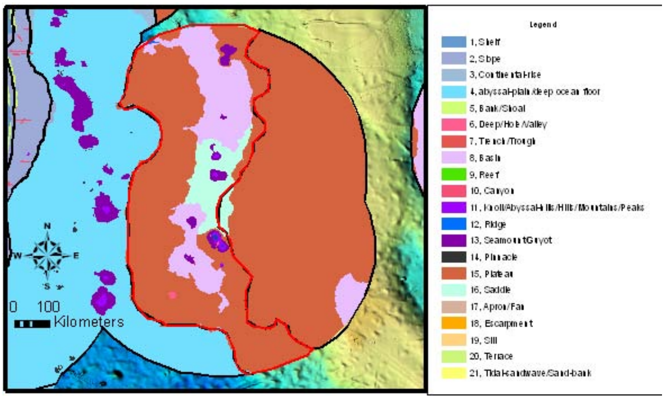
Figure 7-28 Lord Howe Complex sub-region (3a) (left), and Lord Howe Plateau sub-region (3b) (right) showing locations of selected features



a) Location of sub-region 3a

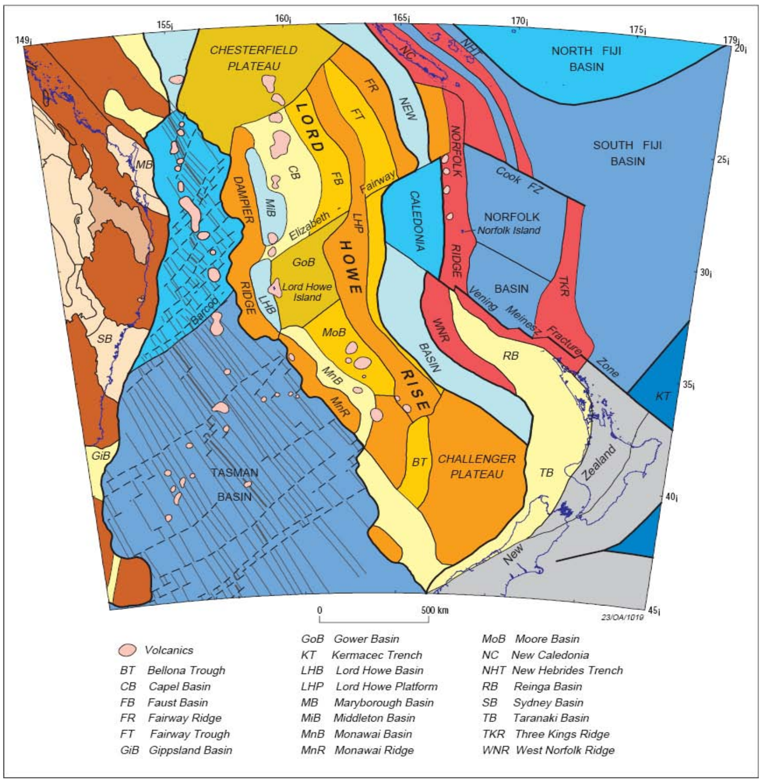


b) Sub-region 3a overlaid on IMCRA bioregions



c) Sub-region 3a overlaid on geomorphic features

Figure 7-29 Lord Howe Complex sub-region (3a), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.



Source: (Alcock *et al*., 1999)

Figure 7-30 Tectonic Provinces of the Lord Howe region

7.9.2 Important Drivers and Ecological Features

Pelagic

The Lord Howe Complex sub-region is impacted upon by the southerly flow of the East Australian Current (EAC) and associated Tasman Front, and the anti-cyclonic, warm core eddies that forms at its point of divergence. The separation leads to the formation of two large stationary eddies close to the coast known as eddy J (34°S) and eddy K (32°S) (Figure 6-5). The EAC's eastern divergence is related to the north most eddy K. On the eastern side of the eddy, part of its flow branches off and moves eastward in a series of meanders. This powerful flow, the Tasman Front, can be followed eastwards across the Lord Howe Ridge and towards the west coast of New Zealand.

The surface currents bring warm tropical surface water into the system on a seasonal basis. This inflow of warm water transport vagrant species across the sub-region, including many tropical species from the north such as whale sharks, dugong and turtles. The associated eddies can generate upwellings and downwellings which have direct implications on the productivity of the adjacent waters and indeed the distribution of associated communities of pelagic fish which including kingfish, *Seriola lalandi*, redfish, *Centroberyx* sp., and rosy jobfish, *Pristipomoides multidens* (Koslow, 2007).

The Tasman Front currents that are forced around the contours of the seamounts and ridges, forms localised eddies on the slope of the seamount or one directly above the seamount, known as a Taylor Column. The eddies have strong marginal currents of 2 - 4 knots with central isothermal layers up to 300 m deep, termed 'warm-cores' that have a relatively high biomass of plankton and micronekton. Increased plankton biomass over the seamounts also attracts dense shoals of lantern fish, mysid shrimps and squid vertically migrate at night to feed on the organisms. In turn, they become a food source for larger pelagic species including shark species such as the smooth hammerhead shark, *Sphyrna zygaena*, and the Galapagos whaler shark, *Carcharhinus galapagensis* (Rogers, 2004).

Demersal

The demersal environment of the Lord Howe Complex sub-region is dominated by a large seamount chain, and it is the interaction of bottom currents with these seamounts that appears to be the main driver shaping this ecosystem. As the slow moving deep water currents are forced over the sharp reliefs they increase in velocity. The enhanced currents erode sediment from the rises and disperse organic material (e.g. zooplankton faecal matter, whale falls) attracting filter feeders such as coral, which colonise the exposed hard substratum and feed upon the organic material (Koslow, 2007). The eroded sediments are deposited into the surrounding basins (Launay *et al*., 1997). The removal of sediment from the system acts to significantly reduce the turbidity of the water, allowing photosynthetic organisms such as corals to colonise much greater depths (Koslow, 2007).

The primary ecological features of the demersal zone around seamounts are deep-sea suspension feeders with gorgonians being the dominant group. It would be expected that a broad range of deep water corals such as stony corals (*Lopheila sp.*) and other groups which colonise hard substrates would be present. Various groups of soft corals such as gold and red corals; gorgonians or sea fans; hydrozoans; sponges, bryozoans and a variety of echinoderm groups such as brittle stars would also be present (Koslow, 2007). Seamount-associated species of fish are typically slow growing species which have exceptionally long life histories (Rogers, 2004). They can be broadly categorised into those associated with the deepwater coral gardens (e.g. rockfishes) which are used for refuge and those associated with the seamount itself (e.g. orange roughy), which feed on other fish, squid and crustaceans brought in by the currents. Vertically migrating plankton such as krill also become prey when they become trapped above the seamounts which block their downward migration (Koslow, 2007).

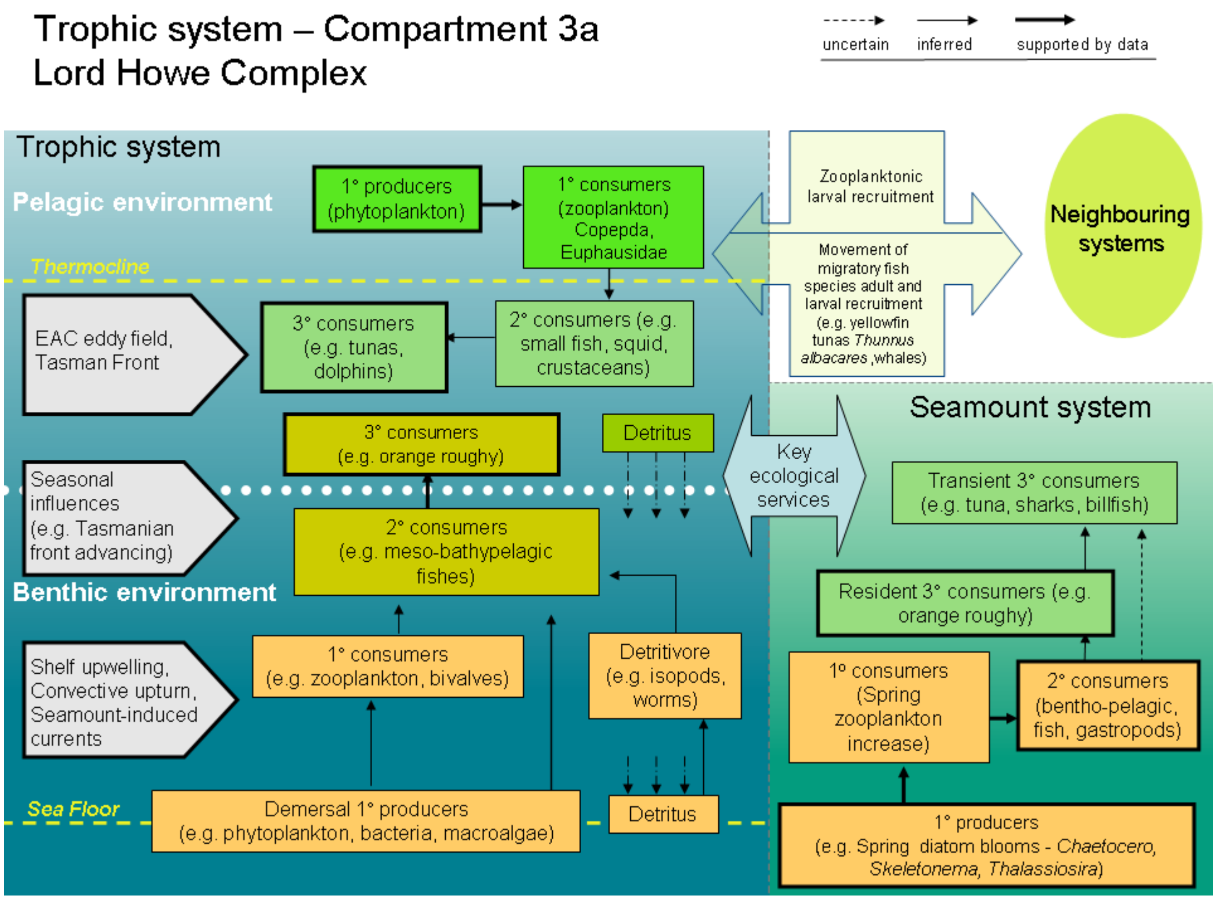


Figure 7-31 Eco-physical model for the Lord Howe Complex Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. Seamounts are important ecological features in this sub-region and are also described.

7.9.3 Productivity flows

Phytoplankton biomass and primary production are nutrient-limited in this sub-region. Primary production in this sub-region has a seasonal trend, being most prolific during August and November and peaking in October (Lyne and Hayes, 2005). As the waters reach their production threshold, nutrient exhaustion in the euphotic zone causes a reduction of primary production from November to February. As previously mentioned, seamounts intercept currents causing localised upwelling of nutrients onto the somewhat shallow pinnacles where increased abundance of plankton and availability of sunlight can lead to short-lived diatom blooms (days to weeks) and associated increases in zooplankton production, such as copepods and euphausiids (Norse *et al*., 2005).

At the seamount peak, productivity flows conform to conventional pelagic environmental processes. Primary productivity would be driven by phytoplankton and consumed by secondary producers in the form of vertically migrating zooplankton (such as crustaceans, larval molluscs, larval fishes). Primary consumers such as sea urchins which occur on the seamounts of the Lord Howe Ridge feed on the producers and eventually become prey themselves for secondary consumers such as the orange roughy and cephalopods. Significant tertiary consumers in this environment are transient billfish, tuna and other large pelagic predators such as sharks, marine mammals and seabirds that either migrate seasonally or pass through the sub-region following prey fish and highly abundant, endemic seamount species.

7.9.4 Connectivity with other Sub-regions

The EAC is the principle mechanism facilitating connectivity between the Lord Howe Complex sub-region and its neighbouring sub-regions. The jet-like meander of Eddie K which redirects the EAC east facilitates the transport of planktonic larvae and large vagrant and migratory species such as billfish and tuna (see sub-region 2c). Connectivity in the demersal environment would be relatively low, however as the Dampier Ridge and the LHP would act as a physical barrier to most demersal species inhabiting adjacent basins. Further to this, prolonged duration of the previously mentioned Taylor's Columns can allow eggs and larvae to remain in the waters above the seamount until they settle, enhancing local retention and endemicity (Norse & Crowder, 2005). Species with limited dispersal potential would display the greatest localisation as the immediately adjacent regions would be relatively featureless and nutrient poor making them less suitable for settlement. Conversely, under the right conditions seamount hydrology can actually facilitate long-distance dispersal with the strong vertically flowing currents acting to keep eggs and larva suspended in the pelagic were they can be transported outside the sub-region by the EAC. (O'Hara, 2007).

7.9.5 Interactions with important species and habitats

The Lord Howe Complex sub-region is characterised by the presence of a seamount chain. Seamounts are hotspots of productivity with the steep rises forcing bottom currents to form up-wellings of nutrients in a process known as the island wake effect (Norse and Crowder, 2005). The conditions are ideal for filter-feeding benthic organisms such as coral which typically form fringing coral reefs at the pinnacle of the seamounts. The enhanced currents also act to remove suspended sediment from the system, allowing the deeper colonisation of photosynthetic organisms in the clearer waters. Black corals (*Antipathidae spp.*) and pink precious coral (*Corallium* spp.) are examples of those species which have flourished under these conditions within the Lord Howe Complex sub-region (Koslow, 2007). The enhanced nutrient concentration and habitat complexity make seamounts an oasis for deepwater marine species in what is predominantly a featureless environment. One such species is the Orange roughy (*Hoplostethus atlanticus*), which aggregate near prominent topographic features such as seamounts, plateaus and canyons, especially during spawning and feeding. The Lord Howe seamount chain supports an exceptional abundance of this species which use the unique environments to increase larval survival (Rogers, 2004) (Koslow, 2007).

7.9.6 Vulnerability to impacts and change

Human disturbances have had the greatest impact on the Lord Howe seamount chain, and these impacts have arisen almost solely from fishing. Fishing efforts are non-selective impacting upon both target and by-catch species of corals, fish and crustaceans. Many seamount-associated species of fish are particularly vulnerable to overexploitation as they are slow growing, slow to mature and long lived (over 100 years in the case of orange roughy). Also, some seamount species including the roughy, form large aggregations above seamounts for reproduction allowing them to be easily targeted by trawlers, and therefore making them even more vulnerable to over-exploitation (Rogers, 2004). Furthermore, studies have clearly shown that trawling is highly destructive to the benthic communities of seamounts which has consequently affected the distribution and abundance of associated fauna (Stone *et al*., 2003). The damage and removal of framework building corals especially, has enduring effects upon the ecosystem as they take thousands of years to grow into a mature reef and recolonisation and regrowth in spoiled areas is expected to be similarly slow (Rogers, 2004).

High levels of endemism in seamount communities means that past unregulated fishing of the Lord Howe Complex sub-region may have already lead to local extinctions among benthic seamount communities. Moreover, it is not known how the seamount species extinction will impact the wider ocean.

Seamounts are also vulnerable to the effects of global climate change which may cause changes in sea temperatures, alterations in the flow of ocean currents and changes in patterns of productivity. As mentioned earlier coral species such as *Lophelia pertusa*, live at their physical limits and are extremely sensitive to changes in the physical characteristics of the waters around them (Department of Environment & Heritage, 2002).

7.9.7 Information gaps

- Spatial coverage of sampling of seamounts is poor due to the challenge of sampling such a topographically complex environment and data gaps currently impede a comprehensive assessment of biodiversity and species distributions.
- The amount of knowledge regarding the physical and biological drivers of abyssal seamounts remains sparse in relation to continental shelf and slope communities. Understanding of these unique ecosystems is important to ensuring that the critical components are addressed within any zonal management plan.

7.10 Lord Howe Plateau Sub-region (3b)

7.10.1 Description

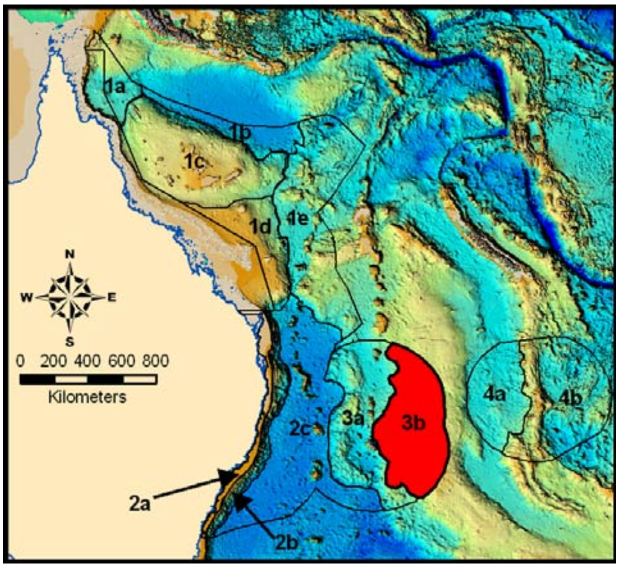
The Lord Howe Plateau sub-region (3b) lays within the Lord Howe region in the Tasman Sea off the East Coast of Australia (30°S, 162°E). On its western border lies the Lord Howe Complex (3a). The sub-region is defined geomorphically by the Lord Howe Rise which stretches 400-600km from east to west and extends1600 km from southwest of New Caledonia to the Challenger Plateau, west of New Zealand (Speare *et al*., 2004) (Figure 7-28). The LHP runs north to south along the Lord Howe Rise near its eastern flank where it rises from the seafloor to form an extensive, flattened plateau. The LHP has relatively uniform topography and lies in depths of 1000 to 1500m. The waters of the Tasman Sea are characteristically temperate although warm tropical waters seasonally flow into the sub-region via the East Australian Current (EAC) which sheds warm core eddies along its eastern divergence. The tropical waters (warm and low density) cause fluctuations in water temperature (18-23°C) and salinity on a seasonal basis (Speare *et al*., 2004).

7.10.2 Important Drivers and Ecological Features

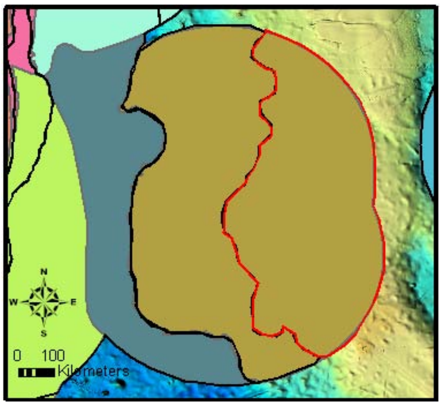
Pelagic

The principle driver in the pelagic environment of the Lord Howe Plateau sub-region is the Tasman Front and the subsequent easterly migration of eddy features and fronts. Upon initial contact with the Lord Howe Rise, which lies on the western side of the plateau, the current flow has been observed to dissipate and part of the flow is deflected north. Surface waters from the Tasman Front are less dense (i.e. warmer and less saline) than the cool waters of the Tasman Sea and consequently the temperature and salinity over the Lord Howe Plateau seasonally fluctuates due to the advection of these low salinity waters (Marchesiello & Middleton, 2000). The currents also facilitate the transport of vagrant species across the sub-region from both tropical and temperate origins as well as planktonic organisms (i.e. larvae) (Bakun, 2006).

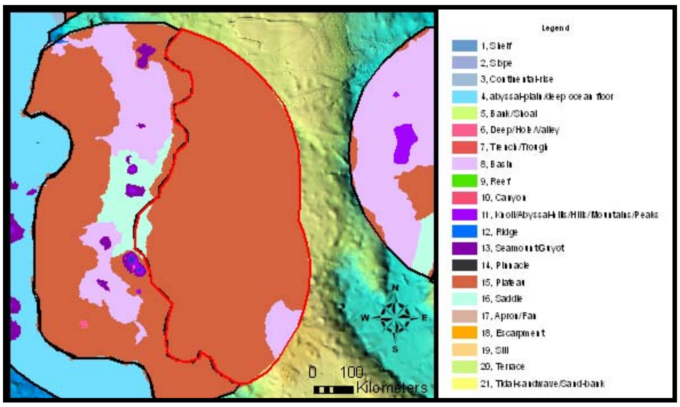
The important ecological features associated with the pelagic environment of this sub-region include transient populations of highly migratory, secondary and tertiary pelagic consumers, notably small fish schools and pelagic predators such as yellow-fin tuna (*Thunnus albacares*), blue marlin (*Makaira nigricans*) and striped marlin (*Tetrapturus audax*). Although there may be some level of seasonal aggregation or transient attraction to certain areas there would be few ‘resident’ populations.



a) Location of Sub-region 3b



b) Sub-region 3b overlaid on IMCRA Bioregions



c) Sub-region 3b overlaid on Geomorphic Features

Figure 7-32 Lord Howe Plateau sub-region (3b), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

Demersal

Even though the Lord Howe Plateau is raised greatly above the seafloor it still lays in relatively deep waters (1000 to 1500 m). The platform itself is relatively featureless, topographically speaking and bathymetry and geomorphology (and the related seabed facie) are believed to be the primary drivers of the demersal environment.

The ecophysical system on the platform is likely to be driven primarily by the distribution of particulate organic matter (POM) in the form of marine snow (particles mm-cm sized, consisting of dead and dying phytoplankton, zooplankton exoskeletons, fecal matter, etc.) and whale falls and is thus dependent in part to seasonal trends and processes in the pelagic. The bottom currents are slow and consistent in this sub-region and the benthic community, like other typical featureless deep-sea plateaux, is likely to be patchily distributed and relatively sparse.

The distribution of food resources is likely to be the main limiting/determining factor for many infauna species. In areas of low productivity, organic matter is usually consumed at the sediment/water interface, while in areas of high productivity, the epifauna may not consume all *in-situ* or falling organic matter, possibly leading to sediment pore waters becoming anoxic (Jorissen *et al*., 2007). Bottom-currents would also drive particle size distribution over the flat surface of the platform which would have some influence on the distribution of benthic assemblages (Gage and Tyler, 1991). Bottom currents in this sub-region are dominated by the northerly-flowing Sub-Antarctic Water Mass, which, as described for other sub-regions, may represent an avenue for connectivity in the demersal environment.

The primary ecological features of the demersal environment on the platform is expected to include species that are adapted to both soft and hard sediments. Soft sediment, mobile epifauna includes ophiuroids, echinoderms, polychaetes, sea-pens and other related organisms which are typically supported by microbial processes at the sediment surface. Infaunal assemblages that include filter-feeders and detritivores would also be included under this broad category. Areas of high current associated with the hard substrate may support more established epibenthic organisms including scattered populations of suspension feeding sponges and azoothanthellate deepwater corals at their depth limit. These would in turn support groups such as crabs, cephalopods, echinoderms which would live amongst the deep reefs for cover.

A joint Australian and New Zealand survey, NORFANZ, was carried out in 2003 (Williams *et al.*, 2006*b*), aimed at identifying the biodiversity and endemicity of the benthic seamount fauna on a number of seamounts in the Lord Howe Province, Norfolk Province and in the Southern Seamounts field. At the time of writing, data collected in this study are not completed analysed and so site-specific conclusions are not available. However, in total, some 516 species of fish and macroinvertebrates were obtained, 36% of which were new to science and potentially endemics (Williams *et al.*, 2006*a*). The research also found little overlap between the community composition of seamounts sharing the same habitat type, at similar depth and latitude, within 1,000 km of each other. It may be that these taxa have adapted their life histories because of the small size of seamounts and the considerable distances between them and their niche environment which restricts dispersal and concentrates site-specific seamount populations.

Data analysed for the ophiuroids (brittle stars) collected in the voyage indicate that, faunistically, the seamounts sampled in the Lord Howe province were similar to eachother and were differentiated from the Tasmanian seamount fauna. The Norfolk seamounts had similarities with both the Lord Howe and the Tasmanian seamounts. For ophiuroids, depth appeared to be one major controlling factor (Williams *et al.*, 2006*a*).

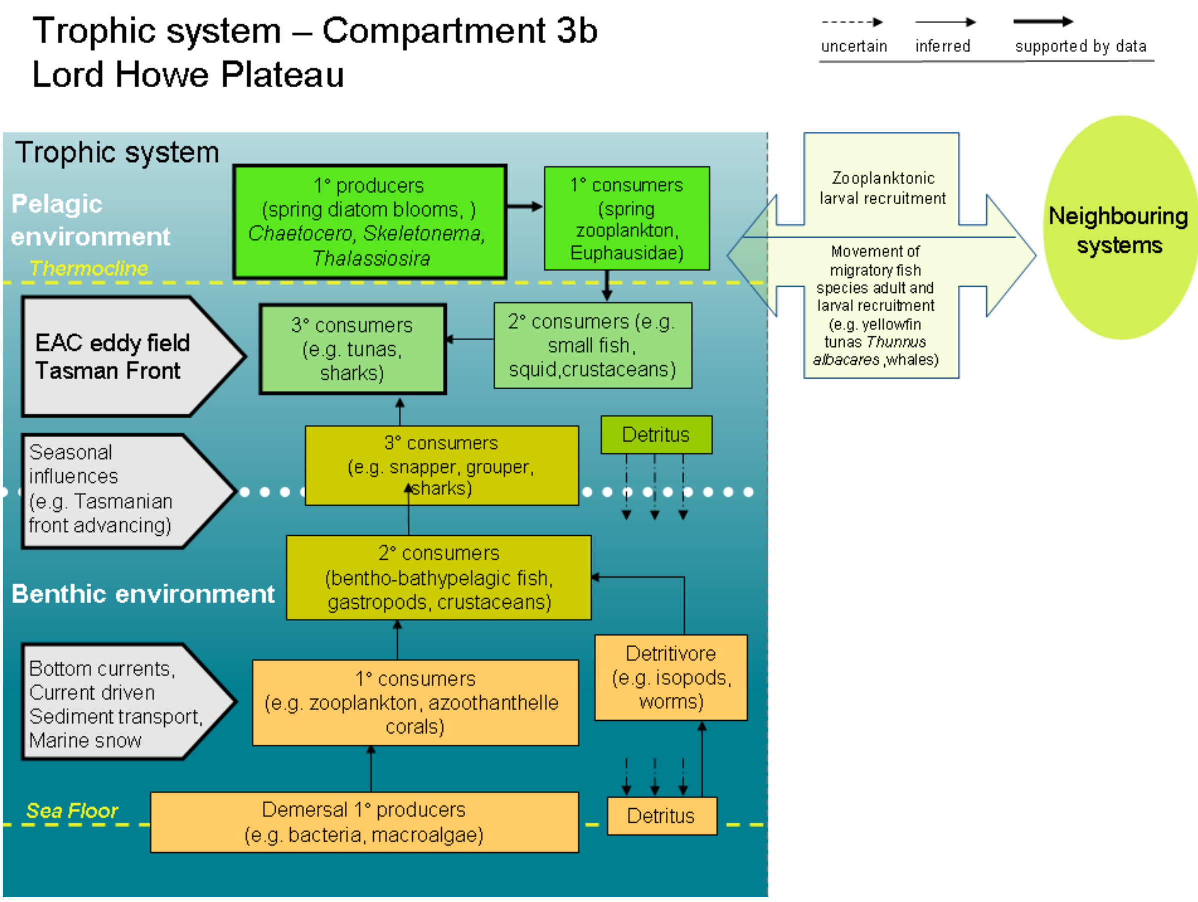


Figure 7-33 Eco-physical model for the Lord Howe Plateau sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions.

7.10.3 Productivity flows

Pelagic productivity flows on the Lord Howe Plateau sub-region conform to conventional oceanic processes. Primary production is driven by the pelagic environment and is seasonally influenced by fluctuations in the Tasman front. Production is greatest during August and November and peaks in October as the front brings cool nutrient rich water into the system from the Antarctic (Lyne and Hayes, 2005). As the waters reach their production threshold, nutrient exhaustion in the euphotic zone causes a reduction of primary production from November to February. The phytoplankton is consumed by secondary producers in the form of zooplankton (such as crustaceans, larval molluscs, larval fishes). These would in turn attract secondary consumers such as planktonic jellyfish and salps as well as nektonic secondary consumers such as transient small-fish and squid. Significant tertiary consumers in this environment are transient billfish, tuna and other large pelagic predators such as sharks and marine mammals that either migrate seasonally or pass through the sub-region following prey fish.

The benthic environment of the Lord Howe Plateau sub-region is dominated by current-driven transport of sediments/nutrients and cycling of POM (such as marine snow and other falling organic matter and detritus) through bacterial detrital food webs. Epi-benthic communities would be driven by these processes in the absence of light with boring sponges, deepwater corals, anemones, bryozoans, gorgonians, polychaetes, barnacles and bivalves providing habitat complexity and food sources for a range of higher groups including bentho-pelagic fish or invertebrate communities.

As is common in deep sea habitats, the productivity flows between the pelagic and demersal environments are not strongly connected, with falling detritus from the pelagic environment facilitating the main form of linkage.

7.10.4 Connectivity with other Sub-regions

The EAC, Tasman Front and eddies would be the principle mechanism facilitating connectivity between the Lord Howe Plateau sub-region and its neighbouring sub-regions. The easterly divergence of the EAC along the Tasmanian front would allow transportation of planktonic larvae and larger vagrant and migratory species such as billfish and tuna. The Sub-Antarctic Water Mass may provide a means of connectivity for the demersal environment.

It is unknown whether the steep rise of the platform, and the separation of this platform by the deep troughs of sub-region 3a and 4a, would act as a physical barrier to connectivity of demersal habitats.

7.10.5 Interactions with important species and habitats

The Lord Howe Plateau sub-region is expected to be characterised by relatively featureless seabed, with sparsely-populated ecological communities, probably dominated by epi-benthic detritivores and filter-feeders. If appropriate conditions are met, including availability of hard sediment and suitable delivery of organic matter via bottom currents, the platform may support deep water reef communities. These deep reefs would be expected to be dominated by filter-feeding epi-fauna (i.e., sponges, bryozoans, azooxanthellate corals), which may in-turn support demersal consumers such as crustaceans, echinoderms, bivalves, cephalopods and fishes (Rogers, 2004).

7.10.6 Vulnerability to impacts and change

The species composition and transport across the Lord Howe Plateau sub-region is dependent upon the EAC and so the pelagic ecophysical system is vulnerable to changes to these physical processes (timing, strength, duration). The vulnerability of deep water reef systems to bottom-trawling has been well-documented for other areas and, should these reefs occur in this sub-region, they would most likely be sensitive to this impact. Benthic environments are also vulnerable to activities relating to oil and gas resource exploitation as they are more easily accessible on the relatively shallow platform then deep water deposits. Demersal communities may be vulnerable to alterations in delivery of detrital matter and other organic processes (e.g. down-slope sediment transport) and near-bottom oceanographic processes.

7.10.7 Information gaps

Data for the Lord Howe Plateau are limited. Some of the main information gaps, as they related to the ability to define ecophysical systems are:

- Occurrence, endemicity and assemblages on the Lord Howe Plateau, particularly, the potential for significant deep reef systems;
- Relationships between this and more northern plateau and mechanisms of connectivity;
- The influence of the Lord Howe seamount chain upon community structure of the plateau;
- Determinants of pelagic, meso-pelagic and bathypelagic assemblages.

7.11 New Caledonia Basin Sub-region (4a)

7.11.1 Description

The New Caledonia Basin sub-region (4a), covering over 147,371 km^2, is part of IMCRA bioregion PB21, the Norfolk Island Province. This sub-region is situated in the central Tasman Sea, approximately midway between New Caledonia and New Zealand (Williams *et al*, 2006), in the warm-temperate waters of the Coral Sea Circulation (Water Mass P13; mean temp. - 19.15°C) (Lyne and Hayes, 2005).

The bed of the New Caledonia Basin sub-region forms part the central segment of the New Caledonia Basin which is generally flat-lying and occurs in water depths of 3,000 m, between Lord Howe Rise (Sub-region 3b), to the west and Norfolk Ridge (Sub-region 4b) to the east (Harris *et al.*, 2003) (Figure 7-34).

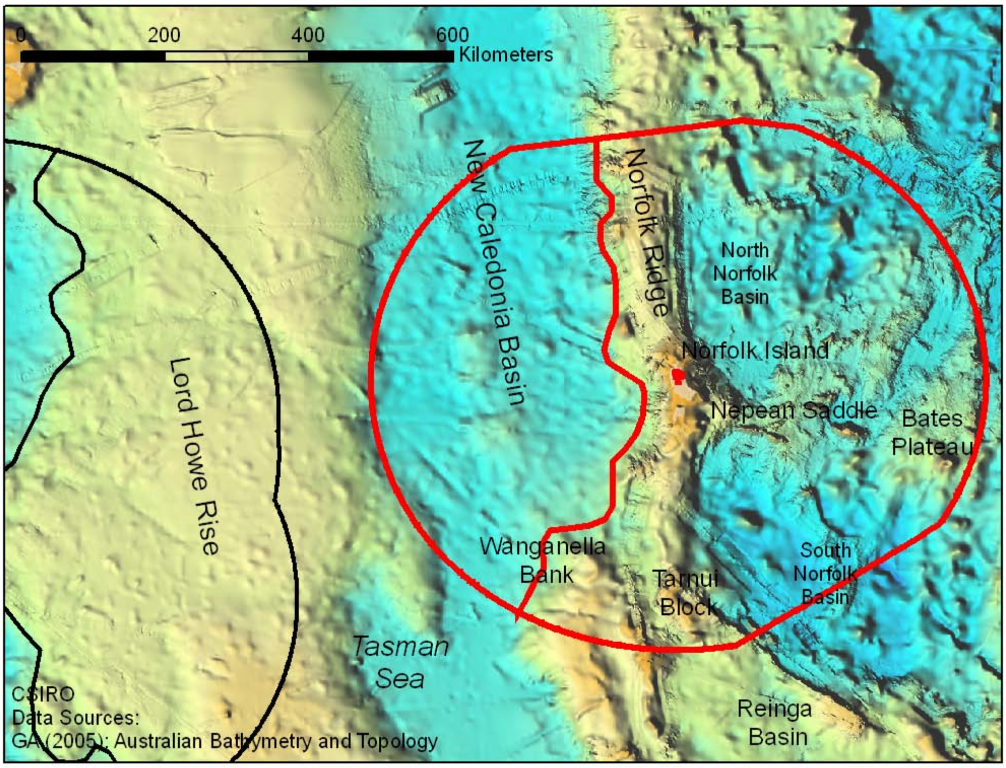
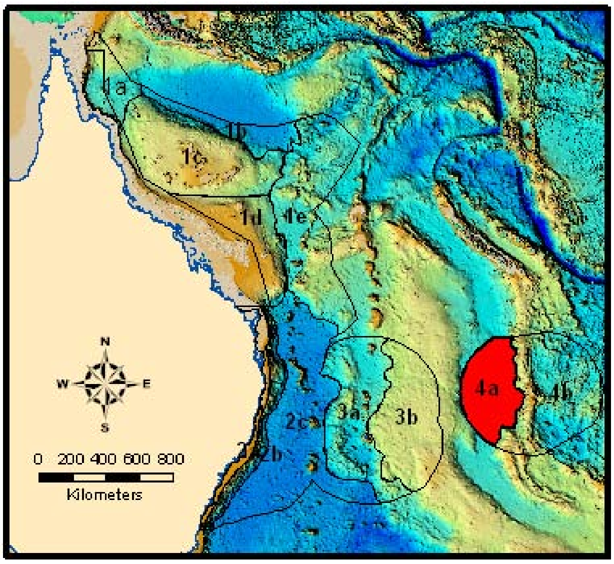
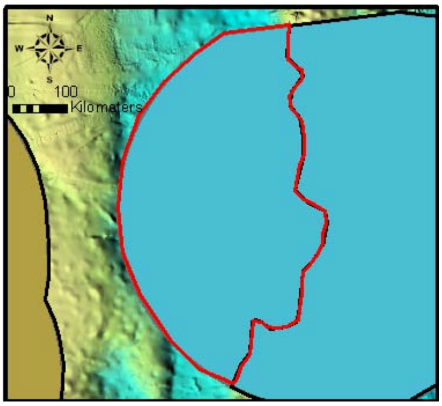


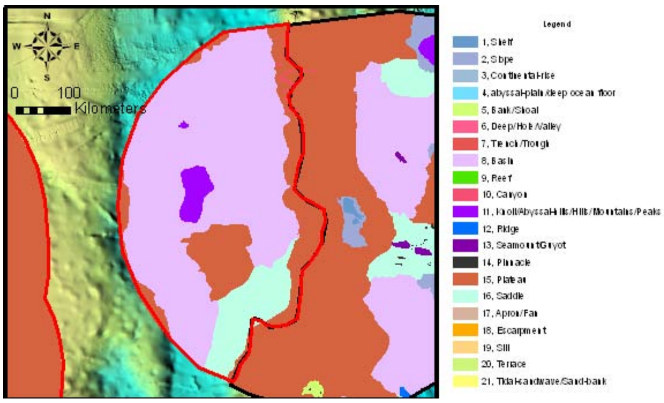
Figure 7-34 New Caledonia Basin sub-region (4a) (left), and Norfolk Complex sub-region (4b) (right) showing locations of selected features



a) Location of sub-region 4a



b) Sub-region 4a overlaid on IMCRA bioregions



c) Sub-region 4a overlaid on geomorphic features

Figure 7-35 New Caledonia Basin sub-region (4a), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

7.11.2 Important Drivers and Ecological Features

Pelagic

The eastward flow of the Tasman Front occurs between 33°and 35°S (current B in Figure 6-2) and passes through the south of the New Caledonia Basin, while a relatively smaller jet, called the North Tasman flow (current C in Figure 6-2), passes through the north (Ridgway and Dunn, 2003). Once it has passed over the Lord Howe Rise, the Tasman Front flow enters the deep waters of the New Caledonia Basin and proceeds unchecked until it impinges on the irregular topography of the Norfolk Ridge.

The Tasman Front is characterised by strong thermal gradients that produce significant velocities at the frontal zone. In general, the temperature changes across the front from 19°C in the Coral Sea waters to 17°C in the Tasman Sea waters over a distance of approximately 10 km. Advective processes associated with the fronts act to increase nutrient concentrations in the euphotic zone and the increased concentration of food particles and weakly-swimming zooplankton leads to multi-trophic-level blooming of productivity, ultimately attracting larger nektonic predators such as squid, fish (e.g. redfish, *Centroberyx affinis*), sharks (*Galeorhinus galeus*) and killer whales.

Demersal

The little that is known about demersal communities at sub-tropical and temperate latitudes, throughout the Pacific Ocean, is evident in this sub-region. It may be possible to form assumptions based on the bathymetry and current regime within the New Caledonia Basin. Nutrient mixing may be caused by the movement of the EAC/Tasman Front through this sub-region. Conversely, due to the linear, flat-lying nature of the seabed, the flow of the EAC/Tasman Front is unimpeded, thereby transporting and possibly scouring nutrient rich sediments from the basin until it reaches the Norfolk Ridge on the eastern edge of the sub-region.

There have been a few scientific surveys of demersal fish resources in the waters of Norfolk Island, including results from a recent operation under a Scientific Permit issued by AFMA (AFMA, 2000). But these studies tend to be in the adjoining Norfolk Complex sub-region (4b), with limited overlap with this sub-region. One such study, conducted in May 1990, by the Japanese research boat Eikyu Maru, undertook experimental demersal trawl shots in a survey along the Norfolk Ridge, targeting alfonsino (*Beryx decadactylus* - AFMA, 2000). Depths of trawls ranged from 139 to 929 metres. The survey found only small alfonsino to the north with little epibenthos and other fish species common to the depths trawled. In contrast, catches in the other trawls to the south found a rich epibenthos.

7.11.3 Productivity flows

Within the waters of the New Caledonia Basin sub-region patterns of phytoplankton growth and primary production are very seasonal and operate in a latitudinal band about 10° wide (Figure 6-11). In July, there is a region of low chlorophyll (0.15–0.2 mg Chl-*a* m^{-3}) between about 20°S and 30°S. In October, the southern edge of the low-chlorophyll region is still at about 30°S, but there is a marked increase south of this.

This increase progresses southward as a front and is quite dynamic. Production is low (100-250 mg C m^{-3} d^{-1}) over much of the region between 20°S and 40°S in July, but it doubles in October between 30°S and 40°S. By January, the high production region has moved further south, into the Subtropical Convergence and Subantarctic waters, but production in the 30°S to 40°S band has dropped back to < 250 mg C m^{-3} d^{-1} (Lyne and Hayes, 2005).

These seasonal shifts in productivity attract squid, fish such as sea perch (*Lutjanus* sp.), blue flathead (*Cubiceps caeruleus*), cod (*Lepidion schmidti)* and their predators including common dolphins (*Grampus griseus*), long-finned pilot whales (*Globicephala* melas), wedge-tailed shearwaters (*Puffinus assimilis*) and shortfin mako sharks (*Isurus oxyricnhus*).

7.11.4 Connectivity with other sub-regions

As described in the Southern Seamounts sub-region (2c), the physical properties of the Tasman Front can cause an aggregation of buoyant or weakly swimming zooplankton which attracts transitory fish such as yellowfin tuna and associated predators (e.g. blue sharks).

As part of the isolated Norfolk Sub-regions it can only be assumed that these transitory species move between the New Caledonia Basin sub-region, the adjoining Norfolk Complex sub-region (4b) and possibly the Lord Howe Sub-regions (3a and 3b).

7.11.5 Interactions with important species and habitats

Localized upwelling may occur as the EAC/Tasman Front is deflected when it reaches the Norfolk Ridge, resulting in a nutrient rich area in the eastern edge of the basin. To the east of the Norfolk Ridge (sub-region 4b, Norfolk Complex) various pelagic and demersal finfish fisheries exist which may crossover into this sub-region, however, at this time there is no information available for this sub-region.

7.11.6 Vulnerability to impacts and change

Cai (2006) reported on recent climate trends in the Southern Hemisphere which may significantly alter the intensity of the EAC and therefore the properties of the Tasman Front. A strengthening of the circumpolar westerly and a weakening of the mid-latitude westerly, extending from the stratosphere to Earth's surface is attributed to Antarctic ozone depletion. The observed surface wind changes forced a southward shift and spin-up of the Southern Ocean super gyre circulation, which links the subtropical South Pacific, Indian and Atlantic Ocean circulation, advecting warm water further southward. The circulation change included a strengthening of the EAC flow through the Tasman Sea. The southward shift may be responsible for the observed unusually large warming in the SH mid-latitude ocean and may contribute to the reported range extension to the south of many marine species in the South West Pacific.

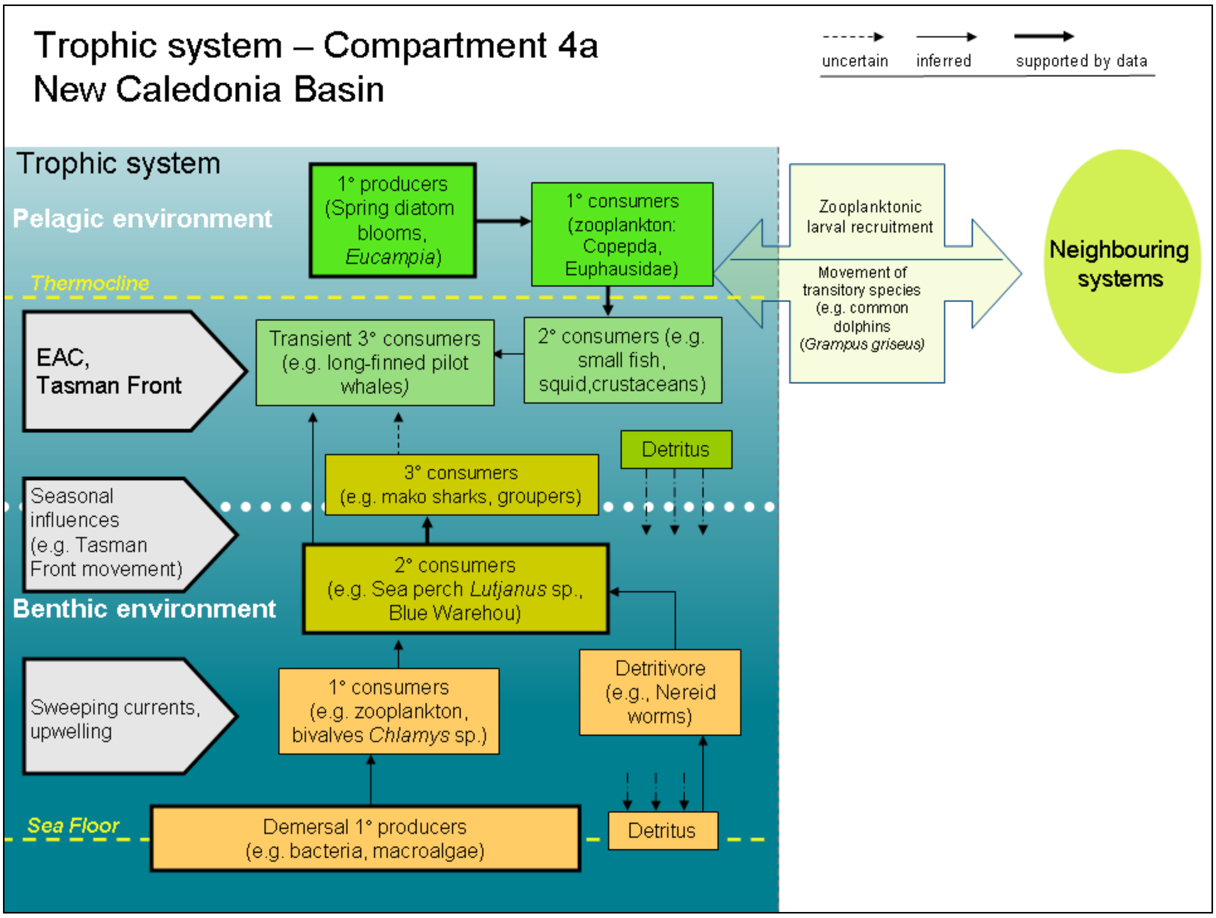


Figure 7-36 Eco-physical model for the New Caledonia Basin Sub-region, showing the major physical and ecological processes in the sub-region basins, and their trophic interactions.

7.11.7 Information gaps

- Links between biological and physical properties in this sub-region (Baird *et al*, 2007).
- The effects of climate change on the movement of the Tasman Front (Cai, 2006).
- Sediment characterisation and flow regime.
- Floral and faunal communities.
- Endemicity.

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7.12 Norfolk Complex Sub-region (4b)

7.12.1 Description

The Norfolk Complex sub-region (4b), covering over 283,422 km^2, is part of IMCRA bioregion PB21, the Norfolk Island Province, which lies in the central Tasman Sea approximately midway between New Caledonia and New Zealand (Williams *et al*, 2006), in the warm-temperate waters of the Coral Sea Circulation (Water Mass P13; mean temperature - 19.15°C) (Lyne and Hayes, 2005).

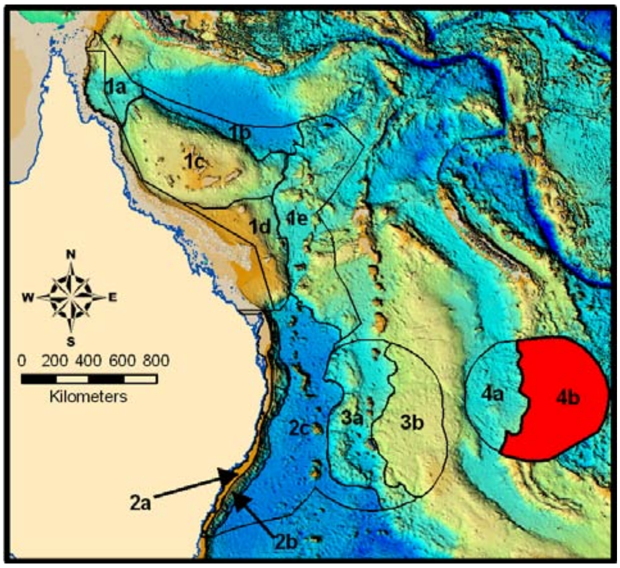
The Norfolk Ridge is a major feature in this sub-region, comprised of a complex system of ridges and basins, extending from New Caledonia in the north to New Zealand in the south (Figure 7-34). The northern section is a steep-sided, narrow submerged continental ridge, approximately 70 km wide, with water depths at the crest between 500 – 1,500 m (Harris *et al.,* 2003). The volcanically formed Norfolk Island is situated on the central section.

The southward continuation of the Norfolk Ridge is called the West Norfolk Ridge system. It is comprised of a series of NW-trending ridges and basins which includes the Wanganella Bank region (Wanganella Bank, Wanganella Trough and Wanganella Ridge), Reinga Basin and Tarnui Block (Figure 7-34). Water depths in the West Norfolk Ridge system range from 300 – 1,000 m on the ridges to 1500 – 2000 m in the intervening basins (Harris *et al.,* 2003).

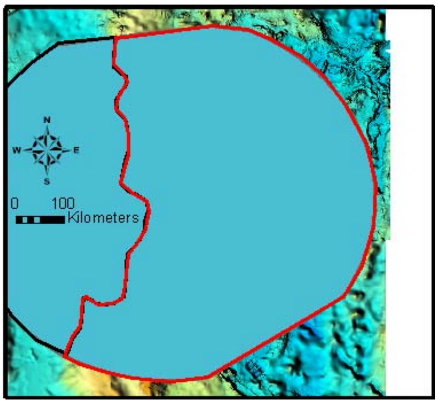
7.12.2 Important Drivers and Ecological Features

Pelagic

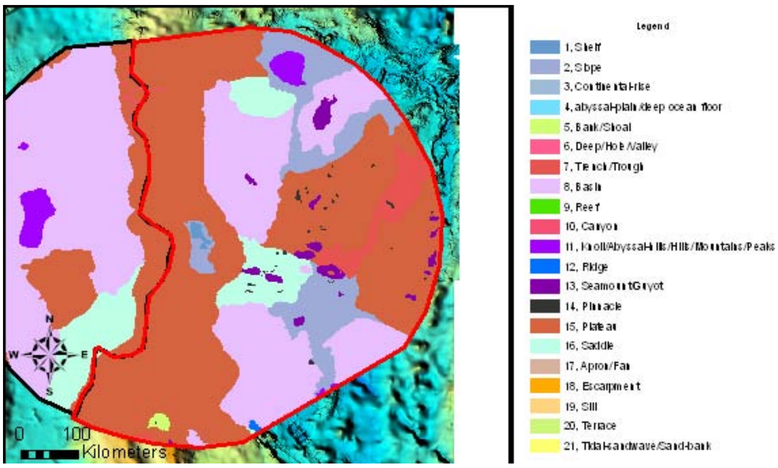
The Norfolk Complex sub-region is influenced by the Tasman Front. The North Tasman flow is a current filament (current C in Figure 6-2) which detaches from the EAC at approximately 31°C and loops northward over the Lord Howe Rise, then veers diagonally northwestward between 165° and 170°E (Ridgway and Dunn, 2003). This diversion is caused when North Tasman flow encounters the subsurface westward flow on the northern edge of the Norfolk Eddy (eddy I in Figure 6-2). This quasi-permanent eddy is a stationary feature. Within the thermocline, the Norfolk Eddy has a temperature and salinity signature of more than 1 °C and 0.05 psu, respectively, and is still evident as a distinct feature at 1500 m (Ridgway *et al*., 2002). Depth-averaged steric height derived from the temperature (*T*) and salinity (*S*) fields in the CSIRO Atlas of Regional Seas (CARS) is shown in Figure 7-38.



a) Location of Sub-region 4b



b) Sub-region 4b overlaid on IMCRA Bioregions



c) Sub-region 4b overlaid on Geomorphic Features

Figure 7-37 Norfolk Complex sub-region (4b), showing (a) the location of the sub-region in the East Marine Region (b) the sub-region boundaries in comparison to the IMCRA bioregions and (c) it's boundaries in relation to the geomorphic features map.

The Norfolk Eddy covers the seamounts and pinnacles in the east-southeast of this sub-region, e.g. Blackbourne Seamount, while the northeast which has deeper seamounts and pinnacles is influenced by lower steric heights (Figure 7-38). Flow fields often observed in association with biogeographic boundaries have the potential to constrain a species' geographic range (Gaylord and Gaines, 2000) and because the Norfolk Eddy's physical conditions exist down to 1,500 m, the potential for larval retention from the seamounts of the Nepean Saddle, Bates Plateau and South Norfolk Basin region may be increased and contribute to high levels of endemism in the area immediately under the eddy. It may then follow that the seamounts and pinnacles in the absence of the Norfolk Eddy and different geomorphology in the lower steric heights, in the north of 4b, have a different larval pool (Williams et al., 2006a).

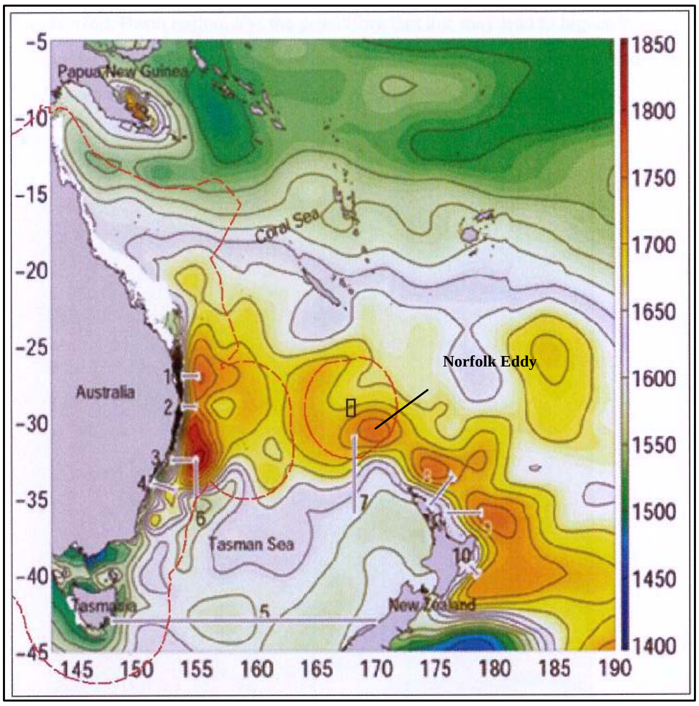


Figure 7-38 Depth-averaged steric height (or mass transport function, $P_{0/2000}$) derived from the T and S fields in the CARS atlas (Ridgway and Dunn, 2003). Overlaid with the Australian EEZ (AMBIS) and the Norfolk Inshore Fishery Box (AFMA).

Demersal

The Norfolk Complex is adjacent to the New Caledonian section of the Norfolk Ridge which is known to support an archaic benthic fauna (sponges, hydroids, crinoids, molluscs and echinoderms) similar to the fauna which originally inhabited the margin of Gondwana, including some groups which were thought to have become extinct in the Upper Jurassic (e.g. Lithisid sponge; Williams *et al.*, 2006). The Norfolk Ridge, on the western boundary, is a contiguous feature at depths of 1,000 to 2000 m connecting New Zealand, Norfolk Island and New Caledonia with seamounts and other elevated features at 500 to 1,000m depth. Similar, to the theory of transitory stopping points, described in the Southern Seamounts (Gad and Schminke 2002), it has been hypothesised that the Norfolk Ridge provides 'stepping-stones' for the transoceanic dispersal of planktonic larvae of benthic species (Williams *et al.*, 2006).

The current regime within this sub-region is subject to deflection and increased flow, whereby generally slow-moving deepwater currents (< 5 cm sec^{-1}) may speed up and change direction as they pass over seamounts (20 – 30 cm sec^{-1}; Williams et al., 2006a). This results in seamounts swept clear of fine sediments, therefore, exposing firm substrate which provide anchor points for epifauna. These enhanced flows may also transport nutrient rich waters past seamounts and provide a consistent food-source for filter-feeders, resulting in seamount benthic communities being dominated by emergent, filter feeding fauna. The plankton and micronekton prey aggregations described above also attract benthopelagic, commercially valuable fish such as Orange Roughy (*Hoplostethus atlanticus*; Koslow 1997), Silver Trevally (*Pseudocaranx dentex*) and Blue Eye Trevalla (*Hyperglyphe antarctica*).

As mentioned in Section 7.10.2, the multi-national NORFANZ voyage of 2003 sampled seamounts in the Norfolk Province, along with those in the Lord Howe Province and outside Australia's EEZ. While data are not completely analysed at the time of writing, initial indications for the whole data set indicate the potential for endemicity, at least among the sessile invertebrate fauna (Williams *et al.*, 2006*a*). Initial analysis of ophiuroid data obtained in this study suggested that, faunistically, the Norfolk seamounts had similarities with Tasmanian, Lord Howe and New Caledonian seamounts.

7.12.3 Productivity flows

The Norfolk Complex is situated within a band of annual mean sea-surface chlorophyll-*a* concentrations between 0.1 and 0.2 mg m^{-3} (Williams *et al.*, 2006). Generally, the Coral Sea and the EAC are nutrient poor, therefore, chlorophyll levels are low. While in the Tasman Sea there is higher productivity associated with regularly occurring spring and autumn phytoplankton blooms. These blooms are a result of vertical mixing of the water column caused by eddies spinning off to the south as they split off from the Tasman Front-EAC separation.

In addition, the Norfolk Eddy and an eddy south of this sub-region, called the East Cape Eddy, (eddies III and IV, respectively as in Figure 6-2) have been described as a physical mechanism for nutrient retention which also contributes to the spring and autumn phytoplankton blooms, followed by peak biomass of salps in the region (Bradford *et al.*, 1982; Williams *et al.*, 2006).

The energy for the deep-sea biota is mainly derived from an attenuated 'rain' of detritus from remote surface waters (typically 1–10 g C_{org} m^{-2} yr^{-1}). Detrital food particles range from the fresh remains of phytoplankton (or 'phytodetritus') to the carcasses of whales (Glover and Smith 2003). The purely detrital base of deep-sea food webs contrasts sharply with those of most epipelagic, shallow water and terrestrial ecosystems, which are sustained largely by locally produced organic matter (Polunin *et al.*, 2001). Due to the low flux of organic energy, the biomass of deep benthic communities is typically only 0.001–1% of that in shallow-water benthic or terrestrial communities (Glover and Smith, 2003). Low food flux, combined with low temperatures (1 – 4°C), yield relatively low rates of growth, respiration, reproduction, recruitment and bioturbation in the deep sea (Glover and Smith 2003). In general, the deep-sea floor is also characterized by very low physical energy, including sluggish currents (0.25 knots), very slow sediment accumulation rates (0.1 – 10 cm per thousand years), and an absence of sunlight (Glover and Smith 2003).

Seamounts, however, have been described as oases of increased productivity in the otherwise nutrient-poor open ocean. This is due to the influence of seamount topography on water currents and the interception of mesopelagic vertical migrators such as micronektonic fishes and zooplankton from the deep-scattering layers, as described above. This combination of physical drivers leads to exposed, hard substrate for filter-feeder attachment and nutrient rich waters. Enhanced supply of food may lead to dense aggregations of habitat-forming epifauna that in turn provide shelter and food for other animals. This enhanced benthic productivity combined with the previously described intersection of deep-scattering layers, aggregates commercial fisheries in quantities that are exploited by pelagic and benthic contact fishing.

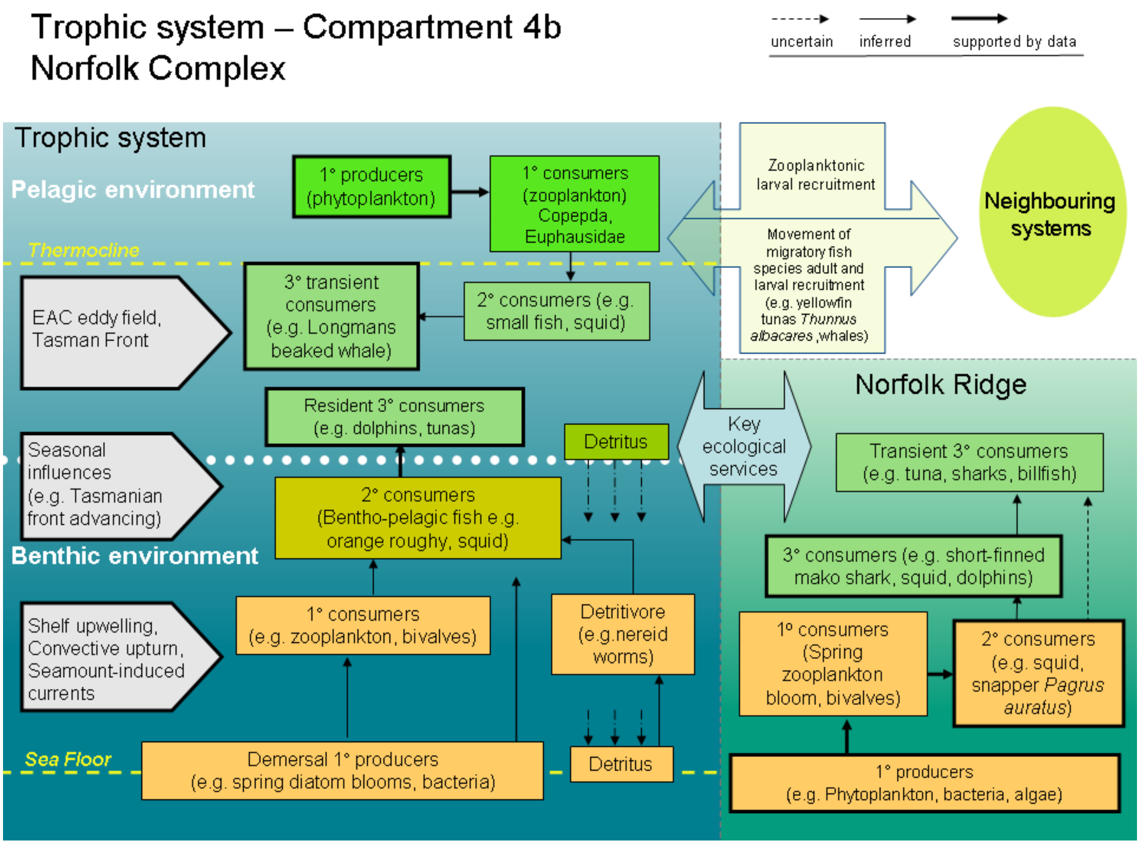


Figure 7-39 Eco-physical model for the Norfolk Complex Sub-region, showing the major physical and ecological processes in the sub-region, and the main ecological groups and their trophic interactions. The Norfolk Ridge is an important ecological feature in this sub-region and is also described.

7.12.4 Connectivity with other Sub-regions

Due to it's isolation from the Northern Sub-regions (1a-e) and the Southern Sub-regions (2a-e) along the eastern Australian coast, sub-region connectivity is not clear but for the attachment to the New Caledonia Basin sub-region (4a) and possibly with the Lord Howe sub-regions (3a and 3b). The transport of plankton and benthic planktonic larvae may occur as the North Tasman flow enters this sub-region from the west via Lord Howe Rise and the New Caledonia Basin. As described above, with regard to dispersal restrictive life histories, and below in 'Vulnerability to impacts and change', connectivity between seamounts in this sub-region i.e. the exchange of animals between seamounts, is limited as witnessed by the NORFANZ research showing seamount specific endemicity and also by the pressures from demersal finfish trawls which reduce numbers of seamount species.

7.12.5 Interactions with important species and habitats

As discussed in the sub-region 2c, seamounts are biomass hot spots because they can induce leeward plumes of enhanced productivity caused by localized upwelling, i.e. island wake effect (Norse and Crowder 2005). Seamounts may also support high animal biomass because they offer a combination of amplified current flow and complex seafloor habitat for the establishment of oasis-like habitats within the generally barren open ocean. Resident predatory fish, such as both to feed on passing zooplankton and small fishes, such as lanternfishes and Myctophidae, in the water column and to take refuge amidst seamount structures when marauding pelagic sharks or tunas arrive.

The fishes (e.g. Blue Grenadier *Macruronus novaezelandiae*) and other animals that feed on passing organisms and detritus effectively increase the seamounts' filtering capacity, which may then eventually develop into a complex trophic structure providing more food to benthic communities than might otherwise occur. While seamount surveys have found extremely high (>30 percent) levels of apparent endemism (Richer de Forges *et al.*, 2000), this has yet to be confirmed on a genetic basis. The Norfolk Eddy may be attributed to increased lavrval residence time in waters overlying seamount and pinnacle structures in the south of the Norfolk Complex.

Similar to Taylor columns, stationery eddies allow eggs and larvae to stay within waters above a seamount increasing the likelihood of successful settlement on suitable hard substrate. The seamounts are essentially isolated closed populations and it is assumed that gene flow between the seamounts is negligible, however as previously noted above this is yet to be confirmed by investigation of genetic markers. This geographic isolation may eventually modify the life-histories of resident fauna towards reproductively isolated endemics. Such modification of life histories has been observed whereby the initial adaptations to isolation are manifested through shortened larval duration or behaviours that would retain larvae within Taylor columns (Norse and Crowder 2005).

7.12.6 Vulnerability to impacts and change

Due to their highly localised distribution, seamounts are extremely vulnerable to the impacts of fishing (Williams *et al.*, 2006). The extreme longevity and late-maturing of commercially valuable fish such as the Orange Roughy *Hoplostethus atlanticus* (>100 years, maturity at 22 - 40 years) makes them particularly vulnerable to anthropogenic impacts and may take longer periods of time to recover, i.e. to reach a population size necessary to maintain a stable, sexually mature population. Commercial fisheries generally use bottom longlining techniques and bottom trawling method which causes a greater degree of damage to seafloor communities (Chuenpagdee *et al.*, 2003). Fragile, habitat-forming corals and sponges are both subject to trawl damage and may take years to recover, similar to recovery periods following forest clear-cutting (Watling and Norse 1998).

7.12.7 Information gaps

Williams *et al*. (2006) identified a number of information gaps for the sub-region:

- In order to confirm suggestions that Norfolk Island is an area of high endemicity, quantification, by taxonomic and genetic experts, of the differences between the fauna of this sub-region and faunas from continental Australia, the other ridges in the Coral/Tasman Seas and from New Zealand and New Caledonia.
- Quantitative analysis of a broader geographical range of data covering a greater variety of fauna is required to confirm and add detail to suggestions that Norfolk Island is biogeograhically distinct from other sub-regions in the Australian Marine Jurisdiction, at a provincial scale (IMCRA v4.0).
- Greater understanding of the pelagic realm and its influence on the benthic fauna. Particularly the specifics of physical driving processes such as the Norfolk Eddy and their relevance to the distribution of biodiversity.

8. CASE STUDY – TROPIC INTERACTIONS IN OCEANIC WATERS OF EASTERN AUSTRALIA (20º-40ºSOUTH)

The waters off eastern Australia are dominated by the interaction of tropical-origin oligotrophic Coral Sea water with colder nutrient-rich Tasman Sea waters to the south, and divided by the Tasman Front. The relative position of these water masses changes seasonally when warmer waters extend southward either through the position of the Tasman Sea or via the southward extension of the East Australia Current along the eastern seaboard of Australia. There is also a strong interannual signal which at times over-rides the seasonal signal. Recent studies of potential ocean-warming indicate a long-term southward extension of tropical origin water. This region, with its dynamic physical oceanography, is also the site of the Eastern Tuna and Billfish fishery (ETBF), a significant longline fishery which targets a suite of tuna and billfish species which inhabit these waters. Because of the importance of the fishery and the requirement for its sustainable management, FRDC has funded a large scale ecosystem study from which the following summary of trophic interactions is taken.

The dynamic oceanography of the region which includes the East Australia Current and associated warm and cold core eddies and the presence of complex topographic features including the Tasmantid seamount chain limits generalizations of the trophodynamics of the broader region. This is particularly the case for the tunas and billfish, the abundance of which varies seasonally and spatially. For example, southern bluefin tuna, which are present in the southwestern Tasman Sea in winter, are absent at other times of the year. Conversely, striped marlin and swordfish abundance is highest in the region of the ETBF over summer. Tropical tunas, such as yellowfin, tend to dominate in years with higher overall water temperatures. The distribution of albacore tuna is not clear although there is evidence for seasonal migrations from the Coral Sea to as far south as Tasmania.

However, using a mix of methodologies, including stomach contents and biochemical analysis, we have identified three broad groupings into which these large and middle order predators can be grouped, defined on the basis of their prey and biochemical signature. With the exception of the larger sharks such as mako, which has a biochemical signal indicating it feeds on larger species including the tunas and billfish, there is a broad grouping of top predators including adult and sub adult tunas, billfish and medium-sized sharks (Fig. 1). Underlying them is a grouping of fishes ~1 meter in length including species such as dolphin fish, lancet fish and smaller tunas such as albacore. This second group is not usually preyed on by the top predators although there are some ontogenetic predator/prey relationships. Also included in this group is a range of cephalopods that appear to have a role as both predator and prey. Supporting these two groupings is a broad array of smaller micronektonic and zooplankton prey. This last group is dominated by small pelagic fishes including members of the families Myctophidae, Macrorhamphosidae, Scombridae and Nomeidae. Crustaceans, including pelagic larval brachyurans and euphausiids, usually a minor component of the diet of younger tunas and billfish, are occasionally dominant as prey, particularly in terms of occurrence, in yellowfin tuna and striped marlin. Overlying these more general relationships are the influences of physical oceanography and predator/prey length relationships. Predators associated with the East Australia Current prey more frequently in the surface layers whereas those feeding in more offshore waters tend to feed at greater depth. The end result is a shift from a more fish-based diet in inshore waters to one dominated by squid offshore. Predator/prey interactions are also structured on the basis of size or length with the range and size of prey available to a predator increasing as it grows through the predation window. This relationship is underlined by the presence of juvenile swordfish in the stomachs of the fast-swimming (and growing) dolphin fish. Prey type is also determined by the vertical distribution of the predator. Species such as dolphin fish and yellowfin tuna that are mainly restricted to the upper layers of the water column having a significantly different prey to those such as swordfish that feed at depth. Notably, these differences extend to species differences underlining the need for detailed food web studies (Figure 7.2).

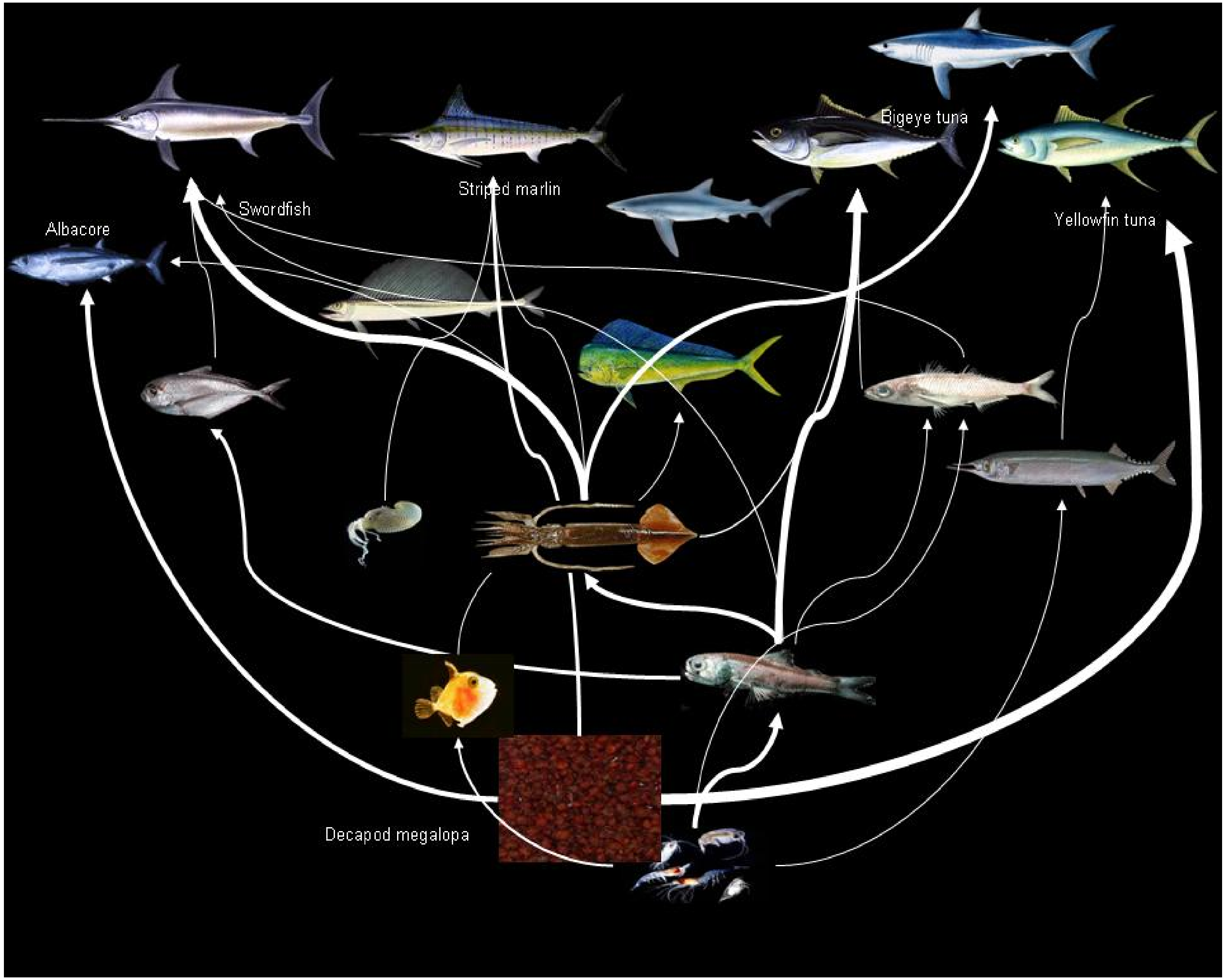


Figure 8-1 Schematic food web of the waters of the Eastern Exclusive Economic Zone showing the main food chain pathways between top predators and their micronektonic prey (data from FRDC Project 2004/063

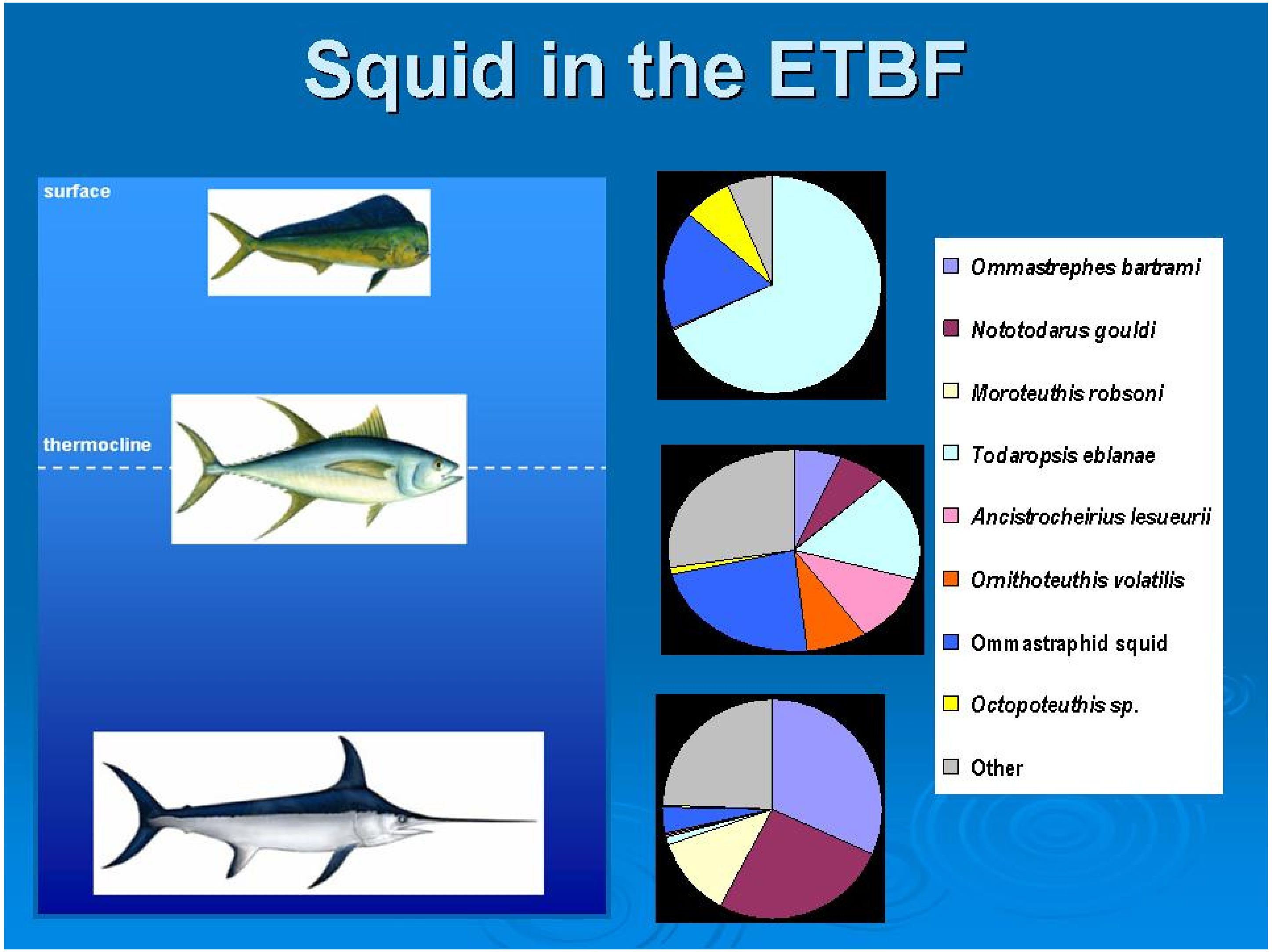


Figure 8-2 Prey type is determined not only by area and season in the region but by the depth of water a predator usually inhabits. Shown here are differences in prey species composition within a major taxon, in this case squid, for predators inhabiting different depths.

9. DIFFERENCES BETWEEN SUB-SYSTEMS

The eco-physical systems (sub-regions) described in this report are characterised by a combination of drivers and features unique to each. In general, the shelf, slope and abyssal sub-regions are markedly different with depth related habitat drivers influencing the ecology of the sub-regions in fundamental and predictable ways. However, within this schema, other important habitat drivers such as water temperature, current patterns and geomorphology influence sub-regions in such a way that each has a unique set of habitats, communities and other features.

The pelagic environments of many of the sub-regions also have unique features. The only shelf sub-region, the Eastern Shelf (2a), has a unique combination of processes leading to local upwelling and high productivity. The more southerly offshore sub-regions also contain localised regions of high productivity by way of the interaction between the EAC and the Tasman Sea to form eddies and front systems. In contrast, the northern tropical sub-regions are more influenced by strongly seasonal wind regimes that drive currents and transport plankton, larvae, nutrients and sediments.

There is one unifying driver in the pelagic environment and that is the warm East Australian current (EAC) which dominates the pelagic waters in the East Marine region. Several of the large pelagic fish species (e.g. black marlin) migrate through the region under the influence of, or using the trophic features set up by this current. Related to the EAC, a common feature of many of the slope and abyssal sub-regions is that they have relatively warm oligotrophic surface waters, a deep chlorophyll maximum between 60 and 150 m and colder, and more saline, high nutrient water masses in their deeper realms.

The benthic habitats differ markedly throughout the region. The shallow reef and slope systems and in the Cape Province, Coral Sea reefs and islands (Qld Plateau, Marion Plateau and Northern Seamounts Field), Eastern Shelf, Lord Howe and Norfolk complexes are all distinctly different in their species assemblages. In other benthic habitats, the large-scale geomorphic features interact with bathymetry and seabed facies to dictate unique demersal community composition in each. The continental slope fish assemblages have been shown to differ throughout the region (Last *et al*., 2005), and the abyssal plains, although poorly understood, appear to have different characteristics between sub-regions.

The East Marine Region is a unique and complex region. It appears that this complexity and diversity in it's ecophysical systems will require a relatively intricate spatial management plan to adequately conserve the range of unique habitats and communities that it supports.

10. DISCUSSION AND CONCLUSIONS

10.1 Important Features

The East Marine Region contains a number of regionally significant ecological features and processes that are either unique to the region, characterise the region, or are primary ecological drivers of the region. These features are described below for the pelagic and demersal environments.

10.1.1 Pelagic

The most obvious pelagic feature in the East Marine Region is the East Australian Current (EAC), an iconic oceanographic feature that originates in the north of the region and migrates south. This current system, and its associated gyres and eddies, is the primary process whereby warm waters are delivered to southern coastal waters, and thereafter to the outlying Lord Howe and Norfolk islands, and is the primary driver of abundance, distribution and dispersal of pelagic and shelf-slope demersal organisms. The EAC is largely a 'coastal' current system and Ridgeway & Dunn (2003) indicate that the current system, at least for some periods, can be thought of as an eddy-dominated system rather than a consistent 'stream'. True coastal upwelling (the delivery of deep-nutrient-rich waters into the euphotic zone), driven by the southerly flow of the EAC, has some level of predictability or periodicity for some locations, particularly off the northern NSW coast and is recognised as an important pelagic feature.

While the EAC operates on a large spatial scale and is a permanent feature (albeit with seasonal variation in the extent of its southerly penetration and extent of easterly migration of eddies), the pelagic environment in the open ocean also responds to transient oceanographic features that operate on a smaller spatial scale such as temporary eddies, gyres and fronts. These random oceanographic conditions have the effect of 'concentrating' phytoplankton and zooplankton (i.e. productivity) which attracts highly mobile and transient consumers such as small fish and squid schools which in-turn attracts highly mobile, transient pelagic predators that range throughout the region. While some aggregations are periodic, or able to be predicted from proxies such as water temperature (e.g. southern bluefin tuna), the drivers of pelagic predator distribution are not well understood for some species which roam through very large areas of open ocean to locate these features and hunt.

Some important pelagic features of the East Marine Region occur where currents interact with topography. For example, in the Coral Sea the island-wake effect has been identified as a process causing the aggregation of meso-pelagic fishes. Additionally, the interaction between currents and seamounts has been implicated in the aggregation of billfish, primarily, in the pelagic zone over the seamounts that are targeted by commercial fishing. The interaction between currents and seamounts is also an important driver for demersal communities and is described below.

The pelagic environment of the East Marine Region provides habitat for migrating or transient marine mammals, the most notable of which is probably the annual humpback whale migrations between the Southern Ocean and breeding areas off the coast of Queensland, although these movements may be concentrated in state waters. Seabirds are also a significant feature of the pelagic environment in the East Marine Region.

With respect to sub-regionalisation, the important principal arising from this review is that, while water mass differentiation was used to distinguish generally tropical waters from temperate waters, the pelagic environment is a continuous, connected system with no physical boundaries, harbouring organisms that are adapted to a long-ranging, transitory life-history and thus, there is limited basis for sub-regionalisation. However, the open ocean is layered and while surface waters are laterally connected, there are limitations to vertical mixing and vertical distribution of organisms, due primary to temperature, light, density and other physical depth-dependent factors. While some surface characteristics can extend into deep water, such as higher temperatures under eddy features extending to the seafloor some 1000 m below, the separation of surface waters from bottom waters is reflected in the delineation of the surface water and bottom water ocean masses. The bottom waters of the East Marine Region are dominated by the generally north-flowing Sub-Antarctic Water Mass, a relatively uniform body of water. Therefore, there is some vertical differentiation in the pelagic environment (i.e. pelagic, mesopelagic, bathypelagic zones) with processes such as diurnal vertical migration of zooplankton, upwelling and topographically-induced upwelling providing avenues for mixing through these layers.

10.1.2 Demersal

The demersal environment of the EMR contains a diverse array of identifiable features including:

- Eastern Cape York slope and reefs: assemblages with affinities with the Torres Strait and Arafura Sea and differentiation from Great Barrier Reef.
- Coral Sea islands, reefs and slope: assemblages differentiated from Great Barrier Reef communities;
- Queensland and Marion Plateaux
- Queensland and Townsville troughs;
- Eastern Australian Shelf and Slope;
- Tasmantid and Lord Howe seamount chains;
- Lord Howe Rise;
- Norfolk Ridge, upon which Norfolk Island lies.

These are large-scale geomorphic features interact with water column characteristics, bathymetry and seabed facies to produce a vast variety of demersal communities..

The Queensland and Marion Plateaux support islands and coral reefs that are interesting in that the shallow demersal assemblages display some biogeographical differentiation from the neighbouring Great Barrier Reef (GBR). These plateaux also support ecophysical systems that underlie significant commercial and recreational fisheries.

The extensive seamount systems are iconic features that have been demonstrated to be hotspots of demersal biodiversity, typically in the form of deepwater reefs, dominated by filter-feeders that benefit from topographically-induced upwelling and increased availability of particulate organic matter and other nutrient sources. As a result, seamounts are also known to represent aggregation sites of deep-water fin-fish, including orange roughy.

The eastern shelf and slope are focus areas of demersal fisheries and the southern slope is part of the South East Fishery (SEF), with slope habitats offshore of Ulladulla-Bateman's Bay and Sydney-Newcastle targeted for demersal fin-fish and the deepwater prawn fishery. To the north of Barrenjoey Point (north of Sydney) to Smoky Cape (near Southwest Rocks) the shelf and slope are fished in the NSW ocean trawl fishery that targets finfish and prawns out to 4000 m depth. From Smoky Cape to the NSW/QLD border, the shelf and slope are targeted for deepwater prawns. Slope habitats typically display vertical zonation in sessile benthic community assemblages and demersal fish assemblages. The eastern slope encompasses a large number of canyons (although not in the density of those in the Southeast Marine Region) which, in other regions, are reported to represent areas of high biodiversity and areas of topographically-induced upwelling.

The ecology of the demersal environments of Lord Howe and Norfolk regions have not been studied in detail but research to date has identified some peculiarities. Shallow-water demersal communities at Lord Howe Island, for example, includes a mix of species that would be expected from these latitudes as well as sub-tropical species. This phenomenon that may be related to the easterly migration of warm eddies from sub-tropical waters into the area. Norfolk Island is quite distinct within the EMR in that its demersal assemblages have more affinities with New Caledonia than with eastern Australia.

10.2 Vulnerability to Impacts and Change

10.2.1 Climate change

Although understanding the impacts of climate change on Australia's marine regions is still in its early days current climate change predictions include a range of physical and ecological changes in the East marine region (Hobday *et al.*, 2006). In particular, strengthening southward flow of EAC resulting in less mixing of surface waters reducing nutrient input from deep waters, and increased ocean acidity. Changes already attributed to climate change include increased frequency of algal blooms and introductions of new species (e.g. long-spined sea urchin and green crab) in the Tasman Sea, that were previously excluded due to unsuitable conditions (CSIRO unpublished report).

The southward shift in distribution caused by ocean warming will displace many local species and will result in an earlier annual appearance of many groups; especially species that live at the limits of their physical tolerances. This will alter trophic and competitive relationships among species and disrupt foodwebs. There are also implications for larval health and transport and therefore recruitment to adult benthic and pelagic populations. For example, enhanced stratification will lead to a lower abundance of zooplankton but increased incidence of jellyfish blooms with potentially dramatic effects on higher trophic levels.

Deeper communities appear less vulnerable to climate change. However, reductions in the amount of phyto and zooplankton will lead to reductions in the amounts of particulate organic matter (or detrital rain) that these communities rely as a important energy source.

Shallow coral reefs such as Ashmore and Boot reefs may be heavily affected by sea surface temperature increases. Many reef systems have suffered severe coral bleaching under increased water temperatures (Oxley *et al.*, 2003) and this can lead to coral death if prolonged for more than about six weeks. Climate change may also cause an increase in severe weather conditions such as cyclone activity. Although coral reefs in this region are currently impacted by sporadic cyclone activity (and receive the associated physical damage), a more frequent rate of cyclone damage may alter the species composition of coral communities and subsequently their associated fish and other benthic invertebrate communities.

10.2.2 Impacts of fishing

Seamounts occur in several sub-regions and are extremely vulnerable to impacts of fishing due to the life history characteristics of many of the species impacted. For example, orange roughy, deep water corals and other sessile benthic invertebrates are vulnerable to trawling and take very long time periods (1000's of years in some cases) to recover (Stone *et al*., 2003; Rogers, 2004). High levels of endemism in seamount communities means that past unregulated fishing of some sub-regions may have already resulted in local extinctions among benthic seamount communities. Other fishing operations such as long-lining, and foreign unregulated fishing, have the potential to impact on highly vulnerable species such as albatross, sea turtles and elasmobranchs. These issues require urgent attention by way of robust assessments of the extinction risk to these species via current fishing activities and, if necessary, effective, additional mitigation programs introduced.

Significant impacts on many species groups can have widespread influences on the broader community through flow-on trophic cascade effects. Goldsworthy *et al*. (2003) notes the recovery of seals as an influence likely to shape the South East Fishery (SEF) ecosystem. While Bulman *et al*. (2006) suggests that current proposals to reduce or even eliminate discarding in the trawl fishery are also likely to have implications on the trophic dynamics of the SEF. Impacts on top level predators, such as billfish and tunas, is poorly understood, but may have significant impacts on the community composition and stability of both the pelagic and benthic systems. The ecosystem role and impacts of fishing on sea cucumber (bech-de-mer) populations are also poorly understood, although there is some evidence that these animals may play an important role in nutrient recycling and habitat health in intertidal and subtidal ecosystems.

10.2.3 Other impacts

Many habitats and communities in the East Marine Region are also vulnerable to impacts such as oil and gas exploration and extraction, and introduced species. Oil and gas exploration is responsible for a range of impacts that can smother or poison benthic habitats in the vicinity of the operation and impacts benthic communities in the vicinity of the exploration platforms. These include oil spills, drilling fluid, produced formation waters and sedimentation. Introduced species (e.g. from shipping ballast waters) can also have a major impact on coastal benthic communities in particular.

Coastal and reef communities are vulnerable to invasion by species from different parts of the world. In particular, species that have similar tolerances to specific Australian habitats but are adapted to a different community structure where their numbers would normally be regulated within a stable food web and ecological system. However, some introduced species are able to proliferate in their new habitat, and in doing so, displace less competitive local species. This can lead to local or wide spread extinctions and major changes in the species composition of these important habitats.

10.3 Information Gaps

In the course of this review, the authors have identified a number of information gaps in the understanding of biological and ecological processes and, on a finer scale, information gaps about specific places or species. For example, the remote areas of the Cape Province, Lord Howe Island and Norfolk Island are clearly under-represented in the literature. The Coral Sea Islands have received some research attention but are also generally under-studied. Seamounts in the East Marine Region are generally less well-studied than those in southern areas and research has been focussed on a small number of seamounts that are of pelagic fisheries interest. Also by way of example, literature tends to be focussed towards charismatic species or species of fisheries/by-catch significance. Indeed, some of the information gaps are surprising given the East Region’s proximity to Australia’s eastern seaboard population centres and iconic species and areas.

Rather than itemise all of these unknowns, the following discussion on information gaps is limited to information gaps that are of particular relevance to broad-scale scale conservation planning. The information gaps presenting in each of the sub-systems above can be grouped into the following categories:

- Deepwater faunal assemblages;
- Endemism;
- Dispersal and connectivity;
- Regionally iconic areas;
- Trophic webs and life-cycles of important species.

10.3.1 Deepwater Faunal Assemblages

In general terms, shallow water environments are much more intensively studied than deepwater environments, a fact that is no doubt related to logistics and costs of deepwater research. Much of the knowledge of deep sea fauna is derived from by-catch in trawl fisheries, principally in the southern waters (Probert *et al*., 1997; Koslow & Gowlett-Holmes, 1998) and due to the unstructured nature of this sampling a detailed knowledge of faunal assemblages in many areas is not available (Smith, 2002). Perspectives on the faunal composition in these areas therefore, are likely to change as more research sampling is carried out. Furthermore, it has only been realised in the past 10 years that corals form an extremely large proportion of the biomass found in the deep sea and the true extent of deepwater reefs, octocoral gardens and the communities they may support is not fully understood (Koslow, 2007). Further sampling of the East Region's slope and seamount habitats would no doubt uncover new details about the extent of deepwater reefs and other important ecological features.

10.3.2 Endemism

Some sub-regions are colonised by unique benthic fauna that are distinct from that found in other areas of Australia's EEZ. Recent surveys suggest that there is a high level of endemism among certain structures, for example seamounts, in the Tasman and Coral Seas, referring mainly to species of antipatherians and corals (Forges *et al.*, 2000). However, the apparent high level of endemism has been questioned by some authors who state that endemism must be tempered against limited collections and poorly known systematics and genetic work would be required to confirm these assertions. Furthermore, endemism is related to dispersal mechanisms, which are poorly known for most deep sea species.

10.3.3 Dispersal and Connectivity

There are questions related to the level of connectivity between the sub-regions of the East Marine Region, which, for most species, is a function of the mechanisms of larval dispersal in ocean currents. This review has identified a number of known oceanographic features that represent pathways for connectivity or barriers to connectivity (i.e. potential faunal retention in gyres). This review has also identified a number of unknowns with respect to the dispersal of deep sea organisms and connectivity between demersal sub-systems. Some deepwater invertebrates show significant genetic linkages between habitats indicating long distance larval dispersal (Poore & O'Hara, 2007) while ecological sampling has identified distinctions at the level of the 'assemblage' that are relevant to conservation planning.

The EAC is clearly a major avenue of connectivity and dispersal throughout the East Marine Region. While the oceanography of the EAC is well studied and understood, its influence on pelagic and, more so demersal, ecology are less well understood. This review has demonstrated that pelagic predators such as sharks, dolphins, tunas and billfish range throughout the East Region, with the EAC obviously presenting a conduit. Further, the EAC has been shown to interact with topography of the seabed to produce upwelling and eddies, although the influence of this process on driving benthic communities is uncertain. Further, the role of the EAC (and associated phytoplankton and zooplankton communities) in the ontogeny of pelagic and demersal fishes is not well understood.

The vortices that form over seamounts as a result of topographically-induced bottom currents are also thought to have a similar influence. However, it is unknown to what extent these circulation cells facilitate retention or dispersal of larvae across sub-regions. The vortices formed over seamounts (Taylor columns) for instance, may be a hindrance to larval dispersal. Around seamounts of unequal shape or along seamount chains for example, there are different current regimes, which may not hinder dispersal and could well facilitate long distance larval transport by bridging the gap across the ocean floor (Gad and Schminke, 2002).

10.3.4 Regional Iconic Status / Representativeness

Commonwealth marine parks and reserves have established at regionally iconic sites in the East Marine Region:

- Lord Howe Island Marine Park (sub-region 3a);
- Elizabeth and Middleton Reef Marine Park (sub-region 3a);
- Coringa-Herald National Nature Reserve (sub-region 1c);
- Lihou Reef National Nature Reserve (sub-region 1c);
- Solitary Islands Marine Reserve (sub-region 2a).

This review has found that, in terms of shallow waters that are generally more comprehensively studied than deep waters, the research effort in shallow tropical waters has been focussed towards the Great Barrier Reef. Research conducted outside the GBR has identified biogeographic patterns that are relevant to future conservation planning.

Spatially, the arrangement of existing marine parks and nature reserves does not reflect the connectivity between sub-regions that has been identified in this review (albeit with some unknowns).

Future conservation planning obviously must take into account representativeness of sites within the East Marine Region and this review has identified potentially iconic sites in terms of faunal biogeography or in terms of unique representativeness within the region. These include:

- Britannia/Queensland/Brisbane/Moreton and Recorder Seamounts (sub-region 2c);
- Bird/Cato islands, Kenn Reef, Keen Plateau (sub-region 1e);
- Ashmore and Boot reefs (sub-region 1a);
- Canyons on the Eastern Slope (sub-region 2a);
- Lord Howe Rise (sub-region 3b);
- Norfolk Ridge (sub-region 4b);
- EAC eddies (sub-regions 2a,b,c primarily);
- Northern Seamounts (sub-region 1e).

Given the gaps in the knowledge of some of these sites, their potential iconic status or representativeness is difficult to assess and this will be the subject of further conservation planning and workshops with scientists and stakeholders.

10.3.5 Trophic Webs and Life-cycles of Important Species

The life-cycles of some species of fisheries and ecological importance are still remarkably unclear (e.g. billfish and deepwater demersal species). Trophic webs, particularly in deep sea environments are not well studied and in this review, much of the data for seamounts in particular come from southern waters. The trophic systems of the Eastern Slope canyons are inferred from those of the South-east Region as these have been studied in more detail, but again, future research may identify life-cycle and trophic web interactions specific to the East Region.

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12. APPENDICES

12.1 Appendix 1. Abiotic statistics generated for the sub-regions of the Eastern Marine Region

Depth statistics for the sub-regions of the Eastern Marine Region. Data generated from gridded bathymetry (Geosciences Australia)

Name		Mean depth (m)	Min Depth (m)	Max Depth (m)	Mean slope (%)	Min slope (%)	Max Slope (%)
Cape Province	1a	-2462.55	230	-3869	2.10	0	175.06
Coral Sea Abyssal Basin	1b	-4328.23	-2568	-4915	1.93	0	36.99
Queensland Plateau	1c	-1496.13	74	-4536	2.06	0	153.23
Marion Plateau	1d	-1178.76	92	-4243	2.19	0	280.18
Northern Seamounts Field	1e	-2683.04	23	-4742	3.19	0	377.70
Eastern Shelf	2a	-95.26	0	-822	0.62	0	38.06
Eastern Slope	2b	-2574.19	-42	-5269	10.38	0	229.10
Southern Seamounts Field	2c	-4563.90	-124	-5263	2.91	0	237.49
Lord Howe Complex	3a	-3111.88	-5	-5141	3.87	0	663.99
Lord Howe Plateau	3b	-1485.23	-259	-2761	1.17	0	190.64
New Caledonia Basin	4a	-3185.39	-1831	-3992			
Norfolk Complex	4b	-2561.66	1	-4947			

Temperature (C°) for the sub-regions of the Eastern Marine Region - annual mean (and seasonal (monthly) for SST) at the surface (SST), 150 m, 500 m, 1000 m and 2000 m; and monthly. SST from NOAA, depth data derived from CARS.

Name		SST Mean	SST Jan	SST April	SST July	SST Oct	Ave Temp 150m	Ave Temp 500m	Ave Temp 1000m	Ave Temp 2000m
Cape Province	1a	26.42	28.91	27.17	24.70	25.47	22.05	8.72	4.24	2.31
Coral Sea Abyssal Basin	1b	26.52	28.13	27.29	24.88	25.84	22.43	8.97	4.11	2.33
Queensland Plateau	1c	26.16	28.05	26.84	24.35	25.29	22.53	9.71	4.30	2.31
Marion Plateau	1d	25.33	27.07	26.28	23.42	24.26	21.66	10.61	4.65	2.32
Northern Seamounts Field	1e	25.31	26.90	26.30	23.56	24.32	21.63	10.60	4.50	2.36
Eastern Shelf	2a	22.30	24.39	23.92	20.12	20.50	15.89	9.09	4.90	2.27
Eastern Slope	2b	22.63	24.65	24.06	20.56	20.93	17.90	10.16	5.13	2.29
Southern Seamounts Field	2c	22.09	24.05	23.55	20.06	20.54	18.89	11.35	5.48	2.36
Lord Howe Complex	3a	21.63	23.54	23.10	19.69	20.01	18.53	11.19	5.46	2.36
Lord Howe Plateau	3b	21.10	23.00	22.57	19.19	19.46	18.46	10.97	5.46	2.36
New Caledonia Basin	4a	21.31	23.13	22.63	19.51	19.87	18.41	11.22	5.53	2.33
Norfolk Complex	4b	20.99	22.78	22.43	19.24	19.40	17.90	10.94	5.49	2.35

Average salinity (ppt) for the sub-regions the Eastern Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface salinity	Min surface salinity	Max surface salinity	Mean salinity 150m	Mean salinity 500m	Mean salinity 1000m	Mean salinity 2000m
Cape Province	1a	34.96	34.71	35.04	35.61	34.63	34.50	34.65
Coral Sea Abyssal Basin	1b	35.04	34.87	35.15	35.65	34.64	34.50	34.65
Queensland Plateau	1c	35.11	34.98	35.24	35.63	34.72	34.49	34.65
Marion Plateau	1d	35.25	35.08	35.48	35.60	34.83	34.47	34.66
Northern Seamounts Field	1e	35.24	34.81	35.63	35.63	34.83	34.48	34.65
Eastern Shelf	2a	35.40	34.70	35.60	35.40	34.69	34.47	34.68
Eastern Slope	2b	35.54	35.29	35.64	35.54	34.82	34.47	34.68
Southern Seamounts Field	2c	35.59	35.31	35.68	35.59	34.96	34.47	34.66
Lord Howe Complex	3a	35.63	35.56	35.69	35.60	34.94	34.47	34.66
Lord Howe Plateau	3b	35.63	35.59	35.68	35.60	34.92	34.47	34.66
New Caledonia Basin	4a	35.66	35.59	35.71	35.61	34.93	34.47	34.65
Norfolk Complex	4b	35.69	35.58	35.75	35.60	34.90	34.46	34.64

Average Nitrogen (uM) and Phosphate (uM) concentration (ppt) for the sub-regions of the Eastern Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean N 0m	Mean N 150m	Mean N 500m	Mean N 1000	Mean N 2000	Mean P 0m	Mean P 150m	Mean P 500m	Mean P 1000	Mean P 2000
Cape Province	1a	0.10	5.48	25.67	37.21	36.50	0.11	0.46	1.56	37.21	2.44
Coral Sea Abyssal Basin	1b	0.09	4.33	23.23	34.91	37.52	0.17	0.49	1.61	34.91	2.61
Queensland Plateau	1c	0.07	3.51	22.01	35.02	38.51	0.14	0.40	1.50	35.02	2.59
Marion Plateau	1d	0.07	3.62	18.55	34.12	39.37	0.14	0.41	1.33	34.12	2.51
Northern Seamounts Field	1e	0.06	2.92	17.85	32.20	35.60	0.16	0.37	1.33	32.20	2.56
Eastern Shelf	2a	0.31	8.81	19.99	32.63	36.13	0.17	0.68	1.45	32.63	2.45
Eastern Slope	2b	0.33	5.49	18.52	32.74	36.21	0.15	0.50	1.31	32.74	2.45
Southern Seamounts Field	2c	0.37	3.78	16.34	32.80	36.85	0.14	0.36	1.15	32.80	2.47
Lord Howe Complex	3a	0.35	3.72	17.19	32.50	36.79	0.17	0.36	1.19	32.50	2.49
Lord Howe Plateau	3b	0.41	3.88	18.22	32.54	36.89	0.18	0.39	1.25	32.54	2.50
New Caledonia Basin	4a	0.25	3.01	16.67	30.32	36.85	0.19	0.38	1.24	30.32	2.58
Norfolk Complex	4b	0.35	3.39	17.50	30.65	36.72	0.19	0.38	1.24	30.65	2.56

Average dissolved oxygen (mg/l) concentration for the sub-regions of the Eastern Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface DO	Min surface DO	Max surface DO	Mean DO 150m	Mean DO 500m	Mean DO 1000m	Mean DO 2000m
Cape Province	1a	4.58	4.54	4.67	3.58	3.98	3.64	3.29
Coral Sea Abyssal Basin	1b	4.68	4.52	4.77	3.78	4.03	3.71	3.30
Queensland Plateau	1c	4.61	4.53	4.72	3.96	3.99	3.75	3.32
Marion Plateau	1d	4.66	4.58	4.75	4.09	4.13	3.91	3.44
Northern Seamounts Field	1e	4.70	4.56	4.92	4.19	4.14	3.90	3.43
Eastern Shelf	2a	5.02	4.70	5.39	4.18	4.41	4.00	3.85
Eastern Slope	2b	4.94	4.70	5.35	4.40	4.39	4.05	3.83
Southern Seamounts Field	2c	4.93	4.70	5.23	4.57	4.36	4.12	3.73
Lord Howe Complex	3a	4.98	4.89	5.12	4.62	4.39	4.13	3.70
Lord Howe Plateau	3b	5.05	4.96	5.12	4.67	4.40	4.14	3.68
New Caledonia Basin	4a	5.02	4.87	5.15	4.73	4.33	4.22	3.50
Norfolk Complex	4b	5.09	4.87	5.27	4.77	4.37	4.25	3.52

Average silicate concentration (uM) concentration for the sub-regions of the Eastern Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface silicate	Min surface silicate	Max surface silicate	Mean silicate 150m	Mean silicate 500m	Mean silicate 1000m	Mean silicate 2000m
Cape Province	1a	1.62	0.78	5.88	35.61	14.57	61.52	111.95
Coral Sea Abyssal Basin	1b	1.09	0.78	1.34	35.65	13.99	60.56	110.67
Queensland Plateau	1c	0.89	0.65	1.23	35.63	11.81	58.31	107.09
Marion Plateau	1d	0.95	0.74	1.11	35.60	9.03	50.26	103.84
Northern Seamounts Field	1e	1.06	0.75	1.29	35.63	9.53	50.26	106.25
Eastern Shelf	2a	1.56	0.57	7.57	35.40	10.68	45.27	96.04
Eastern Slope	2b	1.02	0.59	3.09	35.54	8.90	41.40	95.40
Southern Seamounts Field	2c	0.92	0.54	2.21	35.59	6.73	37.11	96.48
Lord Howe Complex	3a	1.11	0.63	2.22	35.60	6.97	39.98	100.39
Lord Howe Plateau	3b	1.14	0.70	2.06	35.60	7.19	39.78	101.91
New Caledonia Basin	4a	1.04	0.91	1.46	35.61	7.42	38.21	111.26
Norfolk Complex	4b	1.23	1.01	1.65	35.60	8.30	37.42	112.01

Mean annual and monthly Chlorophyll concentration (mg/m^3) for the sub-regions of the Eastern Marine Region. (Derived from MODIS Aqua Ocean Colour Satellite)

Name		Mean Chlorophyll	Mean Chlorophyll January	Mean Chlorophyll April	Mean Chlorophyll July	Mean Chlorophyll October
Cape Province	1a	0.118	0.085	0.109	0.160	0.119
Coral Sea Abyssal Basin	1b	0.094	0.071	0.087	0.132	0.087
Queensland Plateau	1c	0.089	0.070	0.084	0.126	0.077
Marion Plateau	1d	0.086	0.067	0.084	0.121	0.072
Northern Seamounts Field	1e	0.086	0.068	0.086	0.112	0.080
Eastern Shelf	2a	0.272	0.188	0.244	0.297	0.360
Eastern Slope	2b	0.188	0.099	0.176	0.220	0.256
Southern Seamounts Field	2c	0.164	0.093	0.149	0.185	0.228
Lord Howe Complex	3a	0.165	0.095	0.119	0.206	0.243
Lord Howe Plateau	3b	0.172	0.095	0.113	0.227	0.252
New Caledonia Basin	4a	0.149	0.079	0.092	0.199	0.226
Norfolk Complex	4b	0.152	0.088	0.099	0.194	0.229

Mean wave and tidal exceedance (%) for the sub-regions of the Eastern Marine Region generated from estimates from surface wind speed (Met Bureau regional atmospheric model) as inpout to the Wave Model, WAM. Exceedance is defined as the percentage of time that currents are predicted to mobilise sediments of mean grain size.

Name		Mean wave exceedance	Mean tide exceedance
Cape Province	1a	3.75	5.83
Coral Sea Abyssal Basin	1b		
Queensland Plateau	1c	2.35	3.19
Marion Plateau	1d	4.38	1.72
Northern Seamounts Field	1e	0.00	0.00
Eastern Shelf	2a	1.97	0.04
Eastern Slope	2b	0.02	0.00
Southern Seamounts Field	2c		
Lord Howe Complex	3a		
Lord Howe Plateau	3b		
New Caledonia Basin	4a		
Norfolk Complex	4b		

Mean mixed layer depth (m) for the sub-regions of the Eastern Marine Region, calculated from salinity cast data used to generate CARS2000.

Name		Mean mixed layer depth	Min mixed layer depth	Max mixed layer depth
Cape Province	1a	41.33	21	48
Coral Sea Abyssal Basin	1b	40.94	36	48
Queensland Plateau	1c	46.83	37	56
Marion Plateau	1d	51.23	45	59
Northern Seamounts Field	1e	44.44	32	64
Eastern Shelf	2a	27.88	15	39
Eastern Slope	2b	43.89	29	62
Southern Seamounts Field	2c	60.44	42	79
Lord Howe Complex	3a	59.88	39	85
Lord Howe Plateau	3b	62.42	39	81
New Caledonia Basin	4a	59.47	45	78
Norfolk Complex	4b	59.76	45	76

Mean annual and monthly surface current (m/s) for the sub-regions of the Eastern Marine Region; surface currents are generated from steric-height fields, and tidal currents are generated from a tide model for the Australian shelf

Name		Mean Surface currents January	Mean surface currents April	Mean surface currents July	Mean surface currents October
Cape Province	1a	0.116	0.137	0.121	0.107
Coral Sea Abyssal Basin	1b	0.115	0.090	0.062	0.083
Queensland Plateau	1c	0.111	0.092	0.084	0.082
Marion Plateau	1d	0.123	0.123	0.113	0.099
Northern Seamounts Field	1e	0.073	0.066	0.050	0.049
Eastern Shelf	2a	0.303	0.308	0.271	0.304
Eastern Slope	2b	0.392	0.376	0.350	0.382
Southern Seamounts Field	2c	0.190	0.166	0.168	0.176
Lord Howe Complex	3a	0.105	0.088	0.082	0.096
Lord Howe Plateau	3b	0.055	0.063	0.054	0.059
New Caledonia Basin	4a	0.053	0.071	0.056	0.050
Norfolk Complex	4b	0.063	0.065	0.053	0.073

Total (1906-2000) and mean annual cyclone activity for the sub-regions of the Eastern Marine Region, including cyclone path per square km within each sub-region, and average path length for cyclones within each sub-region. Data derived from Met Bureau cyclone data.

Name		Path per sq km (m)	Path per sq km per yr (m)	Average path length (km)
Cape Province	1a	90.45	0.96	91.00
Coral Sea Abyssal Basin	1b	217.92	2.32	135.75
Queensland Plateau	1c	254.29	2.71	350.61
Marion Plateau	1d	251.69	2.68	182.20
Northern Seamounts Field	1e	216.61	2.30	322.65
Eastern Shelf	2a	87.86	0.93	88.31
Eastern Slope	2b	52.79	0.56	102.67
Southern Seamounts Field	2c	68.67	0.73	278.00
Lord Howe Complex	3a	82.02	0.87	308.80
Lord Howe Plateau	3b	41.22	0.44	232.84
New Caledonia Basin	4a	19.14	0.20	313.42
Norfolk Complex	4b	11.26	0.12	290.16

Mean sediment parameters for the sub-regions of the Eastern Marine Region. Mean grain size (mm) and mud etc content (weight %) were compiled from Geoscience Australia's marine sediment database (MARS –Table includes number of samples). Sediment mobility is a representation of the relative importance of tidal currents and ocean waves in mobilising sediments of mean grain size on the seabed, as computed by Geoscience Australia's sediment dynamics model, GEOMAT.

Name		Samples	Mean grain size (mm)	Mean % mud	Mean % sand	Mean % gravel	Mean % carbonate	Mean sediment mobility
Cape Province	1a	1453	0.42	31.17	51.71	17.13	81.07	1.42
Coral Sea Abyssal Basin	1b							
Queensland Plateau	1c	36	0.23	14.15	71.44	14.40	89.24	1.01
Marion Plateau	1d	7009	0.94	5.82	62.69	31.30	85.23	0.30
Northern Seamounts Field	1e							0.00
Eastern Shelf	2a	35398	0.44	3.43	83.60	7.54	47.27	0.65
Eastern Slope	2b	35308	0.52	5.63	75.77	12.94	65.15	0.02
Southern Seamounts Field	2c	990	0.22	22.28	77.04	0.68	71.66	
Lord Howe Complex	3a							
Lord Howe Plateau	3b							
New Caledonia Basin	4a							
Norfolk Complex	4b							