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).

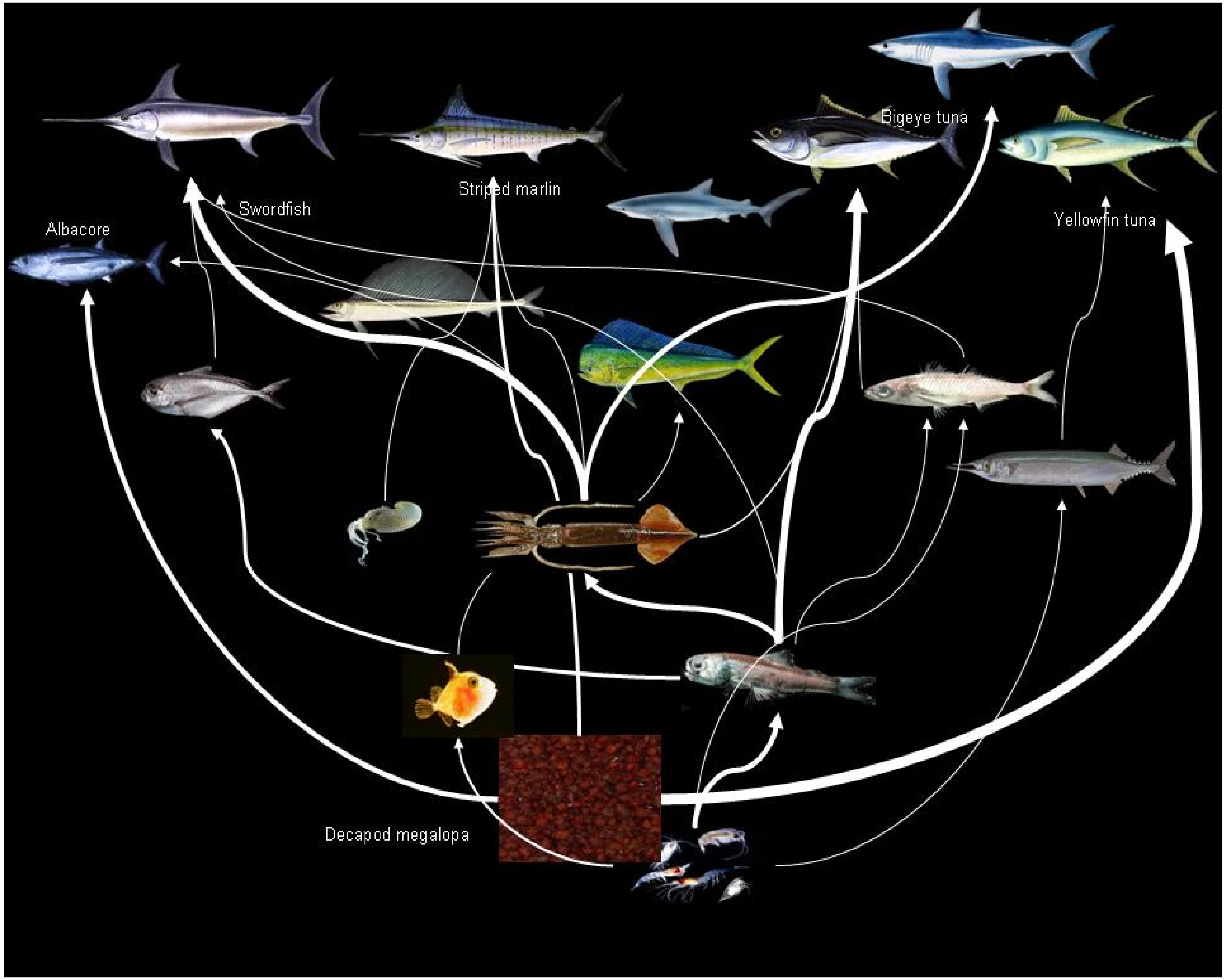
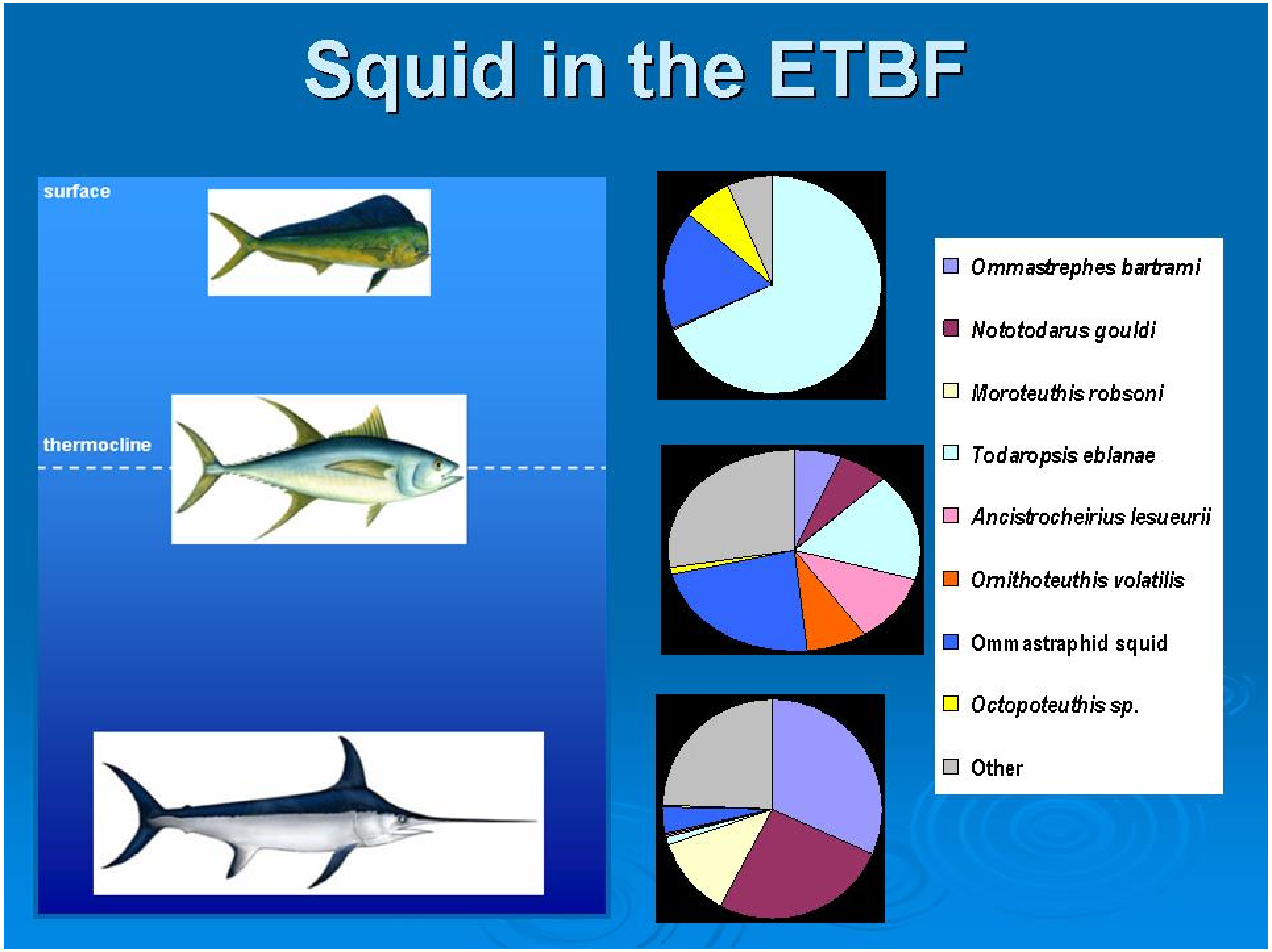


Figure 8-1 Schematic food web of the waters of the Eastern Exclusive Economic Zone showing the main food chain pathways between top predators and their micronektonic prey (data from FRDC Project 2004/063



Squid in the ETBF

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							