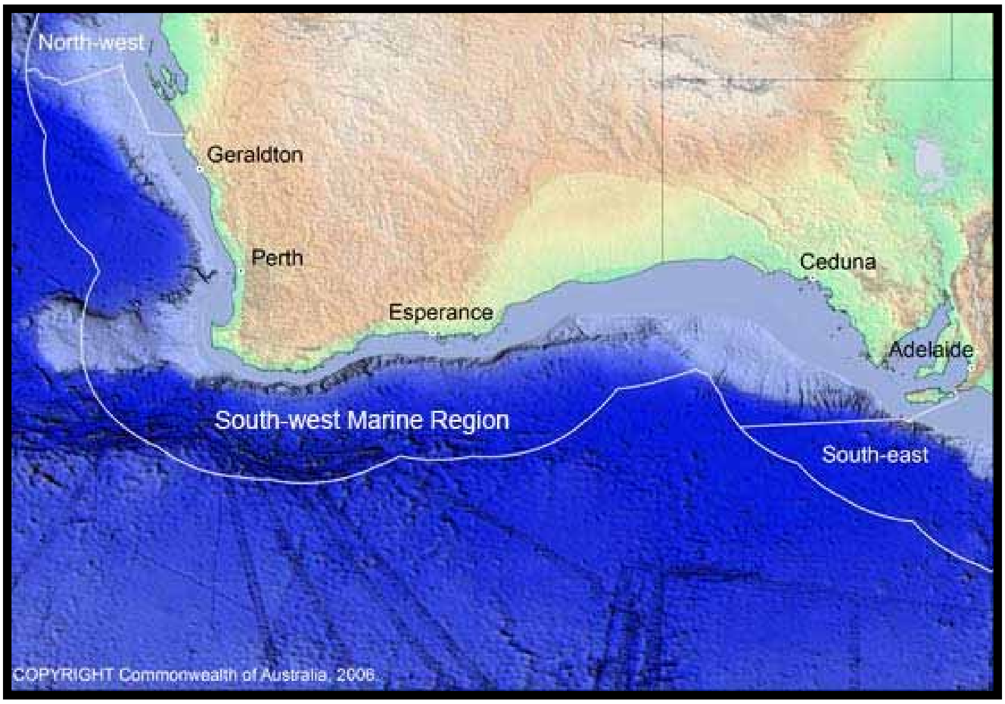
A Characterisation of the Marine Environment of the South-west Marine Region



A summary of an expert workshop convened in Perth, Western Australia, September 2006

This report was prepared by the
Department of Environment and Water Resources

Background

The Department of Environment and Water Resources is developing a South-west Marine Bioregional Plan, under the *Environment Protection and Biodiversity Conservation Act 1999* (hereafter referred to as the EPBC Act). The aim of the Plan is to provide specific guidance for making decisions of relevance to the region under the EPBC Act. The Department requires scientific input at the following key stages in the development of the Plan:

1. During the profiling of the South-west Marine Region, to ensure that the description of the ecological systems of the Region is based upon a comprehensive and up-to-date scientific knowledge, integrated across the relevant disciplines. For the South-west Marine Region, this is being done through:
    a) the National Marine Bioregionalisation, which is based on a synthesis of biological, geological and oceanographic data;
    b) a comprehensive review of relevant literature, which has resulted in two key reports:
        - *The South-west Marine Region: Ecosystems and Key Species Groups;*
        - *Geomorphology and Sedimentology of the South Western Planning Area of Australia*; and
    c) an expert workshop to provide a multidisciplinary characterisation of the marine environment of the South-west Region from a system perspective.
2. During the strategic assessment of threats to regional conservation values, to incorporate scientific understanding of the responses of the Region's ecological systems to current and future threats.
3. During the identification of a set of indicators for monitoring the state of the marine environment in the Region.

The expert workshop

This paper summarises the outcomes and discussions of the expert workshop (i.e. point 1.c), convened in Perth, Western Australia in September 2006 by the Department of Environment and Water Resources (which was then the Department of the Environment and Heritage). The objective of this workshop was to characterise the marine environment of the South-west Marine Region in a way that improves the Department's understanding of how the Region's natural systems work. More specifically, the Department's aims for the workshop were:

- to characterise functional systems within the Region on the basis of their location, their biological and physical components and how these interact;
- to understand links across functional systems and the broad scale drivers of ecosystem functioning across the Region, including the importance of the interface between functional systems and the key processes that link neighbouring systems; and
- to understand the key areas of uncertainty surrounding the Region's ecological systems, as well as the areas for which empirical evidence is available.

Appendix A includes the background papers circulated to participants in advance to the workshop. The papers were intended to provide the participating scientists with a broad overview of the marine planning policy and process, as well as to explain the structure of the workshop.

Following the workshop the Department prepared a draft workshop report, which was provided to attendees, with annotated questions to seek further comments, clarifications and corrections from experts who participated in the workshop. This paper is the final workshop report following incorporation of participants' comments. It captures a representation of the functional relationships among ecological properties of the South-west Marine Region based on the expertise of participants, and it is intended to complement the existing biogeographical and geomorphological classifications of the Region.

Approach to workshop

The Department commissioned the CSIRO Marine and Atmospheric Research (CMAR) to develop a framework for characterising the marine environment. The Department and CMAR 'road-tested' the framework prior to the Perth workshop, using data and experts from the South-east Marine Region. The findings were used to refine the workshop approach, which is illustrated in Figure 1 below.

A range of resources were made available at the workshop, including a number of regional data layers and GIS capabilities, to create and project relevant maps of the Region (see Appendix A for details). Participants were also encouraged to bring any relevant data/tool that may be helpful.

The workshop was run over two days and was facilitated by Professor Bruce Mapstone. Day 1 of the workshop included four brief presentations covering large scale drivers and patterns, to set the regional context. Additional presentations by a number of experts at the workshop outlined research conducted in the Region and underpinned the discussion on how the different systems in the South-west Marine Region functioned. Day 2 of the workshop focused on identifying key drivers of the ecosystems in the South-west Marine Region.

The workshop was structured around a series of steps to characterise the marine environment of the South-west Marine Region:

Step 1 – Identifying major eco-physical systems within the Region

Step 2 – Identifying eco-physical sub-systems

Step 3 – Characterising the ecological systems through conceptual modelling

Step 4 – Reflecting on regional-scale interactions and processes

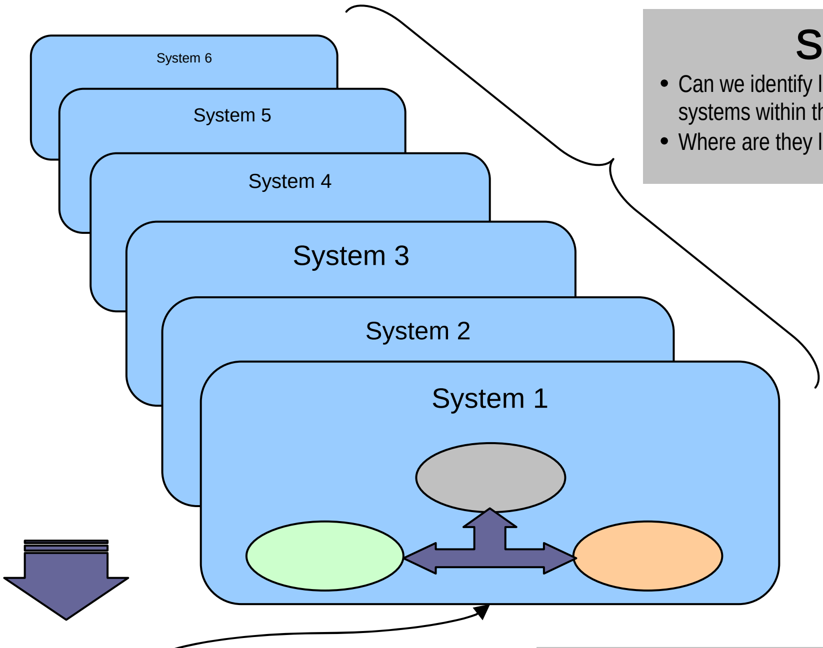
Step 5 – Understanding state of knowledge and areas of uncertainty

Figure 1: Framework for characterising the marine environment using regional knowledge and expertise.

Proposed steps for characterising the marine environment - each step is described by a series of questions. These are meant to illustrate the scope and focus of the discussion at each step, but are not intended to be prescriptive.

Step 1

- Can we identify large-scale ecological systems within the Region?
- Where are they located spatially?



Step 2

- Are there sub-systems?
- What physical strata define them (e.g. depth, oceanography, geomorphology)?

Step 3

- What are the biological components of the system?
- How are they distributed within the system? How much variability is there?
- Are there biological components of particular importance for the system? Why are they important, what ecological role do they play?
- How do the components link to each other? What are the known trophic links? What are the likely trophic links?
- What are the main inputs into the system?
- What are the main outputs from the system?
- What are the key vulnerabilities in the system?
- Summing up, what are the main physical drivers? What are the main biological drivers?

Step 4

- What are the overall, main species/communities/functional groups from an ecosystem functioning perspective?
- What are the overall main spatial areas and their ecological role (hot-spots; aggregations; migration paths; high energy)?
- Where is the productivity in the region? Overall, is the Region a net producer or a net consumer?
- How is the biomass distributed in the Region (spatially/bathymetrically/among functional groups)?
- What is common to all systems? What are the main differences?
- How is biodiversity distributed in the Region (spatially/ in association with specific features)?

Step 5

- Where are the important areas of uncertainty associated with characterisations?
- What aspects of the Region do we have empirical evidence for?
- So we appear to have not picked up on any important projects?
- Are there any important projects we need to know about that will have outputs between 2006 and 2008?
- Are there important studies for the Region in the pipeline?
- What aspects of the region do we have empirical evidence for?

Workshop Participants

The workshop was attended by a broad range of marine scientists with expertise in oceanography, nearshore ecosystems and offshore ecosystems. The workshop was attended by:

Prof. Bruce Mapstone (Chair) – CRC for Antarctic Climate and Ecosystems

Dr Chari Pattiaratchi – The University of Western Australia

Dr Tony Koslow – CSIRO Marine and Atmospheric Research

Dr Scott Condie – CSIRO Marine and Atmospheric Research

Dr Sam McClatchie – South Australian Research and Development Institute

Dr Vince Lyne – CSIRO Marine and Atmospheric Research

Dr Trevor Ward – Greenward Consulting, Western Australia

Prof. Norm Hall – Murdoch University, Western Australia

Dr Chris Simpson – Department of Environment and Conservation, Western Australia

Dr David Currie – South Australian Research and Development Institute

Dr Ian Knuckey – Fishwell Consulting Pty Ltd

Dr Russell Babcock – CSIRO Marine and Atmospheric Research

Assoc. Prof. Jeremy Prince – Biospherics Pty Ltd

Dr Peter Harris – Geoscience Australia

Dr Nick Gales – Department of the Environment and Water Resources

Dr Nick Caputi – Department of Fisheries, Western Australia

Dr Dan Gaughan – Department of Fisheries Western Australia

Dr Jessica Meeuwig – University of Western Australia

Donna Hayes – CSIRO Marine and Atmospheric Research

Dr Fred Wells – Department of Fisheries, Western Australia

Dr Ian Elliot – Department of Environment and Conservation, Western Australia

Chris Burton – Western Whale Research, Western Australia

Ian Cresswell – Department of the Environment and Water Resources

Dr Barbara Musso – Department of the Environment and Water Resources

Emma Campbell – Department of the Environment and Water Resources

Paul Hedge – Department of the Environment and Water Resources

Paula Tomkins – Department of the Environment and Water Resources

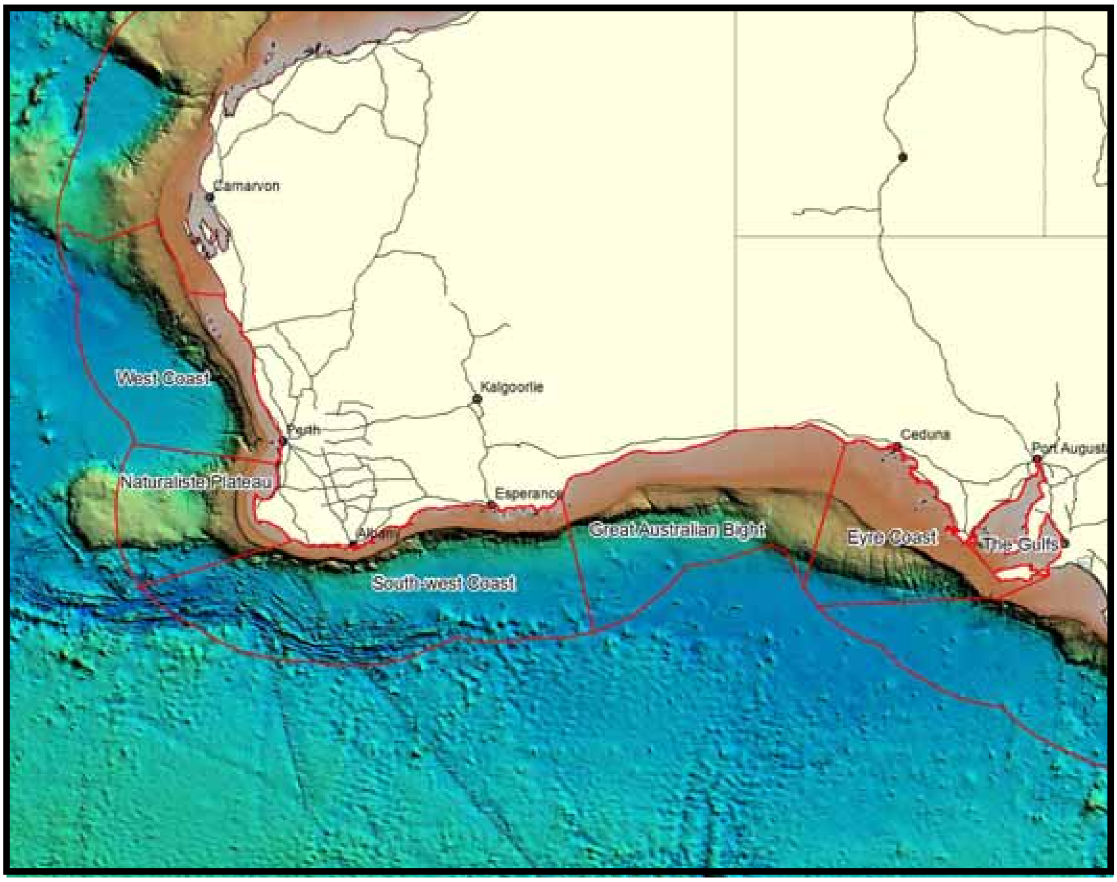
Ben Waining – Department of the Environment and Water Resources

Zoe Cozens – Department of the Environment and Water Resources

The South-west Marine Region

The South-west Marine Region is a 1.2 million km² ocean area that extends from offshore Cape Inscription in Western Australia, to the eastern end of Kangaroo Island in South Australia (see Figure 2).

Figure 2: Map of the South-west Marine Region depicting distinct 'systems' identified by experts at the expert workshop in September 2006.



Key physical drivers of the Region's ecosystems

The South-west Marine Region is characterised by low levels of nutrients and low biomass in the ocean and most of the coastal waters, and diverse marine communities composed of species of temperate origin, which, across much of the Region, mix with tropical and subtropical species. These very broad regional characteristics are primarily due to the main drivers:

- the Leeuwin Current, and its interactions with other currents in the Region, which maintain generally low levels of productivity as well as provide for the distribution and movement of species from sub-tropical to temperate areas;
- the low levels of terrigenous inputs, particularly in the southern part of the Region, which contribute to the low productivity and result in waters that are very clear and allow light to penetrate to considerable depths; and
- a geological history that has shaped the Region in ways that directly influence the range and types of habitat available to its inhabitants.

The Leeuwin Current

The Leeuwin Current is a shallow (< 300 m) and narrow (< 100 km wide) current and represents the main oceanographic driver of the Region's ecosystem. It originates in the tropical waters of the Indian Ocean, as a large-scale difference in water density that causes a change in sea level of approximately 0.5m between the waters off northern Western Australia and those off the southern parts of the state. The sea level difference combined with the earth's rotation (the Coriolos effect) creates the Leeuwin Current, which accelerates as it runs southward down the west coast. The Leeuwin Current wraps around the southern corner of the continent and flows eastward along the coasts of Western and South Australia into the Great Australian Bight and across to the North-West Cape of Tasmania. The Leeuwin Current, the South Australian Current, and the Zeehan Current (off western Tasmania) join to form the longest eastern boundary (ocean-edge) current (5,500 km) in the world, flowing strongly during winter. This has an important effect on poleward transport of tropical biota down the west to the south coast of the Region.

Other currents in the Region include the deep Leeuwin Undercurrent and the Flinders Current, the Western Australian Current, and the coastal and seasonal Capes and Cresswell Currents.

The Leeuwin Current strongly affects the ecology of the region in the following ways:

- The existence of the Leeuwin Current prevents the northward cold and nutrient rich waters of the Western Australian Current from upwelling along the upper slope and shelf break off the Western Australian coast. The waters off Western Australia are uniquely characterised by low levels of productivity and support relatively small fisheries when compared to all other eastern boundary currents in the world, such as the Humboldt Current off Peru and the Benguela Current off Africa.
- The interactions between the Leeuwin Current, the continental shelf and the other currents in the Region have important implications for the productivity and ecology of the Region and probably drive the localised upwelling events that occur both in the southern and western parts of the Region.
- Interactions between the Leeuwin Current and changes in the bathymetry and offshore water of different densities also result in the generation of eddies which move further offshore, transporting with them entire communities of plankton and small pelagic fish. Such eddies have been observed off Shark Bay, the western edge of the Abrolhos Islands, south-west of Jurien Bay, the Perth Canyon, south-west of Cape Naturaliste and Cape Leeuwin, south of Albany and south of Esperance.
- The Leeuwin Current also plays a key role in the distribution of species in the Region. The warm water transported southward in the Leeuwin Current has allowed tropical and sub-tropical species to become established in areas further south than would otherwise occur. For instance, a number of tropical fish, mollusc and hard coral species are found as far south as Rottnest Island (latitude 32^{o} South) because of the Leeuwin Current.
- The 'conveyor belt' system made up by the Leeuwin Current and the deeper Flinders Current is likely to be used for large-scale movements by a number migratory species.

Lack of terrigenous inputs

The ecology of the Region is greatly influenced by the absence of high-flowing river systems and the consequently limited amount of terrigenous (i.e. originating from the land) nutrient inputs to the Region. The combined absence of large-scale upwelling (probably as a result of the dominance of the Leeuwin Current) and the limited nutrient inputs from the land maintains the Region in relatively nutrient-poor status when compared to many other marine environments.

The absence of high-flowing river systems in the Region, and the generally low rate of water-column productivity in the Region, also results in low levels of turbidity (little suspended sediments or other organic particles), making the waters of the Region relatively clear and allowing light to penetrate to benthic communities at greater depths. This provides for a number of light-dependent species and associated communities, e.g. macroalgae and seagrasses on the south-west coast, to be found at much greater depth than elsewhere (up to 120 metres in some parts of the Region).

Geological history and geomorphology

The stable geological history of the Region has shaped a complex and distinctive continental wave-exposed shelf that provides a range of habitats for marine communities. The shelf of the southern part of the Region is the world's largest cool-water carbonate province (i.e. an area characterised by calcareous communities such as bryozoans, molluscs and foraminiferans foraminifera), an iconic feature that has resulted from little or no terrestrial input (either freshwater or sediments) or seasonal oceanic upwelling occurring in a temperate, latitude-parallel shelf. In many parts of the Region the shelf is punctuated with coastal features such as island groups, estuaries, fringing coastal reefs and other geological features that provide sheltered and diverse habitats for marine communities.

In the deeper parts of the Region, the continental slope extends the length of the entire Region and is one of the most canyon-rich areas of the Australian margin. The Region also contains some of the largest areas of abyssal plain on the Australian margin and thus contains some of the most extensive deepwater benthic environments. The Naturaliste Plateau, Australia's deepest temperate-water marginal plateau, is isolated from the shelf by the Naturaliste Trough, forms a large area of approximately 90,000 km² of deep water habitat between 2,000-5,000 m water depths. Similarly, the Diamantina Fracture Zone, a very deep area of complex topography featuring troughs to depths of 7,390 m and ridges which rise up from the seafloor to around 4,000 m depth, provide unique and varied deep water habitats across much of the southern part of the Region.

El Niño Southern Oscillation (ENSO)

A growing body of evidence suggests the ENSO could also be a key driver that affects the Region's productivity and biodiversity. Observations suggest that ENSO events significantly influence the strength of currents and upwelling and the propagation of eddies in the Region. The Leeuwin Current is observed to be strongest during the La Niña phase, as are the mixing mechanisms of the winter overturn; westerly wind strength; number and strength of storm fronts; and rates of surface cooling. Researchers have observed positive relationships between the strength of the Leeuwin Current and Western Rock Lobster settlement on the west coast, Saucer scallop settlements on the west and south coast, and Australian Salmon recruitment in South Australia. In contrast, pilchard recruitment and saucer scallop at the Abrohlos are observed to be negatively correlated with the strength of the Leeuwin Current. There is still much to be learned about the mechanisms linking ENSO with the dynamics of marine productivity and biodiversity in the Region.

Marine communities of the Region

The key drivers of the Region have combined to shape distinctive assemblages of marine life in this Region that are characterised by:

- high species biodiversity;
- long, complex food webs;
- benthic-pelagic coupling; and
- adaptations to low productivity.

High species biodiversity

The Region is known for high species biodiversity and a high level of endemism on the continental shelf and slope. As discussed above, the high species diversity can in some part be attributed to the low nutrient environment which has lead to the development of complex, low biomass ecosystems efficiently recycling limited nutrients and energy flows. The high level of endemism in the Region has been attributed to an extremely stable geological history and lack of mass extinction events, together with the Region's isolation from other land masses, maintained by the consistent, moderating and unidirectional flow of the Leeuwin Current.

The Leeuwin Current greatly influences patterns of biodiversity in the Region by transporting tropical species and their propagules down the west coast of Western Australia and into the Great Australian Bight and beyond. The transport of species by the Leeuwin Current, together with the temperature gradient it maintains from northwest to southeast, also helps to determine the macro-scale distribution of species throughout the Region. This can explain the variety of tropical fish, mollusc and hard coral species that are found as far south as Rottnest Island (32^{o}S) and the occurrence of some tropical species in the fauna of the south coast of the Region.

On the continental shelf, macroalgae (i.e. south-west coast) and seagrass communities (i.e. Shark Bay, Geographe Bay and the South Australian Gulfs) are noted for their extent, species richness and endemism, with some species found at much greater depths than usual (e.g. down to 120 m). The clear waters in this area allow light to reach greater depths. The shelf also has high species diversity among demersal fish communities and among invertebrate taxa such as corals, ascidians, molluscs and echinoderms. The coral reefs of the Abrolhos Islands host a diverse mix of temperate and tropical fish, corals and molluscs. The rocky reefs of the Recherche Archipelago, Albany harbours and Head of the Bight are also coastal areas rich in biodiversity.

Generally speaking, there is a relatively distinct difference between the marine food webs along the southern coast of the Region and those of the western coast, due to the influence of oceanographic and geological factors. To the east of Cape Leeuwin, the influence of the Leeuwin Current is slightly weaker and the influence of the local counter-current, the Flinders Current, relatively stronger. Cape Leeuwin also marks a boundary between coastal reefs made of coastal limestone and those comprised of ancient rounded granite outcrops. The combination of colder water and topographically complex granite reefs creates a structural similarity amongst shallow reef communities along the south coast of the Region, and this is quite distinct from those of the tropically-influenced, cave-rich, limestone reefs of the west coast.

Our understanding of species biodiversity and endemism on the continental slope, continental rise and abyssal plain is very patchy when compared to our knowledge of coastal and shelf communities. Recent research on demersal fish communities of the continental slope reveals high levels of species diversity, particularly on the mid and upper slope west of Western Australia waters, as well as some level of separation between south and west coasts.

Marine scientists suggest other likely areas rich in biodiversity include the deep structures of the Diamantina Fracture Zone, the Naturaliste Plateau, and the numerous submarine canyons that incise the continental slope. This is based on the complexity of the seafloor topography, giving rise to the heterogenous substrate types (rocky to soft-sediment covered), the mix of ocean currents, and the biodiversity patterns observed in the adjacent shallower waters.

Submarine canyons are another feature of the Region that are poorly studied but known elsewhere to be associated with enhanced productivity and biodiversity (e.g. South-east Australia and New Zealand). They are also thought to be ecologically important feeding and breeding areas for a variety of fish species and marine mammals. For example, high densities of krill are known to occur in the Perth Canyon, which is a feeding ground for blue whales.

Similarly, the recently recognised, small 'cryptic' summer upwellings found south of Kangaroo Island, along the Eyre Peninsula and between Cape Leeuwin and Cape Naturaliste have an unknown impact on local biodiversity and remain largely unstudied. These isolated hotspots of productivity are characterised by significantly higher concentrations of phytoplankton, supporting local concentrations of zooplankton, invertebrates, fish, chondricthyans, sea birds and marine mammals.

A further feature of this Region that remains to be fully understood are the various sources of ground-water on the south and west coasts. Apparently in the head of the Bight, significant intrusions of ground water are creating inshore areas with relatively enriched seagrass communities. The importance of these submarine groundwater seeps needs further investigation.

Long, complex food webs

Trophic interactions of marine life in the Region are not well understood, and our knowledge of these is largely derived from the studies of the numerous commercial fisheries that operate in the Region, or from extrapolation of trophic studies in other marine regions.

Generally speaking, food webs in the Region are characterised by numerous trophic linkages between a highly diverse assemblage of organisms. Highly mobile predators are a notable characteristic of marine food webs in the Region, and they include marine mammals (e.g. New Zealand fur seals, Australian sea lions, pygmy blue whales, sperm whales, killer whales, Bryde's whales and dolphins), sharks (e.g. white pointers, bronze whalers and dusky whalers) and piscivorous fish (e.g. tuna, billfish, kingfish, Spanish mackerel, Western Australian dhufish, pink snapper, Australian salmon and gemfish) and a diversity of seabird species. Many of these species are opportunistic predators, that follow frontal features between areas of enhanced productivity, or pursue schools of smaller bait fish (i.e. sardines, anchovy, herring and garfish) as they migrate within the Region.

Food webs associated with the eddies that peel off the Leeuwin Current at a number of locations in the Region are also relatively unstudied. These oceanic features are known to enhance productivity in other systems and influence the distribution of species, but at present the food webs and trophodynamics associated with eddies in this Region, are largely inferred from the knowledge of fishers and the scientific literature reporting on other marine areas. Although the complexity of eddy food webs is not well understood, it is likely that organisms from the higher trophic levels such as marine mammals, seabirds, tuna and billfish are attracted to the eddies and feed at their edge; while other piscivorous fish, such as gemfish are hunting for prey below, taking advantage of the greater concentrations of the smaller fish usually associated with these features.

In contrast to the offshore and deepwater species, many of the shallower-water coastal species are more sedentary and may feed (and breed) within the same part of the Region throughout their life. However, the dominant and distinguishing feature of the flora and fauna assemblages of the Region, is the influence of the Leeuwin Current, coupled with the physical diversity of habitats and the limited land-sourced input of nutrients. The Current has the effect of greatly increasing species diversity by transporting, and to some extent maintaining, a substantial number of tropical species throughout the Region, that would otherwise not be able to either become established or survive. The biogeography of the coastal and inshore areas of the whole Region, both the west and south coast systems, is therefore characterised by a unique mix of tropical and temperate species. This temperate/tropical mix is well documented in many different taxa, including the fish, echinoderms, molluscs, and algae. Taken together, the high species diversity found in a number of taxa (such as the seagrasses) and the high levels of endemism found in all of the taxa, mean the Region can be justifiably described as containing a unique shallow-water flora and fauna.

Information derived from a limited number of studies of the inshore species in the Region, mainly commercially fished species, suggest that at least these species demonstrate a highly flexible diet and prey selection. This appears to be geared to exploit the seasonal availability of different food sources in the inshore waters, and is probably linked to variability in the dominant physical drivers of the Region – the Leeuwin Current, local upwellings, and the winter storms and wave energy from offshore. For the majority of species in the Region, although the plasticity in diet is unknown, the pattern of food exploitation represented in the commercial species is assumed to reflect a broader ecological feature of the fauna.

Offshore and onshore migrations of marine species have important implications for the dynamics of food webs in the Region and provide further mechanisms by which oceanic nutrients can be trapped and transported into shelf and coastal communities. Many marine species are observed to move between shallow and deeper water environments during the course of their lifecycle. Typically, such species spend their juvenile stages in shallower water feeding on and amongst smaller animals like themselves. As sub-adults they may feed across the flats of the shelf, gradually moving offshore towards adult feeding grounds at the shelf edge, on the slope, or in oceanic waters. An example is the western rock lobster, which spends a considerable period of its lifecycle on shallow water reefs as juveniles, before migrating as sub-adults to deeper offshore waters to spawn. Pink snapper have similar migrations, with the exception that the adults that feed in the more productive deeper offshore waters, return to inshore shallower waters to spawn.

In winter, right whales and humpback whales migrate from their offshore summer feeding grounds near the Sub-Antarctic Convergence into and through coastal and shelf waters of the Region to calve and mate. However, it is not clear how extensively they feed in the area.

Benthic-pelagic coupling
Experts speculate the importance of 'benthic-pelagic coupling' for productivity on the continental slope and abyssal plain areas in this Region. This refers to the various ecological and physical processes, which support the capture of the vital deep oceanic nutrients that sporadically become available in the ocean photic zone, and its export out of the pelagic ecosystem into the 'benthic' or bottom ecosystems. Deep sea benthic communities, like those of this Region, are limited by the organic matter supplied from primary production in the shelf and offshore marine environments. The nature of 'benthic-pelagic coupling' determines the nature of these ecosystems. Based on studies carried out in other parts of the world, spatial gradients in surface ocean primary productivity are thought to play a major role in controlling the distribution and diversity of benthic species.

The benthic-pelagic coupling observed throughout the Region is structurally similar to that seen in tropical reef communities, with light absorbing benthic organisms (in the tropics these are typically hard corals) supporting complex, long-lived reef communities. Typically in this Region, long-lived and relatively stable benthic communities comprising macroalgae, sea-grass and sessile benthic invertebrates of the inshore waters (sponges, soft and hard corals, ascidians) depend on episodic pelagic productivity. They become the base of the food chain, where they are grazed by a wide range of other species, or make an important contribution to drift material and detritus exploited by diverse assemblages of species. Thus, oceanic sources of nutrients are coupled directly to the shelf and coastal communities of the Region by benthic algae and seagrasses. At the apex of the shelf and coastal food web are long-lived, large piscivorous fish and sharks which forage over wide areas for benthic and pelagic productivity.

In many parts of the Region, coastal features such as island groups, fringing reefs or other geological features provide the geographic structure needed to shelter the diverse and highly structured benthic communities that couple pelagic productivity to the shelf and coastal ecosystems. The Abrolhos Islands, Shark Bay, the islands and coastal lagoons of the west coast (i.e. the nearshore limestone reef system that extends along most of the west coast of the Region), Geographe Bay, the granite harbours around Albany, the Recherche Archipelago, the shield islands off the Eyre Peninsula and the gulfs of South Australia, all provide large areas of relatively sheltered shallow environments. In these locations communities of macroalgae, seagrass and sessile invertebrates can utilise ephemeral flows of pelagic and land-based nutrients, storing and channelling them into benthic ecosystems via grazing and cropping. In addition to the ocean-sourced nutrients, the assemblages of many of these coastal features also depend on occasional land-based sources of nutrients delivered into the shallow coastal waters, which are then used highly efficiently in the recycling system mentioned above.

Adaptations to low productivity
Breeding behaviour of some species also appears to be a response to a highly variable and uncertain environment. The life strategy of the Australian sea lion, a threatened endemic species of this Region, is thought to similarly reflect strong adaptation to a harsh, low nutrient environment. The relatively small populations of females scattered through the Region are extremely faithful to their natal colonies. Foraging is primarily for large benthic invertebrates found in caves and refuges dispersed around reefs in the area. An extended rearing period for older pups suggests learning about the location of local feeding grounds is important to the species. The breeding cycle is about 13-14 months, and colonies on different islands cycle independently. This staggered timing may help to spread their predation pressure on limited shared resources more evenly through the seasonal cycle. It could also provide further

protection for small genetic populations against predation by making it more difficult for predators to take advantage of young pups during predictable pupping seasons.

The continental shelf, coastal fish and shark fauna of the Region is dominated by large, relatively long lived carnivorous species adapted for ranging widely and feeding opportunistically. These species feed effectively on sparse resources scattered over broad areas, while searching for occasional aggregations of prey species, switching efficiently between opportunistic and targeted feeding behaviours. The largest predators forage areas where productivity is enhanced, such as along the shelf-break, submarine canyons, eddies and areas where small localised upwellings occur.

Systems of the Region

The South-west Marine Region can be conceptualised as a number of relatively distinct large-scale systems, identifiable on the basis of different major eco-physical processes, major ocean currents, eddy systems and seafloor features. Scientists recognise six large-scale eco-physical ‘systems’ in the South-west Marine Region (see Figure 1). These large-scale systems are ecologically relatively distinct, although their spatial boundaries are not defined by sharp lines. The following characterisations of these six systems have been developed to better understand the differing physical environments and the range of ecosystems they support across the Region.

System 1 – The West Coast

The main hydrological characteristics of the West Coast system are defined by the Leeuwin Current, which flows most rapidly through this system, delivering tropical water and therefore tropical species down a relatively constrained continental shelf, heavily incised with submarine canyons.

There are a range of meso-scale physical features on the shelf that provide sheltered, shallow-water habitats for the complex benthic communities characterising the west coast system. Important topographical features on the shelf in this system are the Abrolhos Islands, Beagle Islands and Rottnest Island, Garden Island and Cockburn Sound, and the inshore lagoons that run parallel to the coastline throughout the west coast system. These lagoons are sheltered from the ocean exposure by a limestone barrier reef system that extends almost the full length of this system, providing shallow-water reef habitats for many assemblages, as well as many commercially and recreationally important species.

The Abrolhos Islands have been relatively well studied and are noted for their high biodiversity, particularly of fish, molluscs, corals, and echinoderms. The biodiversity of this ecosystem is attributed to the mixture of temperate and tropical species, and the location of islands near the edge of the continental shelf. The Abrolhos Islands are an ecological mid-point in a gradient extending from the tropical ecosystems of Shark Bay, south along the shelf to the substantially temperate species mix at Rottnest Island. Intertidal platforms on the west end of Rottnest have a substantially greater proportion of tropical species than those on the eastern end. However, being offshore, these island features capture more of the flow of warm Leeuwin Current waters than their adjacent lagoons and shorelines, and in each location, the offshore islands maintain higher areas of tropical faunal assemblages compared to adjacent inshore reefs.

Inshore islands and lagoons are defined by a series of shallow parallel limestone ridges and depressions 5-10 km offshore that create an extensive area of shallow water on the shelf. These ridges and depressions extend almost the entire length of the Rottnest Shelf (i.e. north to Kalbarri). The shallow lagoons are defined by eroded limestone reefs which support extensive beds of macrophytes (primarily *Ecklonia* spp.) which, together with the other macroalgae, seagrasses, and sediment micro-organisms, form the basis of benthic primary production in the lagoons inside the 50 m depth contour. This abundance and distribution of algae is probably produced and maintained by the wave energy that provides repeated disturbance of the habitat and provides the micro-scale supply of nutrients to the complex reef topography and the distribution of detritus. Beds of seagrass, with their associated epiphytic algae, occur in the more sheltered lagoonal areas where nutrient recycling is recognised as essential to ecological processes. The inshore lagoons are inhabited by a diverse range of coralline algae, sponges, molluscs, crustaceans and fish, and are an important area for the recruitment of the commercially and recreationally important western rock lobster, dhufish, pink snapper, breaksea cod, baldchin and blue gropers and it is assumed many other reef species. Much of the western rock lobster biomass lives inside the 50 m depth contour, where it is the dominant large benthic invertebrate. It is also an important part of the food web of the inner shelf where, particularly when they are small, lobster juveniles are preyed upon by octopus, cuttlefish, baldchin groper, blue groper, dhufish, pink snapper, wirrah cod and breaksea cod. They are particularly vulnerable to predation during their synchronised annual moults which occur in November and December, and to a lesser extent April-May. The high biomass and vulnerability to predation, suggest that this is an important trophic pathway for inshore assemblages of a range of species, that prey on lobster juveniles throughout the Region.

The inshore lagoons are also visited by extensive schools of migratory fish that annually visit the area, including herring, garfish, tailor, and Australian salmon. These mid-sized predators feed on the small pelagic fish and squid found throughout the lagoonal areas, and in turn are preyed upon by larger predators such as mulloway, snapper, samson fish, Spanish mackerel and whaler sharks.

These inshore lagoons, protected by the long barrier of fringing reefs, and heavily influenced by the pole-ward Leeuwin Current, represent a globally unique ecosystem of the subtropical continental margins. As a result, at Rottnest Island there are high levels of species diversity resulting from the mix of tropical and temperate species, and high levels of endemicity, ranging from 15 to 20% of the recorded species within several taxa. The Rottnest Island echinoderm fauna includes 28 species endemic to the west coast of WA, and 5 species that have only been found at Rottnest. Demonstrating the major influence of the Leeuwin Current, of the 86 known echinoderm species found at Rottnest, 26 species are not found on the adjacent mainland coast, and 16 of these are tropical species.

The inner and outer shelfs are physically connected to the deeper slope and oceanic waters by the interaction of the Leeuwin Current with the seafloor. Meso-scale eddies peel off the meandering Leeuwin Current in predictable locations along the shelf break (e.g. off Shark Bay, Abrolhos Islands, Jurien Bay and Rottnest Island). Anti-clockwise eddies entrain the water and planktonic communities of the outer shelf and generally move them westward into the Indian Ocean. The planktonic communities entrained by these eddies are not well understood and there is considerable speculation about the level of productivity, communities and trophic links occurring within them. Larvae from coastal sources may be lost into the oceanic environment when eddies dissipate, while stable eddies that interact with the shelf for extended periods may be important mechanisms for transporting larvae and nutrients onto the shelf from the oceanic environment. Not all eddies are the same. Eddies may have warm water cores or cold water cores, some are associated with descending water bodies while for others it is ascending water bodies. In particular circumstances they are thought to be associated with the uplift of cold nutrient rich deep water that enriches surface waters, attracting aggregations of marine life.

Water column production that makes its way to the seafloor of the outer shelf fuels benthic and demersal communities where filter feeding sponges and bryozoans dominate. The demersal fish on the shelf break and upper slope are composed of distinct communities dominated by large snappers. Juvenile snapper migrate from inshore areas to offshore reefs as adults where they breed and feed. These offshore reefs are high energy environments with an abundance of prey, allowing these communities to exist. For example, kelp (*Ecklonia* spp.) produced on Direction Bank - a shallow limestone ridge on the outer shelf - is broken off the reef by storms and transported throughout the area by cross-shelf currents, supporting a variety of detrital communities.

The demersal fish communities of the upper and mid slope are characterised by many endemic species that exhibit diurnal, vertical migrations. These fish follow and feed on the deep scattering layer - an assemblage of pelagic species that feed in the upper 100 m at night before moving into the dark waters between 500-1,000 m during the day. Demersal fish found on and below the lower mid slope do not appear to vertically migrate, but may feed on species in the deep scattering layer during the day, when they are close to the slope habitat. Slope communities in this system are thought to be dominated by numerous species of grenadier and whiptail. These species are typically benthic-pelagic predators, however in this system they appear to be adapted to feed more benthically than pelagically, reflecting the importance of benthic prey compared to their usual pelagic prey species (such as myctophids – lantern fish). The upper to mid slope is probably important for deep-diving toothed and beaked whales that are thought to feed on fish and squid found on the slope. Important invertebrate grazers in this system are deep sea crabs, such as crystal crabs and the champagne crab, which are found in the benthic environments of the mid to upper slope.

The notable features of this system are the numerous submarine canyons that incise the slope. The largest of these by an order of magnitude is the Perth Canyon, the only canyon in the Region to be the subject of scientific research. The Canyon was formed by eroding gravity flows of the ancient Swan River and cuts into the continental shelf to the 100-150 m depth contour just northeast of Rottnest Island. Although the regional importance of the Perth Canyon is yet to be fully understood, it clearly has a major influence on the system. Acting as a major constriction of the shelf, and a source of deep water, its topography may contribute to frequent formation of eddies and frontal structures that occur to the north of Rottnest Island. The Perth Canyon is the southern boundary of a major faunal discontinuity for numerous species groups on the shelf, including sponges, corals, decapods and xanthid crabs. It is also an important feeding area for blue whales and other deep-diving whales, such as beaked and toothed whales, thought to feed on krill swarms that predictably aggregate in the head of the canyon at approximately 200 m depth. It is therefore highly likely that there are many other species that aggregate at times in the Perth Canyon.

In addition to the Perth Canyon, this system is characterised by a large number of smaller canyons that incise the shelf break, along almost the full length of the system. While there is little knowledge of the biological assemblages in these canyons, they are well known features for fishers, and most likely have small-scale productivity and biodiversity driven by localised periodic upwelling.

System 2 - The Naturaliste Plateau

The Naturaliste Plateau System is generally referred to as a transition area between the cooler water systems to south and east and the warmer water systems to the north. The Leeuwin Current changes direction here to follow the continental shelf and flows from west to east. Much of the energy of its flow is dissipated in a complex eddy field generated as the current moves around the corner of the continent. The coastal geomorphology changes from being comprised primarily of limestone reefs to being predominantly eroded granites. The area is also characterised by a narrow continental shelf, the relative absence of canyons on the slope and the presence of an extensive deep plateau extending west of the continent from the deep slope – the Naturaliste Plateau.

In this system, particular areas on the shelf are important for driving productivity. Geographe Bay, a relatively sheltered part of the shelf protected from the prevailing south-westerly wind and swell by Cape Naturaliste, effectively forms a large sheltered lagoon without the shallow fringing reefs of the inshore lagoon as seen north of the Bay. It is noted for its extensive seagrass beds that are thought to account for about 80% of benthic primary production in this system. These seagrass beds are noted for their high biodiversity and endemic species, supporting diverse communities of infauna and epifauna. As with the lagoons to the north, Geographe Bay provides important nursery habitat for many shelf species and for shoals of squid and small planktivorous fish (anchovies, silver sprat, pilchards, garfish and herring) which in turn are preyed upon seasonally by large mobile schools of predatory fish (Australian Salmon, snapper, dhufish, samson fish and whaler sharks). Geographe Bay is also an important pupping ground for dusky whaler sharks which use the shallow seagrass habitat as nursery grounds for several years before ranging out over the shelf to adult feeding grounds along the shelf break. Blue whales and Hump Back Whales also use the deeper parts of the bay as a resting area.

Limestone reefs punctuating parts of the shelf support diverse communities of macroalgae, crustaceans and demersal fish. Although contributing significantly to the primary productivity of this system, they are thought to contribute only about one third of the level of benthic production produced by the seagrass beds of Geographe Bay. Naturaliste Reef (west of Cape Naturaliste) and the Pinnacles (west of Cape Leeuwin) are notable examples of complex, high profile (20 m) limestone reefs in relatively shallow water (< 50 m). These reefs provide important structures for marine life and are thought to be enriched by localised summer upwellings associated with the Capes counter-current – a current driven by south-easterly winds in the early and late summer months. The enhanced nutrient availability across the shelf attracts aggregations of fish to the area and may provide for local hotspots of benthic biodiversity. Phytoplankton blooms, observed by remote sensing, generated by the upwelling of nutrient rich water at these times can extend into Geographe Bay.

In shallow reef habitats, fish species such as blue groper and queen snapper (invertebrate-feeding fish that typify shallow south coast reef systems) are common in comparison to the West Coast system further north. On the mid slope, south of Cape Mentelle, there is a commercial Orange Roughy aggregation fished sporadically by trawlers of the GAB fishery. This is the western-most known occurrence of this species and to some extent this seems to mark the western limit of the slope fish assemblages that characterise eastern Australia.

Similarly to the West Coast System, coastal and shelf habitat is connected to the deeper waters of the outer shelf, shelf-break and upper slope by the same ecological and physical processes: cross-shelf movements, eddy generated currents and upwellings during the summer. However, there have been fewer scientific studies of offshore areas in this part of the Region so there are many more unknowns in this system. Migratory links between the shelf and the shelf break and upper slope are probably similar to the West Coast system in that juvenile rock lobster and pink snapper develop in shallow waters before migrating to the deeper adult habitats closer to the shelf break.

There are also eddy fields in this system where anti-clockwise eddies peel off the Leeuwin Current at Cape Naturaliste. Some of these eddies move west with their entrained nutrients and plankton communities. These deep water eddies penetrate beyond the surface 200-400 m to depths of more than 2000 m. Of particular interest is the interaction of these deep eddies with the seafloor, especially where the seafloor shallows as it climbs to form the Naturaliste

Plateau. This interaction leads to enhanced mixing of the water column and scientists speculate that these meso-scale features will give rise to aggregations of invertebrates, fish and migrating marine mammals and possible local hotspots of biodiversity.

The Naturaliste Plateau is a large and relatively complex feature of the seafloor and has been the subject of very little investigation. However, scientists speculate that given its geomorphological complexity, its location within the deep eddy field of this system, and its proximity to the Sub-tropical Convergence Front (i.e. the only part of the Australian continent to interact directly with this front) it is highly likely that its marine communities are characterised by unique species and high biodiversity.

System 3 – The South-west Coast

The large scale eco-physical features that define the South-west Coast System include the Leeuwin Current moving from west to east and decreasing in strength; a narrow shelf adjoining a steep slope deeply incised by numerous submarine canyons; an extensive area of abyssal plain and the complex topography of the deep (> 2000 m) Diamantina Fracture Zone.

In this system, the water-column productivity of phytoplankton is considered to be a more significant driver of overall production than the benthic productivity, despite productivity remaining relatively low overall. The important physical processes thought to regulate production of phytoplankton communities include the interactions of currents around eddies; other deep ocean currents; and the mixing of shelf break waters on the shelf break and upper slope generating sporadic upwelling. Although relatively unexplored through this system, small upwellings most likely associated with the Flinders Current (a subsurface counter-current running against the Leeuwin Current along the south coast) are thought to coincide with some of the submarine canyons incising the slope. The mixed water generated by these processes probably creates enriched areas for a range of small planktivorous fish, pilchards, mackerels, krill, squid and salps, that in turn attract larger, highly mobile sharks and piscivorous fish (e.g. Australian Salmon, barracouta, tunas and gemfish). These communities are also preyed upon by marine mammals such as the deep-diving toothed whales (including sperm whales), a range of dolphin species (including orca), the New Zealand fur seal and Australian sea lion. Fur seals and sea lions form colonies on the numerous islands of the inner shelf. It is likely that there may have also been elephant seal colonies in this system prior to the early years of European impact.

The faunal assemblage in this system is typical of the cooler water communities seen all the way along the south coast of Australia to Kangaroo Island and the mouth of the Murray River. In the shallow waters, blue groper and queen snapper are prominent, large benthic predators with crushing teeth and plates capable of crushing molluscs and heavily shelled macro-invertebrates like crabs and small lobster. The omnivorous, big-mouthed reef predators, such as the western Australian dhufish and smaller breaksea cod, disappear from the shallow shelf and coastal assemblage to the east of Albany, replaced by mulloway, harlequin cod and ‘nannygai’ (now better known as bight redfish).

In the shallow water of this system, barracouta replace tailor as the dominant shallow water pelagic piscivore, and “salmon-trout” (juvenile Australian salmon) can be observed feeding alongside Australian herring behind the surf zone. On the shallow (< 40 m) coastal reefs of this system, the green lip abalone can comprise a significant biomass as they do along the entire southern Australian coast. This high abalone biomass is a feature of coastal reefs not seen on the temperate reefs of the west coast system, where the reefs mainly occur in even shallower waters. Also in this system, the dominant lobster species changes from the western rock lobster of the west coast system to the southern rock lobster (*Jasus novaehollandae*) found throughout temperate Australia and New Zealand. In addition to these changes, the importance of crustaceans in structuring shallow benthic communities appears to be less in this system compared to those to the west and north (i.e. in this system there is a notable increase in the ratio of benthic fish to crustaceans).

The fish assemblage at the edge of the continental shelf, along the shelf break and down the upper and mid-slope is apparently much the same as the assemblage seen throughout temperate Australia. Krill and small pelagic planktivorous fish are apparently important parts of the production cycle. On the slope there is a decrease in the number of benthic feeding slope fish in this system, a response thought to be related to greater availability of pelagic species (i.e. meso-pelagic fish such as myctophids). Small, but significant, catches of school and gummy shark are caught along the shelf break outside the Recherche Archipelago. In eastern Australia, these two species feed benthic-pelagically on swarming planktivores. Deepwater trawlers monitor, and sporadically fish, a cluster of orange roughy aggregations found amongst deepwater hills along the mid slope in the same area. Industry scientists and some fishers hypothesise that species like blue grenadier and gemfish, may have spawning aggregations amongst the submarine canyons and hills that feature on the slope adjacent to Esperance and Hopetoun. Occasionally, following La Niña periods, recruitment of large numbers of scallops (*Amusium ballot*) are discovered and fished on the shelf adjacent to Esperance.

The differences in composition and behaviour of these South-west Coast communities in comparison to the West Coast systems is related to the relative weakness of the Leeuwin Current, the absence of an inshore barrier reef system, and the relatively greater strength of the deeper counter-current, the Flinders Current. The Flinders Current is responsible for transporting cooler, nutrient enhanced waters from the east, bringing with it propagules and larvae from along the Australian south coast from offshore South Australia. In the shallower waters, the relative lack of reef structures compared to the west coast also plays an important role in structuring the marine system. There is limited microhabitat, such as crevice space, available to shelter lobster biomass, even if large recruitments drift into the area with oceanic currents from the east. There are also relatively few sheltered lagoonal areas.

In this system, the Recherche Archipelago is a notable area of the inner shelf, where numerous dome-like granite outcrops form a network of shield islands. Submerged reefs associated with these islands provide some level of shelter allowing for the development of complex and rich benthic ecosystems, which capture nutrients from the sporadic upwelling from deeper waters. The area is noted for its spectacular topography and high biodiversity, particularly in kelp communities and benthic fish. West of the Archipelago is a large, poorly understood, shallow area (< 100m) that has been the focus of very few studies. In fact, on a recent scientific voyage in a nearby area, the captain of the vessel refused to enter these waters because waters here were unchartered.

The South-west Coast system is characterised by a series of clusters of granite outcrops on and around the coast. In many locations these form semi-sheltered bays, coastal lagoonal estuaries or small, sheltering off-shore islands. The coastline around Albany typifies these ‘onshore versions of the Recherche Archipelago’, providing permanent structure and complexity to the coastal environment, and sheltering a wide range of environments such as estuarine and marine bays with seagrass and sheltered and exposed marine kelp and/or sponge dominated reefs. The sheltered bays are noted for their seagrass beds, diversity of benthic invertebrates, such as molluscs, and variety of fish habitats. Estuarine environments that grade to fresh-water systems running back into low nutrient sand plains are a relatively rare feature in the broader region.

While still little studied, the coastal areas of this system are highly biologically diverse, probably because of the rich variety of nearshore habitats and the residual impact of the Leeuwin Current. For example, more than 400 species of molluscs are known from the waters around Albany and Esperance, including at least 25 tropical species. The echinoderm fauna includes 83 species recorded from the shallow waters around Albany, including 19 species endemic to this system with some extending into adjacent systems to the east. About 115 species of decapod crustaceans have also been recorded from the nearshore Albany area, including 86 species of temperate origin and 27 of tropical origin, indicating a strong influence of the Leeuwin Current in this group of animals.

This system also contains part of the Diamantina Fracture Zone, an extensive and highly complex area of troughs and ridges on the abyssal plain (>4000 m). On the basis of its complexity, its location beneath a major regional oceanic convergence zone, and the high level of endemism in the adjacent shallower habitats, scientists believe it is likely to be characterised by unique species and high biodiversity. However, the ecological characteristics of this area are presently unknown.

System 4 – The Great Australian Bight

The eco-physical features that characterise this system are the particularly broad, shallow continental shelf, and two extensive terraces on the continental slope - the Eyre Terrace to the west and the Ceduna Terrace to the east. These deep-water terraces are ancient sediment deposition zones that have been produced by a long history of downwelling waters. A complex mix of weak downwelling currents are layered through the system from the inner shelf, to the deeper waters the slope, including seasonally alternating flows of small coastal currents, the eastward flowing Leeuwin Current (which is at its weakest in this system), and the westward flowing Flinders Current. Evaporation during summer over the shallow expanses at the head of the Bight, and in South Australia's two gulfs (St Vincent Gulf and Spencer Gulf), creates hypersaline seawater which generates an additional and predictable downwelling force when the system cools during winter.

Much of the standing biomass in this system is likely to be within the highly diverse epibenthos inhabiting the continental shelf, particularly sponges, bryozoans and ascidians that were documented from recent surveys of the eastern Bight area. The continental shelf of this system is part of the world's largest cool-water carbonate province that extends across Australia's southern margin. The species that make up these communities tend to vary from the inner to the outer shelf, and also decrease in abundance moving away from the coast.

The largest proportion of macroscopic biomass in this system is probably within the infauna on the extended shelf and slope of this system, and the system to the east. The ecological importance of this infauna is indicated by the incidental and targeted catch of the Great Australian Bight (GAB) trawl fishery which is principally comprised of latchet and deepwater flathead. Latchet feed directly on large infaunal species, while deepwater flathead are specialised for ambushing smaller species that forage for infauna along the bottom. The infauna of this system should be rich and diverse – given the diversity in sediment facies and varying levels of exposure and depth, together with its stability over geological time frames – but it has never been studied.

Indeed, the continental slope in both this system and further east in System 5 is virtually unknown in terms of both epibenthic and infaunal communities. Other groups mostly unknown in this system are zooplankton and cephalopods, although it is likely that these play an important role as food for higher order predators. The size and variability of the biomass of small pelagic fish such as pilchards, and their role in this system is also poorly known, however, they are thought to be an important dietary source for young blue-fin tuna and presumably also for albacore in deeper waters.

This system lacks any terrestrial input from rivers, although in some areas, groundwater sources are hypothesised to play some role in augmenting coastal ecosystems. With a total absence of fluvial inputs into the system and a lack of predictable eddies, upwellings and canyons cutting into the upper slope and shelf break, the Great Australian Bight is the most nutrient poor of the six systems being described here, particularly on the continental shelf. The mechanisms responsible for the low levels of nutrients that do reach this system are almost entirely unstudied. The anecdotal accounts of commercial fishermen and their catch statistics from the area comprise most of the available information. Generally, the shelves of both System 4 and 5 are characterised by an extremely low concentration of chlorophyll at the surface, and higher concentrations at depth. Schools of small pelagic fish (e.g. pilchards) are commonly associated with small hills and other geomorphic features in inshore waters. A thermocline occurs at approximately 40 m across the shelf and appears to influence species distribution and potentially plays a role in nutrient upwelling. The shelf and slope is characterised by unconsolidated soft sediments which are likely to host infauna communities, but very little is known about species composition and abundance of this fauna.

To a large extent, System 4 survives on inputs from other systems received in the depleted warmer Leeuwin Current flowing from the west, the colder more enriched Flinders Current from the east, and various mixes of these with coastal waters. The downwelling that predominates through this system in winter, would be expected to displace deeper waters and drive some level of winter overturn along the shelf break. However, as the slope is so gradual, this enrichment will be extensive and sparse. Fishermen who have tracked aggregations of school shark through this system describe pulses of “dirty water” that irregularly wash through the system from the west. These pulses are followed by an increased availability of baitfish and squid and, later, larger predators (e.g. dolphin, tuna, sharks). These productivity pulses are highly variable within and between years, with a tendency to be associated with La Niña years. This episodic enhanced production manifests itself through the concentration of many species along the shelf edge, in turn causing sporadic aggregations of predatory species. Highly transitory, higher order predators which normally forage in other systems such as tuna, school and whaler sharks, seals and dolphins. Seabirds are attracted to the area by the ephemeral blooming of shelf edge plankton communities and they then track the food chains associated with these pulses of productivity as they move through the system. Other species caught by fishers may also be responding to these events (e.g. leatherjackets, latchets, stingrays, stingarees, gummy shark and angel shark).

There is apparently a greater degree of seasonal variability in the occurrence and abundance of fish stocks in System 4 and the western part of System 5 compared to the rest of the Region. This variability is clearly driven by the extremely variable nature of primary productivity in this part of the Region. Some of the variability will be due to highly mobile species using the area during times of abundance and foraging offshore in the sub-Antarctic front, or in other parts of the Region when conditions are poor. Species such as redfish and flathead may change between dispersed and aggregated feeding patterns in relation to productivity events, thus changing their vulnerability to fishing and sampling gear rather than changing their actual population size in the area.

Although sporadic pockets of productivity are present within this system, overall it is still characterised by extremely low productivity. For example, Australian sea lions foraging in this system are noted for being relatively skinny, in comparison to those foraging in the more productive waters off Kangaroo Island, in the neighbouring system to the east. For the most part, this system only supports higher order predators that are highly mobile and transitory.

The only relative hotspot of higher productivity is the coastal area around the head of the Bight, which may be enriched by infiltration of groundwater. Satellite images show higher concentrations of chlorophyll a in this area, and this is supported by anecdotal observations of higher concentrations of a number of species such as juvenile Australian salmon, mulloway, school shark, sea lions, dolphins and southern right whales, who use the relatively sheltered areas of mixed seagrass, sand and limestone reef as nurseries and feeding grounds. Benthic studies have also found the highest values of biomass and species richness at the head of the Bight.

System 5 – The Eyre Coast

The eco-physical features that characterise this system are the particularly broad, shallow continental shelf and the Ceduna Terrace on the continental slope. The complex of ocean currents layered from inner shelf to the deeper waters of the slope is similar to that of System 4, and the western half of this system is likely to be dominated by the same downwelling forces as in System 4. However, this system differs from System 4 in the east, where numerous submarine canyons incise the continental slope south of the Eyre Peninsula and to the west and south of Kangaroo Island. These canyons are apparently associated with some level of both summer and winter upwelling which creates several predictable hot spots of productive waters in an otherwise nutrient-poor environment. The main area of upwelling is located at what is known as the Kangaroo Island 'pool' along the 100m depth contour (offshore and to the west of Kangaroo Island). During summer (November to April) periods of south-easterly winds cause a cold tongue of water to be propagated from this 'pool' past the mouth of the Spencer Gulf towards the coast of the western Eyre Peninsula, where it is expressed on the surface around several rocky headlands. These summer upwelling are mainly wind driven and occur as relatively predictable, seasonal pulses. Unlike the Bonney upwelling near the South Australia/Victoria border, upwelling in this system do not appear to be a connected directly to submarine canyons, potentially indicating a weaker upwelling mechanism. We know very little about connectivity between the extensive canyon system on the deeper parts of the slope and about the shelf in this system. There may potentially be a connection between the upwelling described above and infiltration of groundwater that characterises the middle shelf in this system.

The fisheries productivity on the adjacent shelf and coast is enhanced by these seasonal coastal upwellings. The 'Compass Rose Area', west of the Eyre Peninsula, was important to the early school shark fishery and is currently developing as a remote ground for the pilchard fishery. The West Coast prawn fishery and Coffin Bay scallop fishery and oyster industry are also based on this productivity.

The area of canyons which incise the shelf and slope south of Kangaroo Island, both at the shelf edge and the slope, appear to be a highly important area for a range of commercial species as an aggregation area for spawning, mating and feeding, especially during winter. There are highly productive giant crab, lobster and gummy shark grounds along the shelf edge. Commercially important south-eastern Australia slope species including blue grenadier, blueeye trevalla, ling, hapuka, warehou, gemfish, orange roughy and school shark are fished, or have been fished, in the area. Anecdotal accounts from fishers suggest the area is used as a mating ground for school shark, and a spawning ground for blue grenadier. It has also been suggested as a possible spawning ground for the western gemfish. Archival tags placed on school shark showed that they spent a considerable proportion of their time foraging around these canyon systems. It is to be expected that the water column above the canyons and shelf inshore will be important foraging grounds for the large New Zealand fur seal and Australian sea lion colonies found on and around Kangaroo Island. The area of rugged slope offshore from the Eyre Peninsula, to the west of Kangaroo Island, was shown by recent hook surveys to have high levels of commercially valuable slope species, and it also has relatively healthy gulper shark populations compared to the rest of south-eastern Australia. Squid are a very important source of prey for predators in this system and are known to have spawning aggregations off Portland in May. They are a short-lived species (i.e. about 18 months) and appear to move from east to west into the system, but there is considerable uncertainty about their movements in the Region.

The mechanisms that make this area important ecologically are not understood. The pattern of productivity suggests the system is most active in winter rather than summer, suggesting a mechanism other than continental winds is an important driver. Extrapolating from the mechanisms seen elsewhere in the South-west Marine Region and in the South-east Marine Region, the winter enrichment mechanism is likely to be some combination of the winter overturn, augmented by the downwelling of Leeuwin Current waters, hypersaline slumps of inshore water from the GAB and South Australian Gulfs, and shelf break mixing by strong winter frontal systems.

As in the systems to the west, a series of ‘shield islands’ in relatively shallow water along this coast add complexity and degrees of shelter to this system, sheltering complex benthic ecosystems and trapping nutrients in the benthos. These islands are associated with very diverse benthic communities and aggregations of krill and/or salps (these tend to alternate, as observed in the South-east Marine Region). Extensive seagrass beds occur down to 50m depth in the shelter of these islands, and play a nursery role for a number of species (e.g. school and whaler shark pupping areas reported inside the shield islands). At depths greater than 50m, the communities become dominated by sponges.

The eastern part of system 5, with its multiple enrichment sources appears to provide a more predictable environment for predators. The higher productivity of this system is thought to contribute to the differences in predator assemblages when compared to system 4. For example New Zealand fur seals (mostly feeding at the shelf break); Australian sea lions (mainly feeding on the shelf); dolphins, penguins, blue whales, seabirds (mutton birds and albatross) are a feature of the eastern part of this system.

System 6 – The Gulfs (briefly covered during the workshop)

This system, occurring entirely outside the Region, was considered only in the context of its connectivity to the broader Region. There appears to be little connective flow between the gulfs, or the gulfs and offshore systems. During summer there is a definite ‘frontal boundary’ at the mouth of the gulfs based on the density difference between the hyposaline gulf waters and the marine waters outside. The South Australian pilchard fishery currently fishes around the entrance of Spencer Gulf and it is possible that the dynamics of this fishery maybe linked to these frontal features. As the winds of autumn and winter cool the shallows of the gulfs, the frontal features break down and there are density-related outflows from the gulfs which contribute to a stream of westward flowing coastal waters through Backstairs Passage east of Kangaroo Island, but may also add to the winter overturn south of Kangaroo Island.

Ecologically the shallows of the gulfs are important nursery areas for several species significant in the Region which then move into deeper water and offshore outside the gulfs. King George whiting, pink snapper, western king prawns, blue manna crabs and juvenile Australian salmon are known to use the gulfs in this way. Large spawning aggregations of cuttlefish are know to occur at Whyalla at the head of Spencer Gulf, which are known to be a substantial and ubiquitous component of the diet of Australian sea lions in the Region. It is not known whether this aggregation provides recruitment on a local or regional scale.

Appendix A – Background papers provided to participants prior to the workshop

All background papers were circulated to the participants in early September 2006. The contents should be considered as relevant at that time.

- Background Paper 1: Marine Bioregional Planning
- Background Paper 2: Key Department of the Environment and Water Resources Responsibilities for Protecting the Marine Environment and Conserving Marine Biodiversity
- Background Paper 3: National System of Marine Protected Areas
- Background Paper 4: The Workshop

South-west Marine Region

Workshop to Characterise the Marine Environment

Background Paper 1: Marine Bioregional Planning

Purpose

This paper provides an overview of the marine bioregional planning program.

Marine Bioregional Planning

The Australian Government has recently reviewed its approach to marine regional planning, originally designed to implement *Australia's Oceans Policy* (1998). Under the previous regional marine planning program, the Australian Government developed the South-east Regional Marine Plan, which was completed in 2004.

Marine Bioregional Planning replaces the previous Regional Marine Planning program and differs from this by:

- being embedded in the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act), with marine plans now being prepared under Section 176 (Bioregional Plans)
- focusing on matters of relevance to the Department of Environment and Water Resources and particularly the conservation of marine biodiversity
- providing the primary mechanism for the establishment of Marine Protected Areas (MPAs) in Commonwealth waters, in contribution to the National Representative System of MPAs.

The 4-year marine bioregional planning program will cover the entire Commonwealth marine area, which extends from the limit of state waters, three nautical miles from shore, out to the edge of Australia's Exclusive Economic Zone (EEZ), generally about 200 nm offshore.

The first marine region to be the focus of the new approach to marine planning is the South-west.

Desired outcomes

In accordance with s176 of the EPBC Act, the Minister will have to have regard to the Plan in making any decision under the EPBC Act to which the Plan is relevant.

Thus, the key outcomes the Australian Government seeks to achieve through the program are:

- consolidated knowledge base and evidence-based guidance for supporting informed and consistent decisions for the marine environment under the EPBC Act;
- strategic directions for existing and new programs administered by the Department and aimed at the conservation of marine biodiversity and heritage values; and
- a network of representative MPAs.

Program outputs

In each marine region, there will be three main outputs from the planning process:

- A Regional Profile is the first publicly released milestone and aims to:
  - provide a description of the region's ecosystems, heritage values, human uses and benefits. The description also covers the various statutory obligations under the EPBC Act and other environmental legislation that applies in any region, as well as existing conservation measures and other marine spatial management measures such as area closures for fisheries;
  - identify clearly the region's conservation values (see Box 1 for a definition of conservation values for the purpose of marine bioregional planning); and
  - articulate the specifications for the establishment and design of the MPA network in the region.
- Draft Marine Bioregional Plans will:

  - articulate regional priorities for biodiversity and heritage conservation - regional priorities will be set on the basis of a region-wide assessment of the risk to conservation values from current and emerging threats;
  - propose measures to address regional priorities;
  - set guidance for making decisions of relevance to the region under the EPBC Act and other relevant legislation;
  - propose a network of MPAs; and
  - identify regional sustainability indicators.

  The draft Marine Bioregional Plan is subject to statutory public consultation under the EPBC Act

- Marine Bioregional Plans will be finalised on the basis of the outcomes from the statutory consultation on the draft plans.

Marine Bioregional Plans: Conservation values

For the purpose of marine bioregional planning, ‘conservation values’ within a region include:

- listed threatened and migratory species;
- listed threatened ecological communities;
- listed critical habitats;
- listed marine species (s248 of EPBC Act);
- cetaceans;
- listed heritage places, including all shipwrecks; and
- the marine environment, as per s23 and s24 of the EPBC Act.

South-west Marine Region

Workshop to Characterise the Marine Environment

Background Paper 2: Key Department of the Environment and Water Resources Responsibilities for Protecting the Marine Environment and Conserving Marine Biodiversity

Purpose

This paper outlines briefly the main responsibilities that the Department of Environment and Water Resources (DEW) has in relation to the marine environment under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) and the *Environment Protection (Sea Dumping) Act 1981.*

The paper is intended to provide workshop participants with the broader context for why DEW needs to better understand the Commonwealth marine environment.

It is important to note that we have deliberately focused on those aspects of DEW responsibilities that can be informed by a broad and 'system' understanding of the marine environment. For this reason the list below is not comprehensive. Additionally, in considering the potential role of the workshop outcomes for informing decision-making, it is useful to note that, as described in Background Paper 4, this workshop is the first of a series of science inputs in the development of the Marine Bioregional Plans.

Responsibilities under the EPBC Act

Referral, assessment and approval

- The EPBC Act identifies seven matters of national environmental significance: World Heritage properties, national heritage places (from 1 January 2004), Ramsar wetlands of international significance, listed threatened species and ecological communities (excluding species listed as extinct or conservation dependant), migratory species, Commonwealth marine environment, and nuclear actions (including uranium mining).
- Of these seven matters of national environmental significance three are particularly relevant to Marine Bioregional Planning: threatened species, migratory species and the Commonwealth marine environment.
- The EPBC Act requires that proposals for actions that may have a significant impact on a matter of national environmental significance be referred to the Minister for the Environment and Water Resources (Environment Minister) for assessment and approval.
- The DEW has developed *Significant Impact Guidelines for Matters of National Environmental Significance.*
- Under these Guidelines, a referral needs to be submitted to the Environment Minister for assessment if there is a real chance or possibility that an action will have any of the following impacts on the Commonwealth marine environment:

    - result in a known or potential pest species becoming established in the Commonwealth marine area;
    - modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that an adverse impact on marine ecosystem functioning or integrity in a Commonwealth marine area results;
    - have a substantial adverse effect on a population of a marine species or cetacean including its life cycle (e.g. breeding, feeding, migration behaviour, life expectancy) and spatial distribution;
    - result in a substantial change in air quality or water quality (including temperature) which may adversely impact on biodiversity, ecological integrity; social amenity or human health;
    - result in persistent organic chemicals, heavy metals, or other potentially harmful chemicals accumulating in the marine environment such that biodiversity, ecological integrity, social amenity or human health may be adversely affected; or
    - have a substantial adverse impact on heritage values of the Commonwealth marine area, including damage or destruction of an historic shipwreck.

- Marine Bioregional Plans will contain comprehensive descriptions of the marine environment of individual regions and will bring together best available data and knowledge about ecosystem functioning and integrity. This will provide an ecosystem-based knowledge framework for appraising individual proposals and, where appropriate, providing guidance on the type of finer scale information required by the Minister for making decisions.

Fisheries assessment

- Under the EPBC Act DEW is responsible for assessing the environmental performance of all fisheries managed under Commonwealth legislation and state fisheries that have an export component. The purpose of the DEW assessment is to ensure that, over time, fisheries are managed in an ecologically sustainable way.
- The assessments are conducted against the *Guidelines for the Ecologically Sustainable Management of Fisheries* (the Guidelines). The Guidelines outline specific principles and objectives designed to ensure a strategic and transparent approach is used to evaluate the ecological sustainability of fishery management arrangements.
- Under these Guidelines Principle 2 specifies that 'fishing operations should be managed to minimise their impact on the structure, productivity, function and biological diversity of the ecosystem'.
- Under the Guidelines the fishery assessment requires the collection of information and a risk analysis on the susceptibility of each of the following ecosystem components to the fishery:
  1. impact on ecological communities – benthic communities, ecologically related, associated or dependent species and water column communities;
  2. impacts on food chains – structure and productivity/flows; and
  3. impacts on the physical environment – physical habitat and water quality.
- As in relation to referral, assessment and approval of individual actions, Marine Bioregional Plans will improve the Department's capacity to apply an ecosystem-based knowledge framework to the strategic assessment of fisheries. Of particular relevance is the broad understanding of trophic relationships and habitat dependency within a region.

Protected species and communities

- The EPBC Act allows for the listing of species as threatened, migratory, marine or as cetaceans. Commonly, species listed under the EPBC Act are referred to as protected species as it is an offence to kill, injure, take, trade, keep or move a listed species without authorisation.
- Species listed as threatened under the EPBC Act are those that have been identified as having their survival threatened. Under the EPBC Act listed threatened species must be classified into one of the following six categories: extinct, extinct in the wild, critically endangered, endangered, vulnerable or conservation dependent.
- The EPBC Act also allows for the listing of threatened ecological communities. Although to date no ecological communities in the marine environment have been listed under the EPBC Act.
- The Australian Government Minister for the Environment and Water Resources (the Environment Minister) can also identify and list habitat critical to the survival of a listed threatened species or ecological community on the Register of Critical Habitat.
- Migratory species listed under the EPBC Act are species that are already listed under international conventions to which Australia is a signatory and have been identified as species that require or would significantly benefit from international cooperation.
- All cetaceans are listed under the EPBC Act as the Australian Government recognises whales, dolphins and porpoises require protection to ensure their long-term conservation.
- Marine species listed under the EPBC Act are species that the Australian Government recognises require protection to ensure their long-term conservation.

Recovery Planning

- Under the EPBC Act Recovery Plans must be developed and implemented for listed threatened species and ecological communities in Commonwealth areas. When a Recovery Plan applies to areas not within Commonwealth jurisdiction, the Commonwealth must seek the co-operation of the state and territory Governments for implementing the plan.
- Recovery Plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species and ecological communities.
- Recovery plans identify what must be done to protect and restore important populations of threatened species and habitat, as well as how to manage and reduce threatening processes.
- Commonwealth agencies must not take any actions that contravene Recovery Plans.
- To achieve these objectives Recovery Plans must be based on up to date and scientifically rigorous information on the life cycle, population, distribution, critical trophic links, important habitat (including aggregation areas) and threats to the species.

- Any additional information on the life cycle, population, distribution, critical trophic links, important habitat (including aggregation areas) and threats to listed threatened species would assist DEW meet all of its responsibilities under the EPBC Act for threatened species (i.e. developing and implementing recovery plans, ensuring fisheries are managed in an ecologically sustainable way and assessing referrals for actions).

DEW's Responsibilities under the *Environment Protection (Sea Dumping) Act 1981*

Sea dumping

- The *Environment Protection (Sea Dumping) Act 1981* was enacted to fulfil Australia's international responsibilities under the London Convention of 1972 and has been amended to implement the 1996 Protocol to the London Convention (which Australia ratified in 2001). Under the Protocol, Australia is obliged to prohibit ocean disposal of waste materials considered too harmful to the marine environment and regulate the permitted dumping of wastes at sea to ensure the environmental impact is minimised.
- Permits from the DEW are required for all sea dumping operations. Currently, about thirty permits are issued in Australia per year, mainly for the dumping of uncontaminated dredge spoil, disposal of illegal vessels and for burials at sea.
- The *Environment Protection* (Sea Dumping) *Act 1991does* not cover operational discharges from ships, such as sewage and galley scraps. Those are regulated by the Protection of the Sea legislation administered by the Australian Maritime Safety Authority.
- In deciding whether to grant a permit, consideration is given to the type of material proposed to be dumped, the dump site and the potential impacts on the marine environment.
- Information on important habitat for species listed under the EPBC Act, major ocean currents, the locations of upwelling and down welling and key features may inform the identification of areas within a region where dumping is likely to result in significant down-stream effects on ecological systems.

South-west Marine Region

Workshop to Characterise the Marine Environment

Background Paper 3: National System of Marine Protected Areas

Purpose

This paper provides:

a) An overview of the National Representative System of Marine Protected Areas (NRSMPA)
b) DEW's approach to delivering the NRSMPA
c) Information sources to deliver the NRSMPA

The National Representative System of Marine Protected Areas

The *Strategic Plan of Action for the NRSMPA* was agreed by all Australian governments in 1999, in recognition of the need to protect, through marine protected areas, representative examples of the full range of marine ecosystems and habitats.

The primary goal *Strategic Plan of Action* is to build a national system of MPAs that will be:

- Comprehensive, i.e. include MPAs that sample the full range of Australia's ecosystems;
- Adequate, i.e. include MPAs of appropriate size and configuration to ensure the conservation of marine biodiversity and integrity of ecological processes; and
- Representative, i.e. include MPAs that reflect the marine life and habitats of the areas they are chosen to represent.

The establishment of a NRSMPA is a key responsibility and obligation under a number of conventions and strategies endorsed by the Australian Government including the international Convention on Biological Diversity, national commitments under the *Inter-governmental Agreement on the Environment (1992), Australia's Oceans Policy* (1998), the *National Strategy for Ecologically Sustainable Development* (1992) and the *National Strategy for the Conservation of Australia's Biological Diversity* (1996).

A network of representative MPAs has been developed for the South-east Marine Region and DEW is currently progressing towards statutory declaration process and development of individual Plans of Management.

Since finalising the South-east MPAs, the DEW Marine Protected Area (MPA) program has been brought into the broader marine bioregional planning program, to ensure MPAs are developed in a broad context of integrated oceans management and not in isolation of other conservation tools and sectoral management initiatives to achieve biodiversity conservation.

While the primary aim of the MPAs is biodiversity conservation, the Australian Government's policy is to make every effort to minimise unnecessary socio-economic impacts when developing MPAs. Socio-economic and cultural considerations, as well as issues of management practicality and feasibility, will influence the boundaries and the number of individual MPAs and the design of the system as whole.

DEW's approach to delivering the NRSMPA

Background Paper 1 describes the marine planning, program, which is the primary mechanism for the establishment of representative MPAs in Commonwealth waters.

DEW is currently reviewing lessons learnt from the establishment of the South-east network of MPAs. The outcomes will inform the approach to the establishment of representative MPAs in the remaining Regions.

Information sources to deliver the NRSMPA

Ideally, planning and management for the NRSMPA will be based around a detailed understanding of all ecosystems and processes, but it is recognised that this understanding is limited. While there is good information about the geomorphology of Australia's seafloor, biological information is patchy and incomplete, particularly in the deep offshore environments (where, for example, there is limited information on species distribution and ecological processes).

A primary source of information for the identification of the NRSMPA is **Australia's Integrated Marine and Coastal Regionalisation of Australia, v.4 (IMCRA4),** recently established by bringing together the *Interim Marine and Coastal Regionalisation of Australia v.3.3* and the offshore *National Marine Bioregionalisation*. IMCRA 4 represents a synthesis of key biological, geological and oceanographic data to provide a spatial framework for classifying Australia's marine environment into bioregions that make sense ecologically and are at a scale useful for regional planning. It is based on the best information currently available and represents one of the most comprehensive bioregionalisation studies ever undertaken at a national scale. The Australian Government will use the 41 benthic provincial bioregions described in the IMCRA 4 as the primary framework for the development of the NRSMPA.

It is the Australian Government's policy that in the absence of sufficient information about species, habitats and their conservation requirements, decisions about MPA size and management/zoning will be made on a precautionary basis. This approach is consistent with the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), under which the MPAs will be declared, whereby management plans will be reviewed every 7 years to continuously improve information on conservation values and the adequacy of arrangements to protect these values.

South-west Marine Region

Workshop to Characterise the Marine Environment

Background Paper 4: The Workshop

Purpose

The aim of this paper is to:

- provide the rationale and specific objectives of the workshop;
- outline the expected outputs from the workshop;
- describe the approach to be used at the workshop;
- provide a draft agenda for the workshop; and
- list data layers available for the workshop.

Workshop rationale and objectives

The Department of Environment and Water Resources is developing a South-west Marine Bioregional Plan under the *Environment Protection and Biodiversity Conservation Act 1999* (hereafter referred to as the EPBC Act). Background Paper 1 explains in more detail the process of developing Marine Bioregional Plans.

The aim of the Plan is to provide a comprehensive information basis and specific guidance for making decisions of relevance to the Region under the Act. Background Paper 2 provides an overview of the relevant responsibilities of the Australian Government under the EPBC Act and the types of decisions that will be supported by the Plan.

The Department requires scientific input at the following key stages in the development of the Plan:

4. During the profiling of the Region, to ensure that the description of the ecological systems of the Region is based upon a comprehensive and up to date scientific knowledge, integrated across the relevant disciplines. For the South-west Marine Region, this is being done through:
    a) the National Marine Bioregionalisation, which is based on a synthesis of biological, geological and oceanographic data (Background Paper 3 describes the role of the Bioregionalisation in the development of the Plan);
    b) a comprehensive review of relevant literature, which has resulted in two key reports:
        - *The South-west Marine Region: Ecosystems and Key Species Groups*
        - *Geomorphology and Sedimentology of the South Western Planning Area of Australia*; and
    c) this workshop, which will provide a multidisciplinary characterisation of the marine environment of the South-west Marine Region from a system perspective.
5. During the strategic assessment of risks to regional conservation values, to incorporate scientific understanding of the responses of the Region's ecological systems to current and future pressures. While some work has commenced (consideration of future development scenarios for the Region), this phase will occur during the first half of 2007 and it will include a science workshop in mid 2007.
6. During the identification of a set of indicators for monitoring the state of the marine environment in the Region. This will occur later in 2007- early 2008.

Objectives of the workshop

The objective of this workshop is to characterise the marine environment of the South-west Marine Region in a way that improves the Department's understanding of how the Region's natural systems work. More specifically, the Department aims, through the workshop, to:

- characterise functional systems within the Region on the basis of their location, their biological and physical components and how these interact;
- understand links across functional systems and the broad scale drivers of ecosystem functioning across the Region, including the importance of the inter-face between functional systems and the key processes that link neighbouring systems; and
- understand the key areas of uncertainty surrounding the Region's ecological systems, as well as the areas for which empirical evidence is available.

Expected outputs

The Department will compile a Report summarising workshop outcomes and discussions. A draft of the Report will be circulated for comments to the workshop participants. The Report will contribute to the preparation of the South-west Bioregional Profile (see Background Paper 1), which will be released publicly in 2007.

Ideally, the report will capture a representation of the functional relationships among ecological properties of the South-west Marine Region based on the expertise of participants, which will complement the existing biogeographical and geomorphological classifications of the Region.

Approach to workshop

The Department commissioned CSIRO Marine and Atmospheric Research (CMAR) to develop a framework for characterising the marine environment. The Department and CMAR 'road-tested' the framework using data and experts from the South-east Marine Region. The findings were used to refine our thinking on the approach to this workshop, which is described at Attachment A.

The workshop will be structured around a series of steps to characterise the marine environment of the South-west Marine Region. The description of the steps and the questions used in Figure 1 to define the scope are not intended to be strictly prescriptive. However, given the extent of the Region and the potential breadth of discussions about its ecology, it is felt that providing a clear structure and some bounds is necessary. Figure 2 in Attachment A shows some of the outputs generated during the 'road-test' exercise and these may provide further guidance of what the desired products from the workshop discussions may look like.

A draft agenda for the workshop, which broadly reflects the framework, is provided in Attachment B.

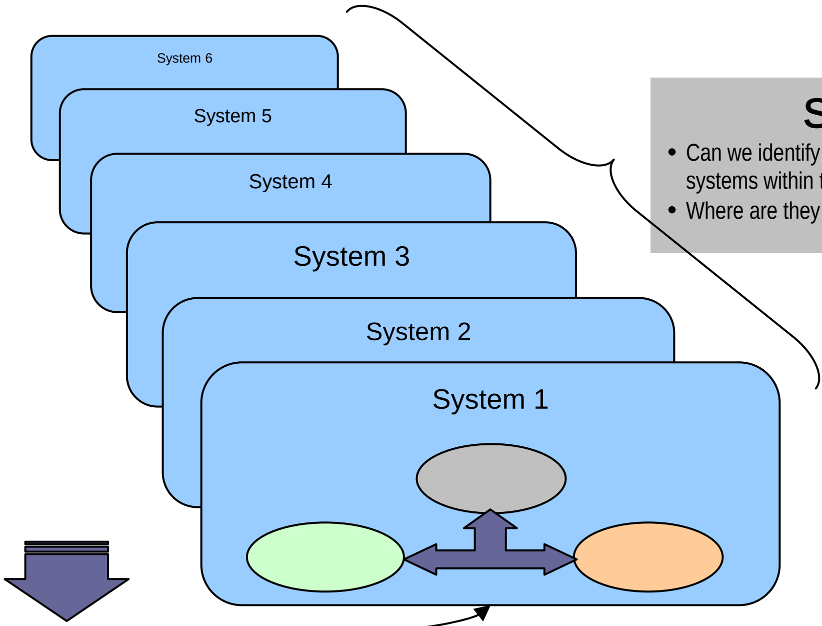
A range of resources will be available at the workshop, including a number of regional data layers and GIS capabilities to create and project relevant maps of the Region. A list of the data layers available is at Attachment C and we encourage you to bring any relevant data/tool that may be helpful.

We also encourage you to read the Chapters 2 and 3 of the report *The South-west Marine Region: Ecosystems and Key Species Groups* and Chapter 6 of the report *Geomorphology and Sedimentology of the South Western Planning Area of Australia*, as these provide excellent syntheses of available knowledge about the Region. Four brief presentations covering large scale drivers and patterns will set the regional context at the beginning of the workshop.

We seek to get from you your knowledge, which we expect to extend beyond the 'hard data' you know about. Essentially, we expect expert advice at roughly three levels: what you know (the empirical evidence); what you think you know (inferences from your data or from observations or experience that are not published, or perhaps publishable); and what you believe (your expert judgements and hypotheses about how the important features of the SW Marine Region and how they work).

Finally, it is important to recognise that the workshop is not intended to be a review or critique of the existing National Marine Bioregionalisation (see Background Paper 3). Rather, we seek to provide a layer of understanding about the system dynamics of the Region that is not captured elsewhere and that will 'overlay' the other information available (including IMCRA4 and the above reports). It might be that there is considerable confluence among the layers, but there will almost certainly also be differences that provide additional understanding about the Region. Such differences should not be seen as deficiencies in one or other layer because each product will represent different sorts of information.

Attachment A – Framework for characterising the marine environment using regional knowledge and expertise.



Step 1

- Can we identify large-scale ecological systems within the Region?
- Where are they located spatially?

Step 2

- Are there sub-systems?
- What physical strata define them (e.g. depth, oceanography, geomorphology)?

Step 3

- What are the biological components of the system?
- How are they distributed within the system? How much variability is there?
- Are there biological components of particular importance for the system? Why are they important, what ecological role do they play?
- How do the components link to each other? What are the known trophic links? What are the likely trophic links?
- What are the main inputs into the system?
- What are the main outputs from the system?
- What are the key vulnerabilities in the system?
- Summing up, what are the main physical drivers? What are the main biological drivers?

Step 4

- What are the overall, main species/communities/functional groups from an ecosystem functioning perspective?
- What are the overall main spatial areas and their ecological role (hot-spots; aggregations; migration paths; high energy)?
- Where is the productivity in the Region? Overall, is the Region a net producer or a net consumer?
- How is the biomass distributed in the Region (spatially/bathymetrically/among functional groups)?
- What is common to all systems? What are the main differences?
- How is biodiversity distributed in the Region (spatially/ in association with specific features…)?

Step 5

- Where are the important areas of uncertainty associated with characterisations?
- What aspects of the Region do we have empirical evidence for?
- So we appear to have not picked up on any important projects?
- Are there any important projects we need to know about that will have outputs between 2006 and 2008?
- Are there important studies for the Region in the pipeline?
- What aspects of the Region do we have empirical evidence for?

Figure 1 – Proposed steps for characterising the marine environment. Each step is described by a series of questions. These are meant to illustrate the scope and focus of the discussion at each step, but are not intended to be prescriptive.

Descriptions of steps for characterising the marine environment

Step 1 – Identifying major eco-physical systems within the Region

This step starts with a map of the South-west Marine Region and requires experts in a plenary session to identify large scale ecological or physical systems that are thought to occur in the Region (see Figure 2 for an example from the South-east Marine Region).

Step 2 – Identifying eco-physical sub-systems

This step examines systems identified in step 1 to identify ecological or physical sub-systems if they are known to exist (see Figure 2 for an example from the South-east Marine Region), particularly those associated with different physical strata, such as depths (e.g. 100s – 1000s of metre depth ranges).

Step 3 – Characterising the ecological systems through conceptual modelling

This step will be undertaken in small groups, will focus on key functional groups and relationships within individual ecological systems - or their sub-systems - and will articulate conceptual models illustrating system components and their interactions. Inputs, outputs, processes, key trophic groups and key functional links are considered to be important factors in the description of each system (see Figure 2 for an example of from the South-east Marine Region).

Step 4 – Reflecting on regional-scale interactions and processes

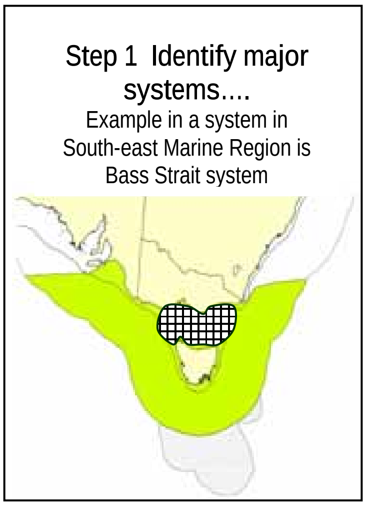
This step is about refocusing experts thinking on the large scale systems identified in Step 1 and will take place in a plenary session. The focus should be on identifying key linkages across systems and process of large scale connectivity. An important part of this step is consideration of parts of the large-scale systems that are relatively ‘internally driven’ with key processes being largely local and those transitional or boundary areas where drivers from neighbouring systems are particularly important.

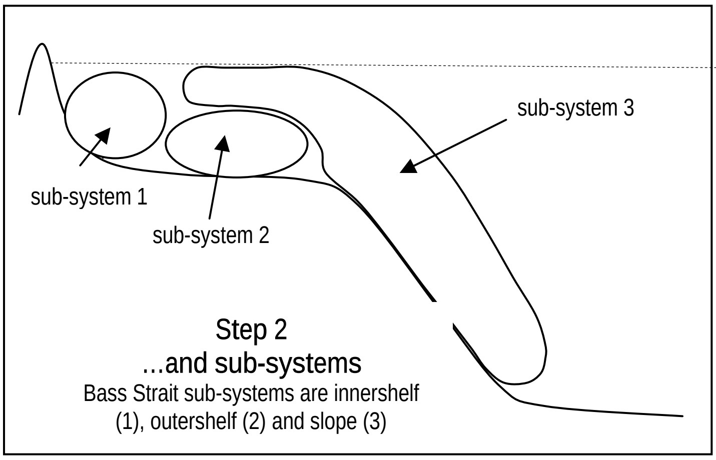
Step 5 – Understanding state of knowledge and areas of uncertainty

This step is crucial for DEW. Having gone through the first four steps and having thus built a ‘system’ picture of the Region, we need a clear statement of the levels of uncertainty associated with that picture and/or parts of it.

It is expected that reference to empirical evidence - or lack of - will be mentioned and discussed at various stages of the workshop and this step ensures that this will be captured. It is also likely that we will need to follow up with specific questions on this after the workshop.

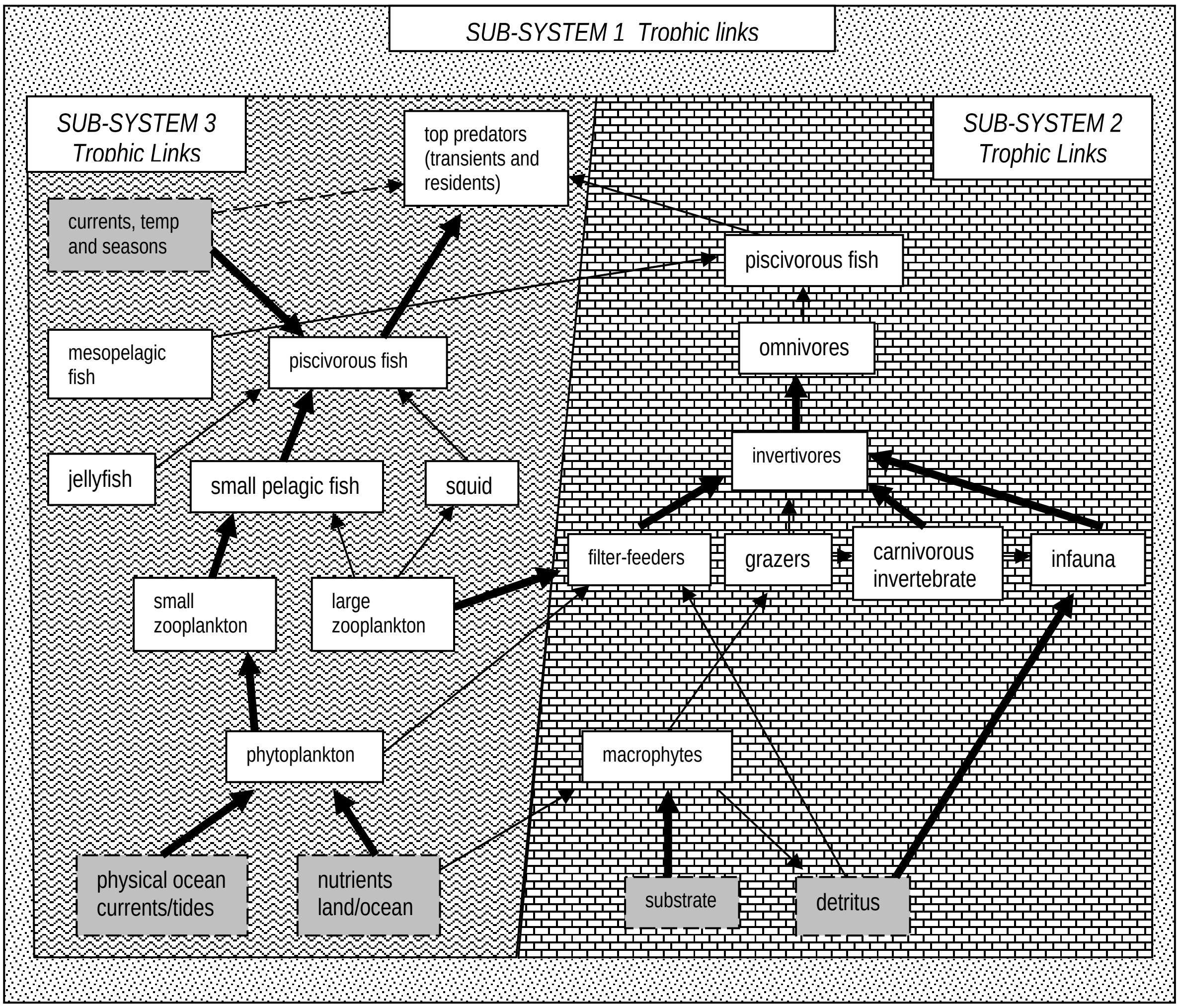
Figure 2 – An example illustrating the type of outputs resulting from some of the steps at Figure 1 when applied to the South-east Marine Region. These outputs were developed during the road-test of the approach to characterise the marine environment in Hobart August 2006.





Step 3 – Conceptual models

Outputs from this step may take different forms and may include diagrams, notes, pictures, foodwebs, digraphs, etc. Below is a diagram that was used to identify trophic groups and trophic links in the Bass Strait system. It was also used to identify differences between sub-systems identified in step 1B. Note, there was also considerable discussion and text explaining the trophic links and trophic groups.



Attachment B - Workshop Agenda

Chair: Professor Bruce Mapstone

Facilitators: Barbara Musso; Paul Hedge

Venue: Department of Fisheries at Hillarys, Northside Drive Hillarys Boat Harbour, Perth, Western Australia. Hillarys is approximately 30 minutes from the city centre.

DAY 1 – Wednesday 27 September	**Notes**	**Time**
1. Context to workshop o Welcome and workshop context o DEW Business	Plenary	9.00
2. Morning tea		10.15
3. Presentations on the Region	Plenary	10.30
4. Systems of the Region	Plenary	12.00
5. Lunch		12.30
6. Systems of the Region	Plenary	1.00
7. Identifying subsystems	Small groups	2.00
8. Major projects in the Region	Plenary	4.15
9. Afternoon tea		4.15
10. Close of day		5.00
Evening dinner for workshop participants	Provided by DEW (no alcohol provided)	6.00 for 6.30 pm
DAY 2 – Thursday 28 September	Notes	Time
1. The day ahead	Plenary	9.00
2. Charactering systems by conceptual modelling	Small groups	9.15
3. Morning tea		10.30
4. Charactering systems by conceptual modelling	Small groups	10.45
5. Lunch		12.30
6. Charactering systems by conceptual modelling	Small groups	1.00
6. Reflecting on regional-scale processes and interactions	Plenary	2.30
7. Afternoon tea		3.30
8. Understanding state of knowledge and areas of uncertainty	Plenary	3.45
9. Summary of workshop	Plenary	4.40
10. Close of workshop		5.00

Attachment C – List of data layers that will be available at the Workshop

DATA	TYPE (GIS unless marked otherwise)	SOURCE
Australian sponge distribution		NOO
Seals distribution		
Australian fur seals		John Arnould (University of Melbourne) and Roger Kirkwood (Philip Island Conservation Park)
New Zealand fur seals		Brad Page
Distribution of threatened species SE	Hard copy map	(NOO 2002)
albatross	GIS	
Birds	Hard copy maps	Birds Australia
Upwelling locations		Oceanography project
Phytoplankton distribution		Oceanography project
Primary production quarterly means.		Oceanography project
Pelagic regionalisation	**GIS**	**Nat. bioregionalisation**
Level 1b surface		
Level 1b Depth 150m		
Level 1b Depth 500m		
Level 1b Depth 1000m		
Level 1b Depth 2000m		
Level 1b Depth 5500m		
Level 2		
Level 3		
Benthic bioregionalisation	**GIS**	**National bioregionalisation**
Provincial bioregions		
Primary bathymetric units		
Biomes		
Geomorphic units		
Demersal fish provinces (slope) 2005	GIS	CSIRO
Demersal fish provinces (shelf) 1996	GIS	CSIRO
IMCRA (shelf) 1998	**GIS**	
Geological	**GIS**	**GA**
Sedimentary basins		
Ocean crust age		
Seabed facies		
Geomorphic features		
Seafloor sediment data		
Wave induced exceedance		

Tidal induced exceedance		
Bathymetry		
Seabed temperature		
Seabed salinity		
Seabed nitrate		
Seabed silicate		
Seabed oxygen		
Seabed phosphate		
Oceanography		
Sea surface height variability (m) quarterly		Oceanography project
Sea surface height annual variance		Oceanography project
Sea surface temperature (degrees celcius) quarterly		Oceanography project
Sea surface temperature annual mean		Oceanography project
Silicate surface		CARS
Silicate 150m		CARS
Silicate 500m		CARS
Silicate 1000m		CARS
Silicate 2000m		CARS
Salinity surface		CARS
Salinity 150m		CARS
Salinity 500m		CARS
Salinity 1000m		CARS
Salinity 2000m		CARS
Phosphate surface		CARS
Phosphate 150m		CARS
Phosphate 500m		CARS
Phosphate 1000m		CARS
Phosphate 2000m		CARS
Oxygen surface		CARS
Oxygen 150m		CARS
Oxygen 500m		CARS
Oxygen 1000m		CARS
Oxygen 2000m		CARS
Nitrate surface		CARS
Nitrate 150m		CARS
Nitrate 500m		CARS
Nitrate 1000m		CARS
Nitrate 2000m		CARS
Chlorophyll quarterly means		Oceanography project
Currents quarterly magnitude and direction		Oceanography project
Mixed layer depth		Oceanography project