PROPOSED

TWEED-BYRON

COMMONWEALTH MARINE RESERVE

Dailan Pugh, January 2012

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There is a parallel world to ours. It too has a volcanic mountain like Mount Warning, formed 20 million years ago as Australia drifted north over a hot spot, though it is four times as high. It too has gorges carved into the rock by the Tweed and Brunswick rivers, though rather than being 100-200 metres deep its canyons are 1,000-2,000 metres deep. While people once wandered around the head of the canyons, its atmosphere has now become so dense that they would implode. Since people left, new weird and wonderful creatures have taken over.

It is hard to fathom how this parallel world can exist with most of us only being vaguely aware of its magnificence. Even the few who study it only have a vague idea of the creatures that inhabit it. Yet humans have come to rely on its bounty, with devastating consequences.

We now have an opportunity to protect a small part of this parallel world, though only if you want to. The Commonwealth Government is now deciding which parts of its Temperate East Marine Region it will protect to establish its promised Comprehensive Adequate and Representative (CAR) marine reserve system. The region extends from Bermagui on the south coast to past Fraser Island and out to beyond Norfolk Island.

The reserve system is required to include a full range of ecosystems, reasonably reflect the biotic diversity within those ecosystems, and have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities. The evidence is that this will require 20-50% of each population and ecosystem to be fully protected from fishing.

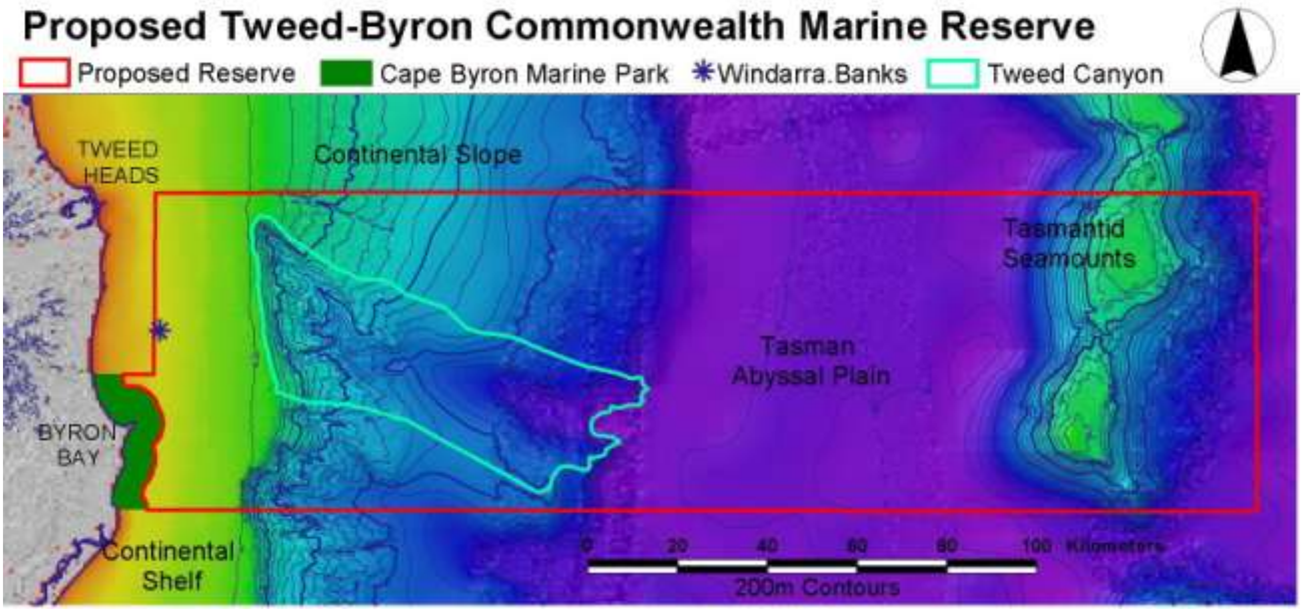
In November 2011 the Commonwealth released proposals for 25% of this region to be incorporated into marine reserves, though most reserves are still available for most forms of fishing, with only 4.3% fully protected in Marine National Park zones.

The proposed outcomes are far worse for coastal ecosystems. For the Commonwealth controlled waters of the continental shelf a mere 1.6% is proposed for reservation, with only 0.01% fully protected. Similarly for the continental slope only 8% is proposed for reservation with none fully protected. This is one of the worst outcomes in Australia. We have been duded.

Numerous ecosystems, key ecological features, biologically important areas and severely depleted species have been excluded.

The Commonwealth originally identified the Tweed Area for Further Assessment for consideration as a reserve, though dropped this without justification. Conservation groups are seeking its restoration by proposing the creation of the 15,000 km^2 Tweed-Byron Commonwealth Marine Reserve covering Commonwealth waters off the Tweed and Byron coasts. It extends from the existing NSW Cape Byron Marine Park (5.5km offshore) out for 220 km to encompass massive 4km high volcanic mountains rising from the Abyssal Plain. The proposed reserve encompasses about 1% of the Temperate East Marine Region.

The aim of this proposal is to protect a sample of waters central to the overlap between Australia's tropical and temperate species, with its own unique ecosystems, that will function as a stepping stone between proposed reserves to the north and south, and contribute to a genuine CAR marine reserve system.



Contour data from Beaman 2010.

Key features of the proposed Tweed-Byron Commonwealth Marine Reserve are:

- The continental shelf consisting of river valleys, cemented dunes, and ancestral shorelines drowned by rising seas from around 15,000 years ago, and now mostly smothered by sand and silt. Grasses and trees have been replaced by sponges and corals, birds by fish, and humans by dolphins and whales.
- The off-shore Windarra Banks reefs and pinnacles rising 30m from the continental shelf, an aggregation site for a plethora of fish, home to giant cod, kingfish and rays, and habitat of the critically endangered Grey Nurse Shark.
- The continental slope dropping from around 220m (24 km from Cape Byron) down to the 4,600m deep Abyssal Plain. The descent takes you from the world of sunlight to the black depths where animals generate their own light. From the southerly flowing tropical waters of the East Australian Current, to an underlying cool sub-Antarctic current flowing northwards over beds of sponges and deep water corals.
- The 2 km deep Tweed Canyon eaten into the continental slope by the ancestral Tweed and Brunswick Rivers. A refuge for species, an area of enhanced productivity, an aggregation site for fish and predators, and a key ecological feature.
- The 4.6-4.9 km deep Tasman Abyssal Plain, 84 km from Cape Byron, formed by seafloor spreading associated with the breakup of the ancient supercontinent of Gondwana over 50 million years ago. Little is known of its inhabitants.
- The 20 million year old volcanic mountains of Britannia 170 km from Cape Byron. Part of the Tasmantid Seamount chain rising up 4 km from the abyssal depths to within 400m of the surface. These are refuges, aggregation sites and places of speciation for unique species.

Canyons such as the Tweed and seamounts such as Britannia are biodiversity hotspots. We know that when we get around to looking properly a large proportion of the species we find will never have been seen before. These are the sites we know should be targeted for reservation.

As you descend over the edge of the continental shelf and down the slope light rapidly diminishes, by 200m photosynthesis stops and by a kilometre down light can no longer penetrate. Knowledge of fish and seafloor organisms diminishes with the light. Many species of the deep have long lives, slow reproduction and slow maturity, and thus are particularly vulnerable to over-fishing. Populations of many higher order predators, along with some targeted commercial fish, have declined by more than 90% off NSW in the last few decades. Complex seafloor communities, including sponge and deep-water coral reefs, are being systematically eliminated by trawling. These are the ecosystems and species most urgently in need of the reservation the Commonwealth is denying them.

Please show your support for marine conservation and the proposed Tweed-Byron Commonwealth Marine Reserve by emailing: Submissions.TemperateEast@environment.gov.au. On its own this proposal does not rectify the manifest deficiencies in the Commonwealth's proposed reserve network, though it is a worthwhile start.

I have consulted the following NGOs and have their express permission to indicate here that they support the recommendations of this submission:

North Coast Environment Council

The Wilderness Society – Newcastle

National Parks Association of NSW

Nature Conservation Council of NSW

Dolphin Ecology & Acoustics Project, Southern Cross University

Whales Alive

Australian Marine Conservation Society

WWF-Australia

Humane Society International

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1. THE PROPOSED TWEED-BYRON COMMONWEALTH MARINE RESERVE

All Australian Governments have committed themselves to establishing a National Representative System of Marine Protected Areas (NRSMPA) that is required to be comprehensive, adequate and representative.

This means that within each bioregion, systems of marine reserves are required to be established that include a full range of ecosystems, reasonably reflect biotic diversity within those ecosystems, and have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

In November 2011 the Commonwealth released proposals for reserves in the Temperate East Marine Region that propose 25% of the region to be incorporated into Marine Reserves, with only 4.3% in fully protected Marine National Park zones. It is apparent that the Commonwealth's proposed marine reserve system is neither comprehensive, nor adequate, nor representative. It does not satisfy the Commonwealth's own criteria.

The Commonwealth waters of the continental shelf are the most neglected with only one reserve proposed across the shelf and none of this is fully protected. The few reserves proposed across the continental slope are too small, missing key areas, avoid the upper slope, and fail to include any fully protected areas. Given that the NSW reserves are limited to shallower waters, protection of the unique ecosystems of these waters is a Commonwealth responsibility.

The extremely poor representation of ecosystems of the middle and outer continental shelf and upper continental slope has been done intentionally to avoid restrictions on trawling grounds. Many of those ecosystems excluded, and species inadequately protected, are known to be highly vulnerable to fishing, particularly trawling. Those most in need are being denied even minimal protection. With no trawling currently occurring on the continental slope off Cape Byron this is the time to protect it.

Of the 4 principal seamount clusters, separated by stretches of the abyssal plain, paralleling the coast in the Temperate East Marine Region, only the two southern clusters are proposed for some protection - one in a Marine National Park Zone and one in a Multiple Use Zone. No protection is proposed for the two likely ecologically distinct northern clusters, notably the Queensland-Britannia complex off Cape Byron.

The proposed Tweed-Byron Marine Reserve is based upon the Commonwealth's Tweed Area for Further Assessment, which was reviewed taking into account the degree to which features identified by the Commonwealth had been incorporated into existing and proposed reserves. The Commonwealth's publicly available digital data was reviewed and assessed using a Geographic Information System. This was supplemented by a literature review.

The Commonwealth identifies:

The proposed conservation objectives for reserve(s) established within the Tweed Area for Further Assessment are:

1. *representation of the Central Eastern Shelf Transition and Central Eastern provincial bioregions*

2. *protection of seafloor features (e.g. continental shelf and slope) and associated ecological processes and biodiversity across a range of depths*

3. *protection of canyons of the continental slope and shelf edge rocky reefs*

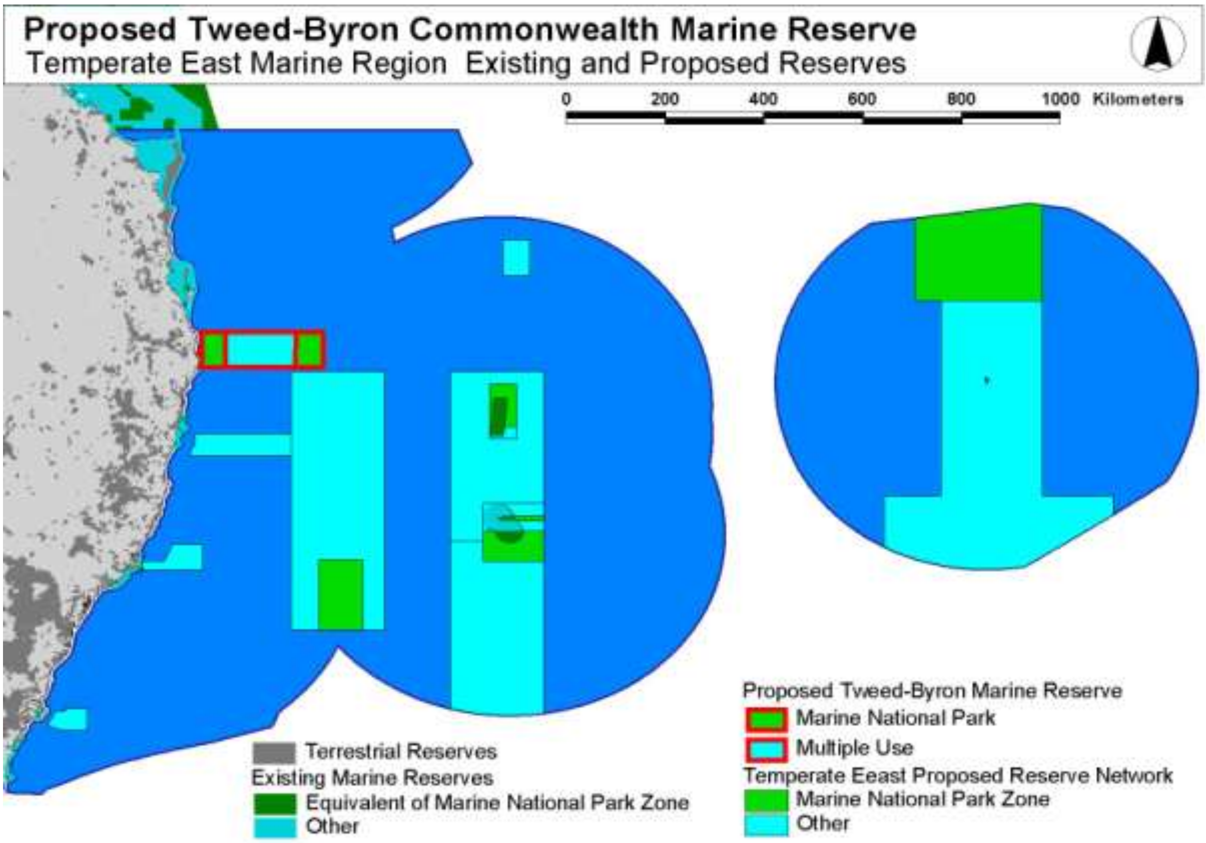
4. *protection of biological communities associated with the continental shelf, and gyres and eddies associated with East Australian Current and*

5. *maintenance of ecological connectivity between coastal waters and deeper ocean environments.*

These objectives have been applied in developing this proposal. Based on this review the area considered has been extended to the east to include a representative sample of the Tasmantid Seamounts.

The reserve system is meant to be based upon the basic goals of **representativeness** and **comprehensiveness,** which means that the reserve system should sample the biotic diversity within the full range of marine ecosystems. The finest level of comprehensive discrimination with Commonwealth data are **bathomes** that account for the depth related changes in species and ecosystems within each marine province (see Section 2). These environmental envelopes each encompass an unknown diversity of ecosystems.

The simplest measure of the third requirement, **adequacy**, is the level of protection that is applied to each targeted feature. Many marine scientists say we should be variously reserving 20-50% of each species, ecosystem and/or bioregion free from fishing (see Section 2). This is the benchmark against which to assess the adequacy of the extent each feature is proposed to be given full protection in Marine National Park zones. A precautionary approach necessitates increased reservation of poorly known features to ensure adequate protection.

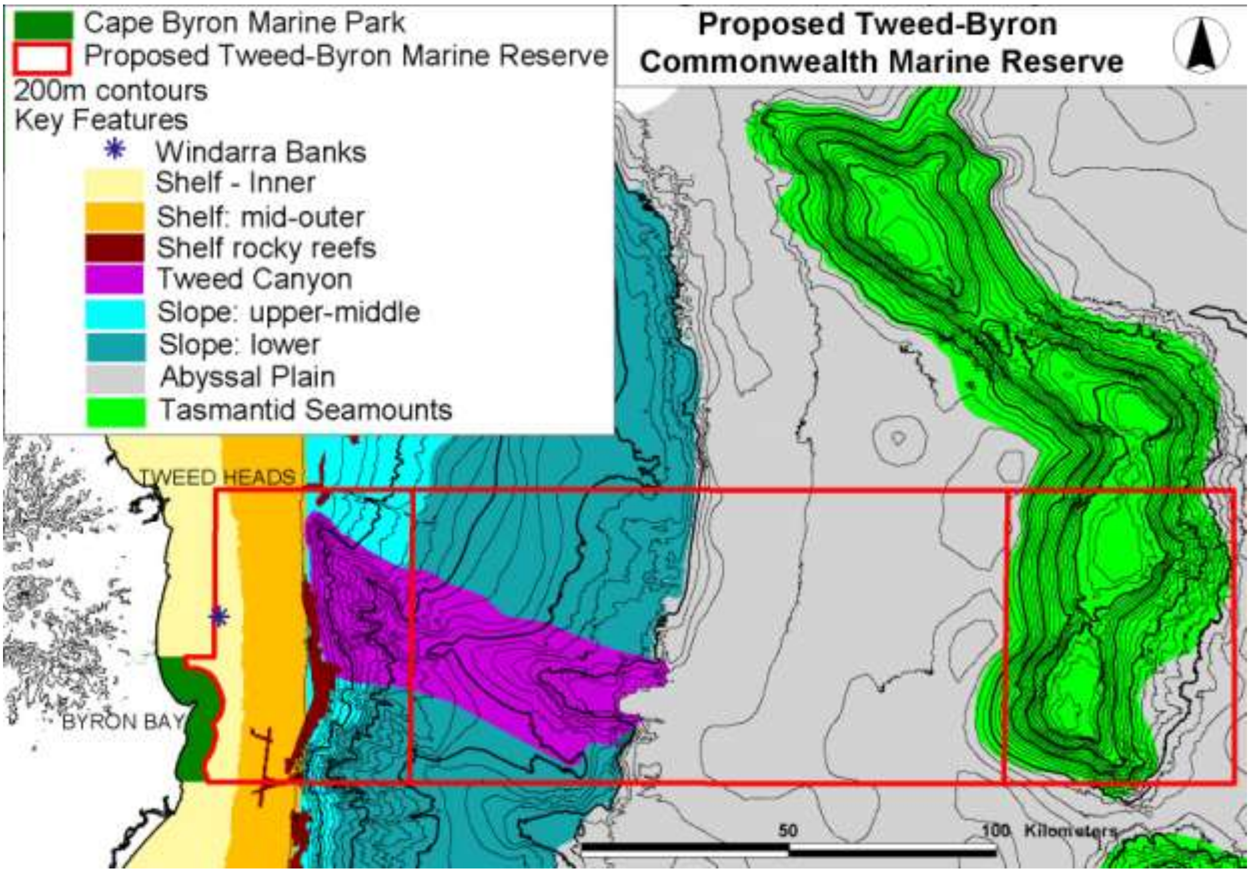


The proposed Tweed-Byron Commonwealth Marine Reserve encompasses some 15,000 km^2 of Commonwealth waters, in a transect from the Cape Byron Marine Park across the shelf, down the slope, and across the abyssal plain to dramatic seamounts. It includes two proposed Marine National Park zones, one of 3,000 km^2 centred on the mid and outer continental shelf and mid and upper continental slope, around the head of the Tweed Canyon, and one of 3,400 km^2 over two peaks associated with the Britannia Guyots.

The proposed reserve encompasses about 1% of the Temperate East Marine Region, with the proposed Marine National Park zones representing 0.4% of the region. It includes needed representation and protection for a number of vulnerable ecosystems, key ecological features, biologically important areas and severely depleted species. On its own it does not rectify the numerous deficiencies in the Commonwealth's proposed reserves, though it does represent a significant improvement.

The proposed Tweed-Byron Marine Reserve is central to a transition between tropical and temperate species from Coffs Harbour to Fraser Island, represents a sample of the distinctive latitudinal variation in species and ecosystems along the east coast, and provides an essential link to enhance connectivity between proposed reserves to the north and south. It is needed to enhance the effectiveness and functioning of the Commonwealth's proposed network of marine reserves.

Key ecological features have been identified by the Commonwealth (DSEWPC 2011) and are considered to be of regional importance for either the region's biodiversity or ecosystem function and integrity. Those of relevance to this proposal are canyons, shelf rocky reefs, and the Tasmantid Seamounts. The Commonwealth (DSEWPC 2011) has identified these as regional priorities.



Contour data from Beaman 2010.

From this review, those features identified as being in particular need of reservation and thus used to design the Tweed-Byron Marine Reserve, are:

Continental shelf - extends from the coast down to 225m depth and encompasses the realm of light where photosynthesis can occur. The waters of the inner shelf are mostly within State waters. The deeper waters (over60-70m) of the shelf are primarily the Commonwealth's responsibility. These waters are known to support distinct species and ecosystems from the shallower coastal waters and are in need of equivalent reservation. Because of the appalling ignorance of most species' requirements and status, the indiscriminate nature of trawling and the known severe impacts on a variety of species, the NSW Ocean Trawl EIS recommends the creation of substantive trawling exclusion areas. The Commonwealth is proposing to increase protection of the shelf waters it controls to 1.6%, with a mere 0.01% proposed for inclusion in Marine National Park Zones. Most shelf ecosystems, including many vulnerable to fishing, will have been totally excluded from the Commonwealth's proposed reserves. The proposed Tweed-Byron Marine Reserve will significantly enhance the protection of deeper shelf waters, though there is also a need for enhanced protection elsewhere off NSW and southern Queensland.

Continental slope - extends from the edge of the shelf at around 225m down to the Abyssal Plain at 4,600m depth. The upper and mid slopes (down to 1,500m depth) encompasses the twilight zone where food is derived from the refuse from above and many fish migrate to shallower waters to feed at night. Many of the deepwater species live long, mature late, and reproduce slowly, which makes them very vulnerable to over-fishing, particularly as breeding aggregations are often targeted. Predators on the upper slope have declined by >90% in recent decades. Many ecosystems are highly vulnerable, particularly to trawling which is forever expanding its reach. The Commonwealth proposes including 8% of the continental slope (reducing to 6.7% of the mid and upper slope) in three reserves, all within Multiple Use Zones, with none in Marine National Park zones. This will only limit bottom fishing. None of the slopes north from Coffs Harbour are proposed for any level of protection. Many slope ecosystems, including many vulnerable to fishing, will have been totally excluded from the Commonwealth's proposed reserves. The continental slopes in the vicinity of the Tweed-Byron Marine Reserve are not currently targeted for trawling, which makes this area a high priority for conservation on the assumption that the complex and vulnerable ecosystems on the seafloor have not yet suffered extensive degradation. The proposed Tweed-Byron Marine Reserve will significantly enhance the protection of slope waters, though there is also a need for enhanced protection elsewhere, particularly off southern Queensland.

Windarra Banks (the Cod Grounds) is one of several banks of notable size on the middle shelf in the East Marine Bioregion. Its pinnacles, reefs and ledges rise 30m from the ocean floor. It is an aggregation site for fish, and is regularly visited by the critically endangered Grey Nurse Shark. It provides an oasis amongst the deeper waters for species such as tropical corals. It is a known priority area for conservation.

Tweed Canyon is one of 30 canyons that have been eroded into the continental slope and shelf from Bass Strait to the Great Barrier Reef. Canyons affect oceanic processes (such as upwellings), enhance productivity, provide a diversity of habitat niches, and are biodiversity hotspots. The Commonwealth identify them as a Key Ecological Feature that should be targeted for reservation, 17% of the area of canyons on the continental slope in the Temperate East are proposed for inclusion in reserves, though none are proposed for inclusion in National park zones, and none of those occurring over the 630km north of Coffs Harbour are proposed for protection. This proposal is designed to include the whole of the Tweed Canyon (along with part of the Richmond Canyon), with the head of the canyon in a Marine National Park Zone.

Shelf Rocky Reefs are scattered in the deeper waters of the outer shelf and upper slope throughout the region. They are likely to encompass some of the most complex and vulnerable ecosystems, changing with depth and latitude. The Commonwealth identify them as a Key Ecological Feature that should be targeted for reservation, yet are only proposing 1.8% of their extent for inclusion in reserves and none in Marine Park zones. A significant area across a range of depths is included in this proposal, though there remains a need for better representation all along the shelf and slope.

Tasmantid Seamounts are a chain of ancient undersea volcanoes in a north-south chain paralleling the coast, oases in the immense desert of the abyssal depths. The Britannia Guyots are part of a cluster off Cape Byron, rising 4,000 m from the seafloor to within 400m of the surface. Seamounts often have highly productive ecosystems, support high biodiversity, encompass unique ecosystems, act as aggregation sites, and have high levels of endemic species. They are particularly vulnerable to the effects of fishing and we still know little about them. In the Temperate East Marine Bioregion there are four major clusters of tall seamounts, with smaller ones between. The southern Barcoo and Taupo Banks are proposed by the Commonwealth for full protection in a Marine National Park zone, and the Derwent Hunter Guyot off Coffs Harbour is proposed for inclusion in a multiple use zone that prohibits trawling. No protection is proposed for the Britannia and Queensland cluster of Guyots off Cape Byron-Brisbane, or Recorder Seamount off Fraser Island. All seamounts should be permanently protected from trawling, and the proposed inclusion of most of the Britannia Guyots in a Marine National Park zone provides partial protection to this cluster, though more protection is required to the north.

Biologically important areas have also been identified by the Commonwealth (DSEWPC 2011), and are those parts of a region that are particularly important for the protection and conservation of protected species. The proposed Tweed-Byron Marine Reserve includes significant parts of priority Biologically Important Areas for three species (see Section 2.3):

Grey Nurse Shark has a distinct east coast population that is thought to comprise 500-1500 individuals and is listed as Critically Endangered. The Commonwealth's proposal is to provide limited (1-3km^2) full protection to two identified aggregation sites in Commonwealth waters, but to provide minimal protection to its overall habitat, with 8.1% of their modelled distribution in existing and proposed reserves (mostly in state waters) and 0.4% of their modelled distribution (already) included in fully protected zones.

White Shark is listed as Vulnerable and found south from Moreton Bay. The Commonwealth's proposal is to incorporate 4.8% of their modelled distribution in existing and proposed reserves, with only 0.2% of their modelled distribution (already) included in fully protected zones.

Loggerhead Turtle is near the southern limit of the distribution of both breeding and inter-breeding habitat at Tweed-Byron. NSW trawlers are not required to have turtle exclusion devices and thus represent a significant threat to this species. Given that nesting occurs on beaches the breeding habitat is within State waters. Currently no existing or proposed Commonwealth reserves include inter-nesting habitat for loggerhead turtles. 7.3% of inter-nesting habitat is included in State reserves, though only a miniscule area is actually protected from fishing.

The ongoing indiscriminate decimation of slow-growing sponge beds and deep-water corals by trawling highlights the need to act urgently to adequately protect and rehabilitate representative samples of deepwater ecosystems (see Section 4.2.2). The millions of fish and invertebrates indiscriminately slaughtered as bycatch off NSW each year, and the lack of even the most basic ecological information on most species, highlights the need for a precautionary approach (see Section 4.2.1). The dramatic decline in populations of dogsharks epitomise the plight of the range of outer shelf and upper slope predators whose populations have been reduced by >90% in recent decades and the urgent need for adequate reserves within which they can recover (see Section 4.2.4). The rapid and dramatic declines in populations of Orange Roughy and similar species on seamounts epitomise the on-going failure of regulation to manage fish stocks (Section 4.2.5).

1.1. Continental Shelf

For half of the past 300,000 years sea levels have been 70 to 120 m below its present level (Lea et al. 2002). At the peak of the last ice age (around 20,000 years ago) sea level was around 120m lower than today. So Aborigines would have once roamed the ancient beaches of the continental shelf 18 km out from the current shoreline of Cape Byron, coastlines that now lie blanketed in silt with rocky headlands turned into rocky reefs, 120m below the sea's surface.

Most of the shelf in the Region can be divided on the basis of water depth into an inner shelf (less than 60 m water depth), middle shelf (60 to 120 m) and an outer shelf (120 m to shelf break). In general, the inner shelf is relatively steep down to 60 m water depth, the middle shelf has a more gentle slope seaward and the outer shelf is a flat, near-horizontal plain. The shelf ends at the shelf break where it gives way to the steepening continental slope. The sediments are generally medium to coarse sand on the inner shelf, fine sand (with mud in limited areas) on the mid shelf and coarse sand and gravel on the outer shelf.

The inner shelf is comprised of gravel patches and bedrock reefs amongst a sandy expanse. There are dunes and ripples formed by the East Australian Current down to 70m, though its influence is felt strongly across the entire shelf and upper slopes. Carbonate sands and hardgrounds occur on the outer shelf seaward of the 75 m isobath. The hardgrounds consist of carbonate sands cemented by calcite, encrusting bryozoans, and by calcareous algae. Terraces, nick points and drowned beach barrier systems are common down to 160 m and were formed during lower sea levels. Temperate reefs are thought to occur along the shelf edge.

The distribution of species and ecosystems occurring on the shelf are primarily governed by depth, latitude and substrate (see Sections 3.1 and 4.1), meaning that most of the ecosystems occurring on the middle and outer shelf will be different to those occurring on the inner shelf. Many of these species and ecosystems are vulnerable to fishing, particularly trawling (see Section 4.2).

The Tweed is central to the temperate/tropical overlap and thus represents a distinct biota – as noted by the Commonwealth, it is "*a major tropical/temperate transition zone for benthic communities in the region*". Few tropical species are found south of Coffs Harbour and few temperate species are found north of Fraser Island (see Section 3.1). This affect can be expected to be present across the whole of the continental shelf, upper slopes and seamounts across the proposal.

The sponge fauna of the Central Eastern Shelf Transition includes around 300 collected species, of which less than a third have been named in the literature, Hooper (2007) states:

> *This area is a significant transition zone with clearly defined species changes at the larger spatial scale. Incursions of temperate and tropical species as well as a suite of other species unique to the region occur at smaller spatial scales*

The shelf waters of this proposal are important for cetaceans. During their migration humpback whales utilize the inner and mid-outer shelf - following the temperate and tropical currents. Humane Society International and WWF have identified the waters off Cape Byron as critical habitat for Humpback Whales. There have been sightings of false killer, orca and short finned pilot whales along the inner and mid-outer shelf east of Ballina. The inner and mid-outer shelf areas are also utilized by semi-resident and transient common dolphin (*Delphinus delphis*) and bottlenose dolphins (*Tursiops truncatus*). These species feed on numerous fish species, some of which are targeted by fisheries. Interactions with fisheries (both direct and indirectly) are recognized as the biggest threat to cetaceans globally and Australia is no exception to this (Harrison et al. 2009).

Windarra Banks (the Cod Grounds) is one of several banks of notable size on the middle shelf in the East Marine Bioregion. It rises from 50-60m depth to within 22-30m of the surface and is thought to be the remains of a partly-cemented drowned coastal sand bar. It is an area of pinnacles, broken reef, gutters, big ledges and drop offs famed by divers. It is a known priority area for conservation.

Windarra Banks is renowned for its variety of sharks. Grey-nurse sharks are regularly observed in winter, and it is likely to be of significance even if they do not use it for the same purposes as the shallower aggregation sites. It is an aggregation site for a large variety of fish, with giant kingfish, cod, rays and mangrove jacks. Windarra Banks are likely to be used by humpback whales as a 'rubbing rock' to remove parasites along their long migration (L.Hawkins pers.comm.).

The vast majority of ecosystems, including many vulnerable to fishing, occurring on the middle and outer shelf have been excluded from the Commonwealth's proposed reserves.

The inner shelf is mostly within state waters and thus catered for with State marine reserves. The middle shelf is mostly within Commonwealth waters, though includes some State waters to the south. The outer shelf is entirely within Commonwealth waters. The Temperate East Marine Region encompasses 45,046km^2 of Commonwealth shelf waters, of which 1.6% are proposed for inclusion in (or already in) marine reserves, with 0.01% proposed for inclusion in Marine National Park Zones. The situation is worse than indicated as the General Use Zone in the Solitary Islands Commonwealth Marine Reserve proposes no constraints on any form of fishing.

TEMPERATE EAST CONTINENTAL SHELF PROPOSED RESERVES		
	Area (km^2)	**Shelf %**
Marine National Park Zone	5	0.01
Habitat Protection Zone	37	0.08
Multiple Use Zone	559	1.24
General Use Zone	114	0.25
TOTAL	**715**	**1.59**

In the Central Eastern Shelf Transition the deeper shelf waters (>70m deep) are separated into 5 bathomes with proposed reservations of 4.6%, 1.5%, 1.6%, 2.9%, and 10.3%, with next to nothing in fully protected Marine National Park zones (see Section 2.1.1).

The proposed Tweed-Byron Marine Reserve includes 1,386km^2 of shelf waters, all of which is proposed for inclusion in Marine National Park Zones. This will significantly enhance the protection of deeper shelf waters, though there is also a need for enhanced protection elsewhere off NSW.

Other obvious starting points are establishing a link across the shelf between the proposed Clarence Commonwealth Marine Reserve (CMR) and the existing Solitary Islands Marine Park, expanding the link between the proposed Hunter CMR and Port Stephens-Great Lakes Marine Park, and linking the proposed Jervis CMR through to the Jervis Bay Marine Park. These should include substantive Marine National Park Zones.

1.2. Continental Slope

The deep sea starts beyond the shallower continental shelf and includes the slope and rise of the continental margin as well as mid-ocean ridges, seamounts and plateaus of the deep ocean floor.

The overall shape and orientation of the continental slope has been inherited from the initial rifting of the continental crust and has been modified by mass wasting and canyons eaten into the slope by rivers during periods of lower sea-levels. The continental slope is mantled with fine sediments and has a range of mass movement features, such as debris slides. It includes basement rock outcrops and hardgrounds. It extends down to 4,600m depth. The toe of the slope is affected by a major fault which has resulted in the Nerang Plateau, where the slope reaches its greatest width of 90 km within the proposed Tweed Byron Marine Reserve.

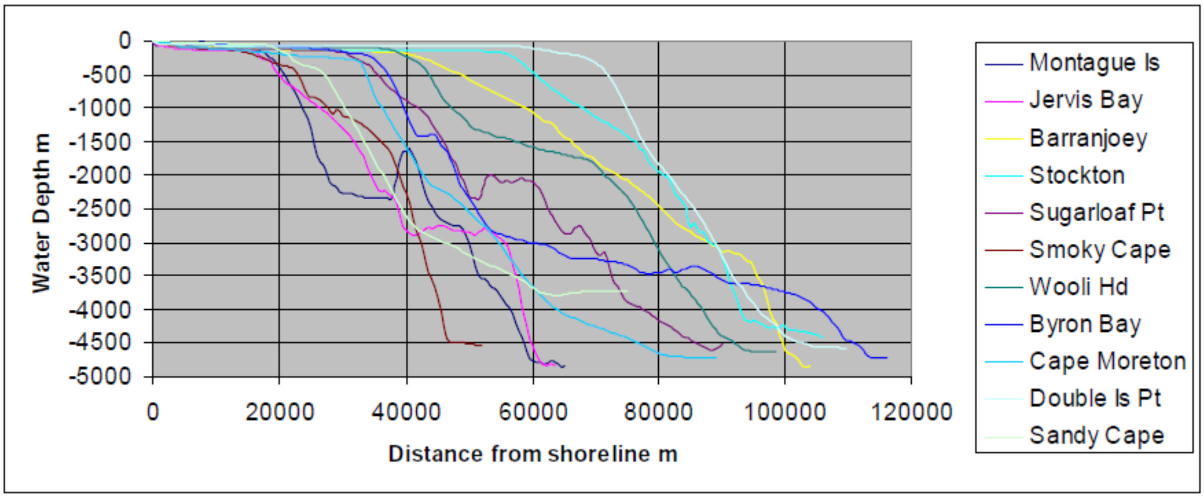
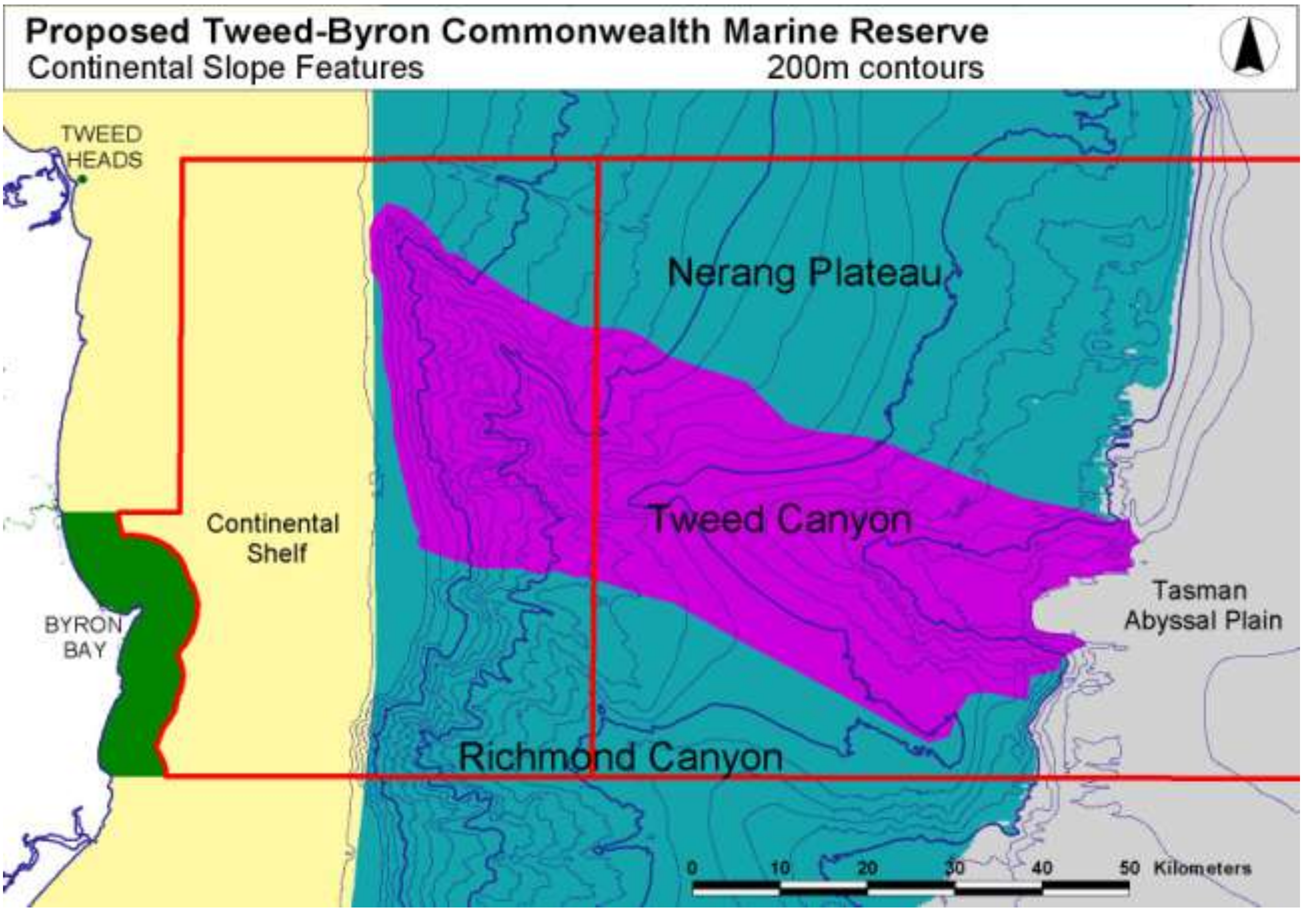


Figure. Profiles of the continental shelf in the EMR normal to the shelf break from the shoreline to the shelf break. It shows the variety of depths and widths of this shelf, note the distinctiveness of the Nerang Plateau.

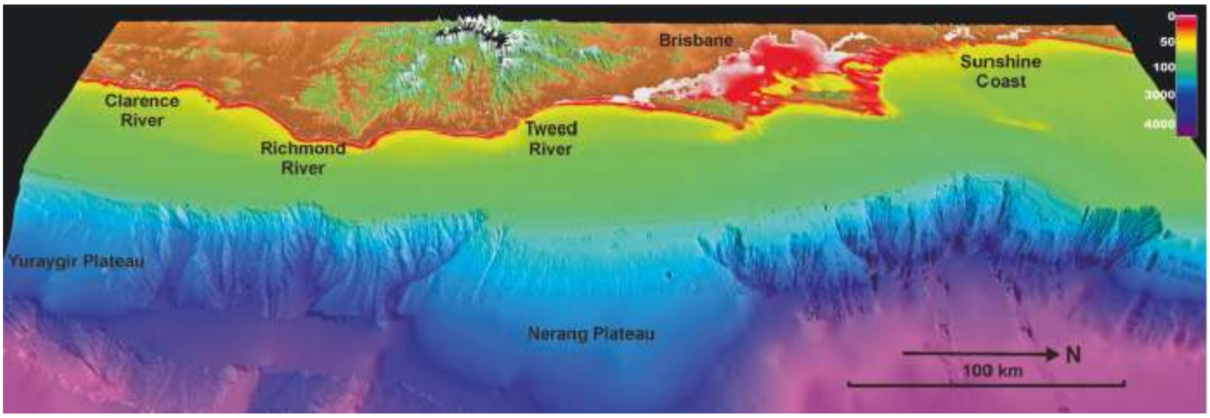
The continental slope is formed of plateaus interspersed with large erosional chasms. The Tweed is one of over 30 linear canyons which penetrate up slope to 160m water depth. Box Canyons are on the lower to middle continental slope and do not connect upslope to feeder canyons. At their seaward terminations, submarine canyons commonly empty onto the abyssal plain where sediments accumulate to form large fan deposits.



Contour data from Beaman 2010.

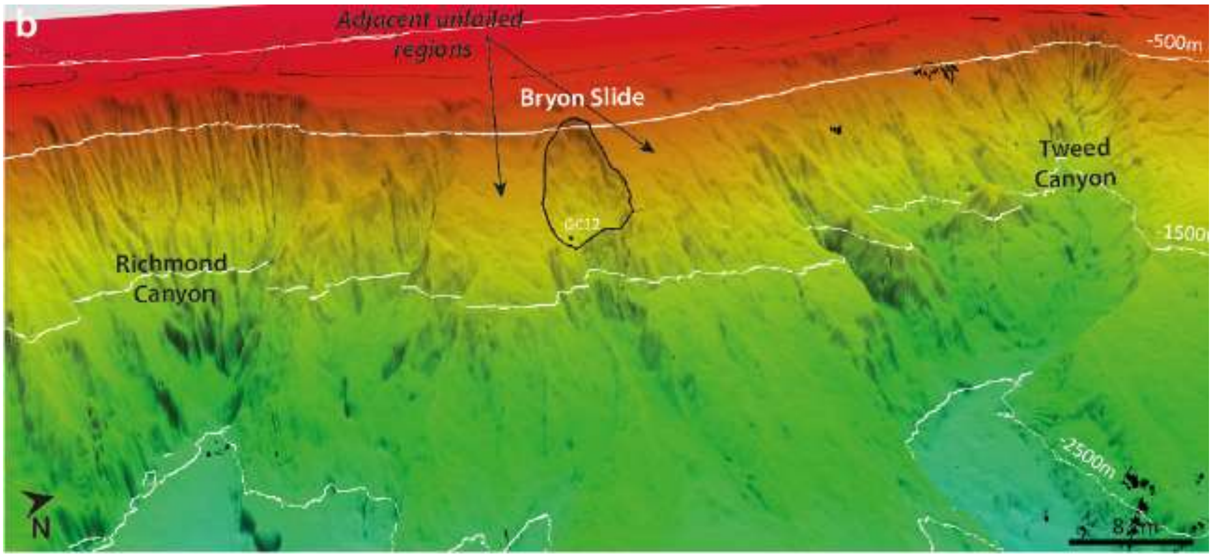
The distribution of sediments on the slope is affected by currents, rock outcrops and debris flows. At times in the past debris flows are considered to have been sufficient to generate tsunamis.

A feature of the upper slope off northern NSW is the presence of hardgrounds, iron rich nodules and phosphate nodules at water depths of 250-450 m due to the low sedimentation rate because of winnowing and erosion by the East Australian Current. Rock outcrops and hardgrounds provide specific habitats for an array of benthic organisms.



Representation of coastal shelf and slope, highlighting the alternation of marginal plateau with steep rifted margin segments dominated by canyons. The Tweed Canyon forms the left (southern) boundary of the Nerang Plateau (From Boyd et. al. 2010)

The upper slope in northern NSW is the only place where phosphate and silica sponge spicules form a significant part of the surface sediment, which indicates relatively high surface water productivity in this area and the presence of sponge reefs.



Close up showing Tweed Canyon and the 3km^2 Byron slide. Slides up to 20km^2 capable of generating large tsunamis have been found elsewhere along the slope. (From Clarke et. al. 2011).

Local upwelling occurs where canyon heads, such as the Tweed and Richmond, have cut into the upper slope. Currents probably flow up and down these canyons on a regular basis and winnow the sediment on the seabed. Canyons have significant effects on oceanic processes (i.e. upwellings and downwellings) and thus productivity, tend to have more hard surfaces that generally support higher biodiversity than sediment, and provide a greater variety of micro-habitats. Canyons can be rich in species and differ from the surrounding continental slope. An abundance of predators, such as cetaceans, are attracted to these locations (SCBD 2008). They thus are hotspots for biodiversity.

There have been strandings of two beaked whale species and pygmy sperm whales along the Tweed-Byron coastline in the last five years. These are deep-ocean dwelling cetaceans that are known to feed along deep ocean canyons and seamounts. Very little is known about their ecology and it is possible that the Tweed Canyon is inhabited by these rare species.

Uiblein et. al (2005) note:

> *Deep-sea canyons may stimulate benthic-pelagic interactions in particular through upwelling events that transport larvae of bottom-dwelling fauna into the open water or enhance the horizontal transport and trapping of vertically migrating organisms on to the shelf (Tommasa et al. 2000). Further, downslope currents associated with the tidal cycle may transport nutrients to deeper waters where they may be used by benthic, benthopelagic and "pseudoceanic" fauna in the areas of submarine canyons.*

They also found that *"Both mesopelagic and demersal fishes showed variation in species composition and spatial distribution within and among the four deep-water canyons"* and considered that:

> *Apart from serving as foraging habitat or a refuge (Yoklavich et al. 2000), canyon bottoms may also be used by demersal fishes for spawning (Uiblein et al., 1996, 1998, Murdoch et al. 1990) or egg-brooding (Drazen et al. 2003).*

The proposed Tweed-Byron Marine Reserve is based on encompassing the whole of the Tweed Canyon, though also includes a significant portion of the head of the Richmond Canyon and part of the Nerang Plateau where the slope reaches its greatest width.

At 200m depth light begins to become insufficient for photosynthesis, though twilight extends down as far as 1,000m, below which bioluminescent animals provide the only light. Our knowledge of what lives in these deeper waters declines faster than the light.

Most of the slope is below the euphotic zone where photosynthesis can occur, and bottom communities along the slope are based on detrital food webs and the rain of detritus from above. Many pelagic species move up to shallower waters to feed at night.

It is apparent that upper-level predators, such as dogsfish, sevengill sharks and skates, of the upper slopes have declined by > 90% in recent decades (Musick 2011, see section 4.2.4). The establishment of the proposed Tweed-Byron Marine Reserve will contribute significantly to the survival of a range of depleted upper slope biota, including the Endeavor Dogfish which is currently being considered for listing as nationally threatened.

Cold-water coral reefs and sponge reefs occupy the lower depths. Sponges are generally slow-growing and sensitive to changes in their environment. Their growth rate is generally two to seven centimeters per year, and they can live to be up to 6,000 years old. Twice as many species of invertebrates can be found in sponge reefs or fields than the surrounding seabed.

Cold-water coral reefs also occur in the deeper waters from the continental shelf to around 2,000 m. Unlike tropical reefs, cold-water corals do not have light-dependent symbiotic algae in their tissues, thus they depend solely on current-transported particulate organic matter and zooplankton (animal plankton) for their food. They grow slowly, at only a tenth of the growth rate of warm-water tropical corals. Some corals have been aged at 1000-6250 years old (Stocks 2004). Many of them produce calcium carbonate skeletons that resemble bushes or trees and provide habitat for associated animal communities (SCBD 2008).

One dredge offshore of Sydney in 1,600 m of water recovered a benthic community of living corals, sponges, annelids, echinoderms, brachiopods, bivalves and gastropods (Heggie *et al.* 1992).

The base of the slope and its orientation is defined by a linear fault scarp formed in the late Cretaceous as the result of rifting of the crust. A north flowing cold current apparently flows along the lower slope. A distinct erosional moat caused by the current occurs in the abyssal seabed at the base of the slope offshore of the Tweed-Byron coast. The gap between the base of slope and the Britannia Guyot is 70km, narrowing to 20km adjacent to the Queensland Guyot.

The Temperate East Marine Region encompasses 65,334 km^2 of Commonwealth slope waters, of which 5,243 km^2 (8%) is proposed for inclusion in 3 marine reserves, all within Multiple Use Zones. No reserves are proposed for the more than 600 km of slopes north from Coffs Harbour. In the Central Eastern Province the upper and mid shelf is separated into 7 bathomes with proposed reservations of 7.3-12.3%, declining to 4.1% and 4.6% for the shallowest upper slope waters (see Section 2.1.2). None of these waters are proposed for fully protected Marine National Park zones.

The proposed Tweed-Byron Marine Reserve incorporates 5,130 km^2 of slope waters, of which 1,565 km^2 is proposed for inclusion in a Marine National Park Zone. This will significantly enhance the protection of slope waters, though there is also a need for enhanced protection elsewhere. Most obviously there is a need for a further reserve to the north to sample the different ecosystems that occur on the slope there and facilitate connectivity with reserves in the Coral Sea.

1.3. Tasman Abyssal Plain

Fault lines began to form along the continental margin around 110 million years ago as the continental crust along the eastern margin of Gondwana began to breakup. The Tasman Abyssal

Plain was formed by a consequent period of sea-floor spreading and volcanism that lasted until around 52 million years ago.

The Tasman Sea Basin is roughly triangular in shape with its apex in the north and widening to the south. This shape reflects its plate tectonic origin when the faulted margins of continental crust opened from the south and new oceanic crust was emplaced.

Most of the seabed in the basin lies at depths of between 4,500 and 4,900 m and it gradually shoals to the north where the seabed is 3,500 m and 3,750 m off the northern tip of Fraser Island. The greatest depths are adjacent to the slope off NSW where the seabed is at 4,900 to 5,000 m deep, presumably eroded by the current. The basin narrows to 250 km off Tweed Heads

Abyssal plains result from the blanketing of an originally uneven surface of oceanic crust by fine-grained sediments, mainly clay and silt, mostly channelled from the continental margin along submarine canyons down into deeper water.

Features on the abyssal plain are isolated basement outcrops forming seamounts and ridges, minor fans/debris deposits/channels at the base of slope on the western margin, and elongate drift mounds on the plain itself. In general, calcareous ooze is present where the seabed is above the Calcite compensation depth (CCD) of 5,000 m and pelagic brown calcareous ‘red’ clay at greater depths where the rate of carbonate sedimentation is equal to the rate of solution and hence no pelagic carbonate survives on the seafloor.

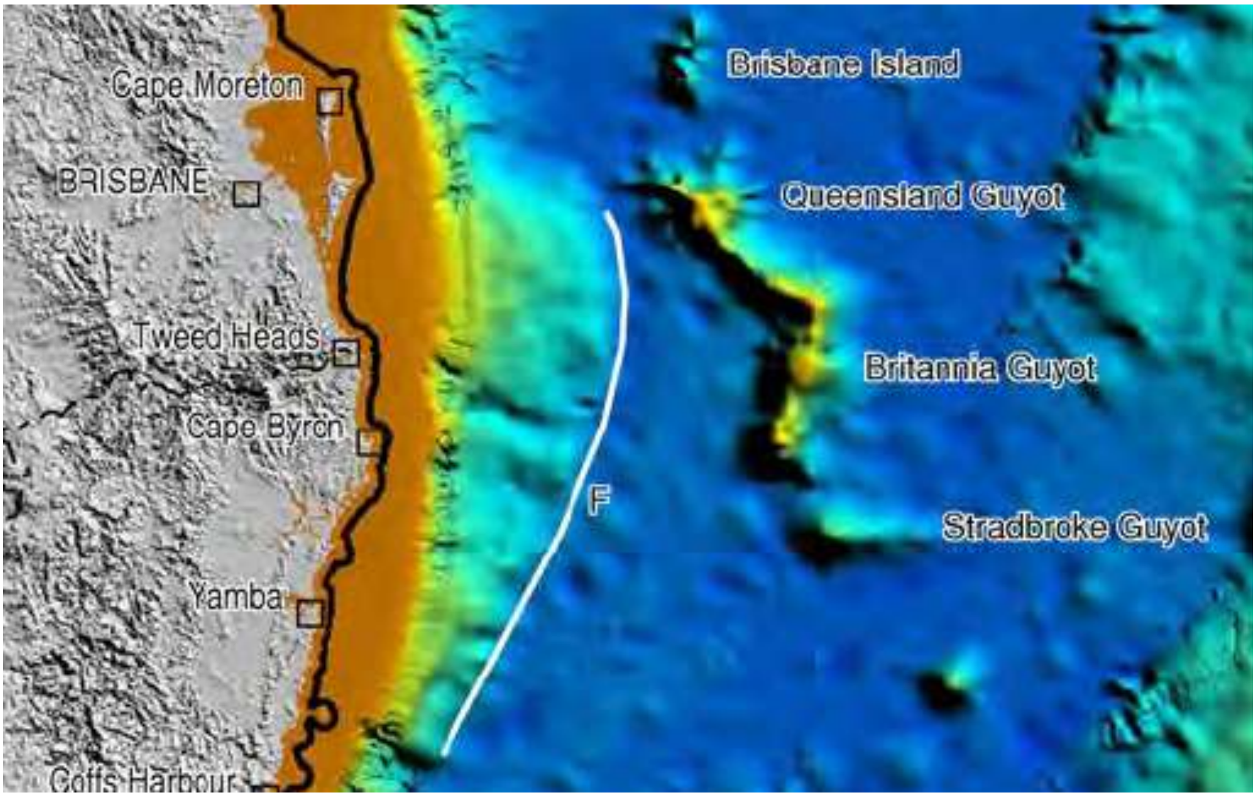


Figure . False colour map showing the geomorphology and bathymetry of the east Australian margin off Cape Byron. F = major fault scarp. Note the relationship between the location of major fracture zone in the oceanic crust and shape of the continental slope.

Little is known of the biodiversity of the Abyssal Plain. SCBD (2008) describe it generally::

> *There is a relatively high diversity of animals living in and on deep-sea sediments, including bottom-dwelling fishes, sea cucumbers, star fishes, brittle stars, anemones, glass sponges,*

sea pens, stalked barnacles, mollusks, worms and small crustaceans. However, despite the large number of rare animals, a few species make up the individuals in deep-sea samples. The most diverse species are macrofauna, small animals of up to 1mm in size.

With current technology fishing is limited to depths of less than 2,000-3,000 m there is no immediate direct fishing threat. Though increasing acidification due to excess atmospheric Carbon Dioxide is a growing threat.

1.4. Tasmantid Seamount chain

Since seafloor spreading ceased the region has been moving north at around 7 cm a year as part of the Australian plate. During this time three hot spots have resulted in north south volcanic mountain chains. The most westerly affected the east coast of Australia, with the Focal Peak, Mount Warning and Ebor volcanos being testimony to this northward passage over an underlying hotspot. The central hotspot formed the Tasmantid Seamount Chain; a series of extinct volcanoes down the centre of the abyssal plain, known as seamounts. The eastern hotspot formed Lord Howe Island.

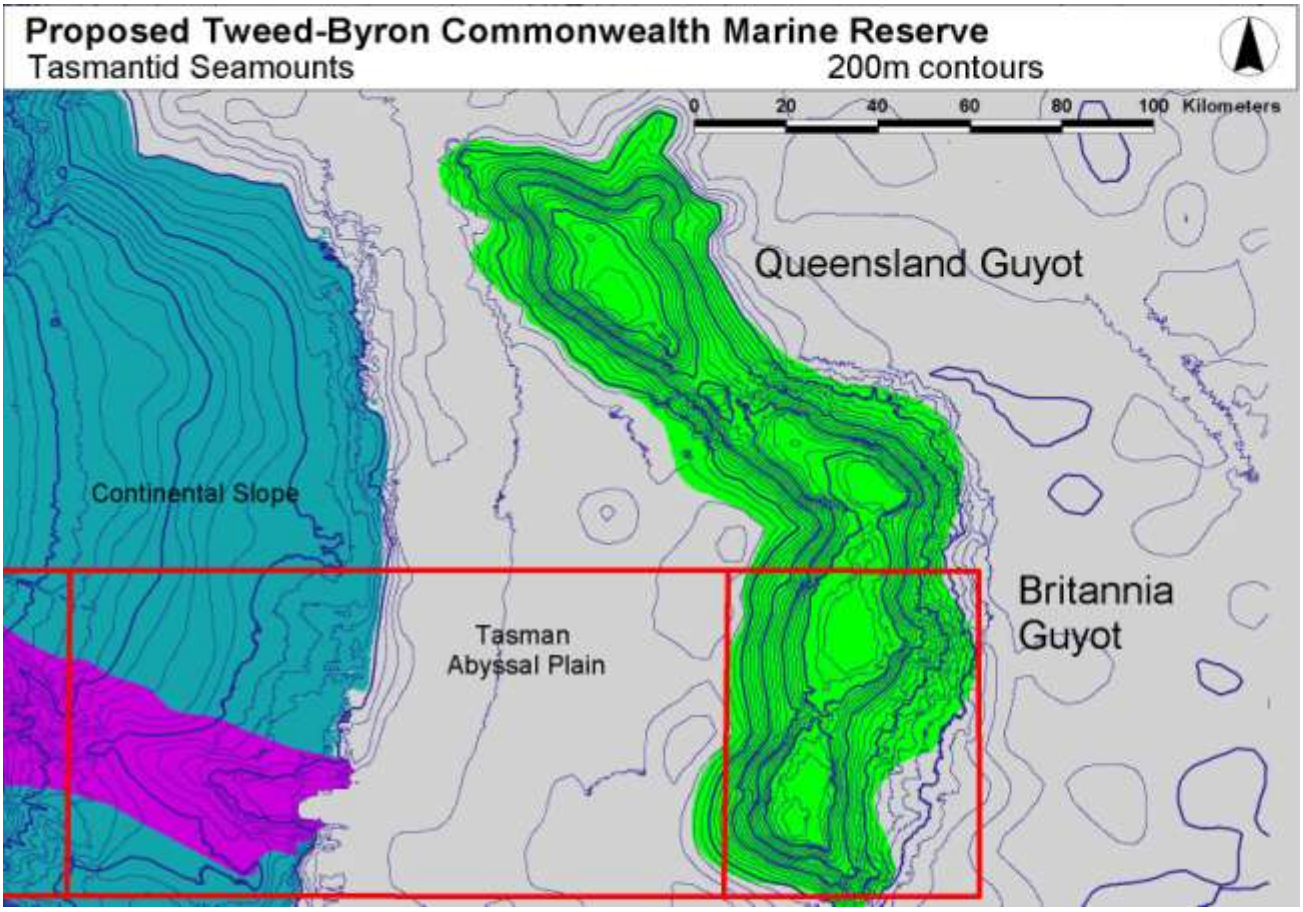
The ages of the volcanoes get progressively older to the north, confirming that they were formed as the crust moved over a hot spot in the mantle. As one seamount is carried away from the hotspot another forms in its place, meaning that the oldest seamounts are furthest away from the hotspot. Britannia and Queensland Guyots are part of a cluster off Cape Byron. The Queensland Guyot has been dated at 21-24 million years old and the Britannia Guyot as 17-21 million years old (Johnson1989).

In the Temperate East Marine Region there are four major clusters of tall seamounts, with smaller ones between. Their north-south orientation and separation ensures a high level of variation between clusters.

Those volcanoes that reached the surface have had their peaks eroded flat by waves. Submerged seamounts that are flat topped are called guyots.

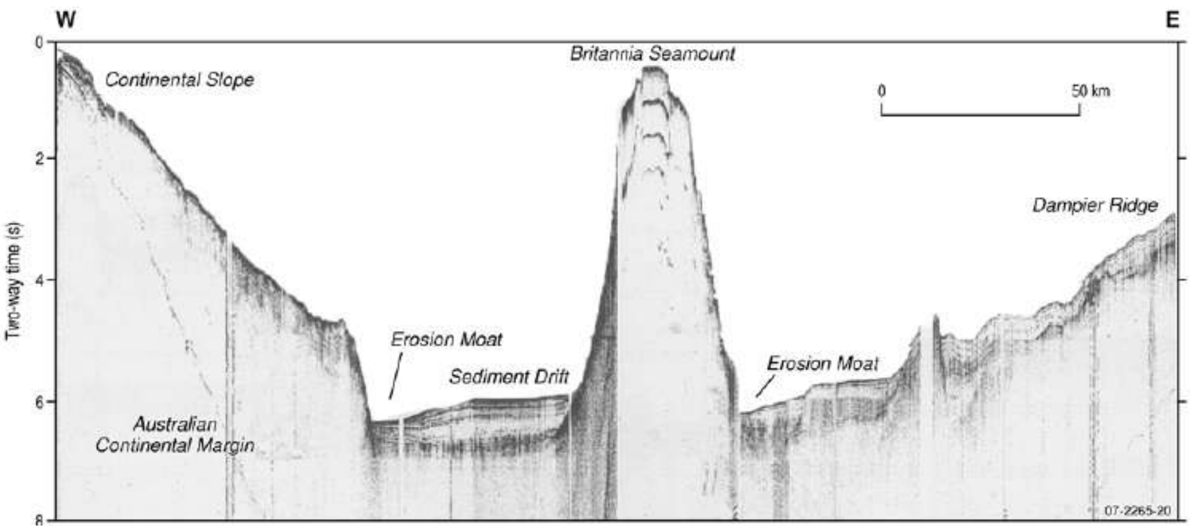
Britannia and Queensland Guyots have remarkably flat summits at a depth of around 600-400m. These are believed to be wave-eroded platforms formed on coral-capped volcanic seamounts during Pleistocene low sea-level that have since been drowned by rising sea-levels and subsidence. The slopes of the seamounts consist of rugged rock outcrops and boulders and blocks with only a relatively thin drape of sediment cover. The seamounts shed sediment to the adjacent seabed to form an apron at their base. The Britannia Guyot has a base 40 km across and rises from a depth of 4,400m to depths of 600-390m.

What are believed to be strong southerly flowing currents on the abyssal plain have eroded a moat on the eastern side of these seamounts. Strong northerly currents have apparently done the same to the base of the continental slope.



Contour data from Beaman 2010.

A large depositional drift, known as the Kennedy Drift, represents a massive piling up of sediments between 100 and 300 m high and 30 to 50 km wide, extending for 600 km to the south from the Britannia Seamount



Seamounts are often highly productive ecosystems that can support high biodiversity and special biological communities, including cold-water coral reefs, as well as abundant fisheries resources. Seamounts often have high levels of endemic species.

From her worldwide study of seamounts Stocks (2004) concluded:

> *The data clearly indicate that seamount communities differ from those found in other deep-sea habitats. Filter-feeding corals, anemones, sponges, and feather stars are common on hard-bottomed seamounts, compared to the deposit-feeding species found most often in the muddy deep sea. The total abundance of life is generally high, leading to descriptions of seamounts as 'underwater oases'. On almost every seamount that has been studied, new species have been found, leading to the conclusion that many species may be endemic to just one or a few seamounts. Extremely long-lived and slow-growing species have also been discovered on seamounts, representing some of the oldest animals known on earth. These same qualities also make seamount communities extremely vulnerable to fishing pressure.*

Seamounts can interrupt the flow of water and affect water circulation in their vicinity. Upwellings are associated with seamounts and the resultant redistribution of nutrients, oxygen and planktons make them zones of high productivity.

The rocky substrates that characterize seamounts commonly support benthic communities dominated by suspension feeders such as corals, sea fans and sponges. This lead Stocks (2004) to state *"seamounts have been likened to underwater gardens because of the branching, tree-like and flower-like corals and sponges that cover many of them"*.

Extensive cold-water coral reefs and assemblages are found associated with seamounts in the waters off Australia and New Zealand. Cold-water coral reefs are associated with rich and diverse assemblages of marine life and are home to thousands of other species, in particular animals like sponges, polychaetes (bristle worms), crustaceans (crabs, lobsters), echinoderms (starfish, sea urchins, brittle stars, feather stars), bryozoans (sea moss) and fish (SCBD 2008).

The Secretariat of the Convention on Biological Diversity (SCBD 2008) summarise the findings of Koslow *et. al. (*2001), stating:

> *Many seamounts may support a large number of endemic species. Studies on seamounts off Southern Tasmania found that 60% of near-bottom fish species caught had not been previously recorded in the Australian ichthyofauna, or were undescribed. This indicates a specialized fauna restricted to the seamounts, probably containing many endemic species. Number of fish species appeared to diminish both on the deepest seamounts and on the most heavily fished seamounts. Invertebrate samples taken in the same area found that 26 to 44% might be new to science, and 35% appeared to be restricted to the seamount habitat. Approximately 48% were apparently endemic to the region. Dense and diverse invertebrate communities are found on Tasmanian seamounts dominated by suspension feeders, including reef-forming and gorgonian corals, hydroids, and sponges. Twenty four to 43% of these species are new to science, and 16 to 33% are endemic to the seamount environment.*
> …
> *Seamounts may play an important role in understanding patterns of marine biogeography, as hot-spots for the evolution of new species, refuges for ancient species, and stepping-stones for species to spread across ocean basins.*

Richer de Forges *et. al.* (2000) state:

> *Here we report the discovery of more than 850 macro- and megafaunal species from seamounts in the Tasman Sea and southeast Coral Sea, of which 29-34% are new to science and potential seamount endemics. Low species overlap between seamounts in different portions of the region indicates that the seamounts in clusters or along ridge systems function as 'island groups' or 'chains,' leading to highly localized species distributions and apparent speciation between groups or ridge systems that is exceptional for the deep sea.*

Sampling (NORFANZ 2006) in the east of this bioregion from 200m to 1.2 km depth around Lord Howe and Norfolk Islands found that species richness is relatively high, with 103 species of macro-invertebrates and 29 fish, so far identified, new to science. There was high variability between sites and apparent highly localised distributions of some species, with two-thirds of macro-invertebrates and almost half the fish species only recorded at single sites.

Richer de Forges (1993) reports on crabs sampled from a number of guyots, including Britannia, identifying 11 species, of which 5 were new species (including one from Britannia), he notes:

> *Their small size and the huge oceanic distances which separate them make these guyots into oases of bathyal fauna in the middle of an immense desert of abyssal depths.*

There is a consistent variation in seamount fauna with latitude off the east coast of Australia (Richer de Forges 1993, Tracey et. al. 2005, NORFANZ 2006), emphasising the need to reserve seamounts throughout their latitudinal range.

Tracey et. al. (2005) found that there could be significant changes in species composition within a single seamount complex, noting:

> *Of the 36 species recorded, five (13%) were caught on every seamount, a further 18 (50%) occurred on three to five seamounts, and six (16%) 'rarer' species occurred on only one seamount.*

In relation to the seamounts within this proposal, DEWHA (2007) identify that they differ from those to the north in the Kenn Transition, and that:

> *There is limited information available on the biota of these seamounts, although what is known suggests that the biota here is different to that found in the nearby Elizabeth-Middleton Reefs area to the east.*

Richer de Forges (1992) considers

> *Although very close to the Chesterfield Islands (2100 km), and to New Caledonia (2700 km), the Britannia guyot seems to possess a particular benthic fauna.*

Gianni (2005) identifies the need for:

> *immediate protection of seamounts, deepwater corals and other biodiversity hotspots from bottom trawling on the high seas to prevent further serial depletion of deepwater fish stocks and damage to the biodiversity of these vulnerable areas.*

The Tasmantid Seamounts are currently covered by the East Coast Deepwater Trawl Exclusion Zone, though this does not negate the need for full and permanent protection. Currently only one of the seamount clusters is covered by the Barcoo and Taupo Seamounts Closure where all fishing is prohibited.

Of the four major clusters of seamounts in the Temperate East Marine Bioregion, the southern Barcoo and Taupo Banks are proposed by the Commonwealth for full protection in a Marine National Park zone and the Derwent Hunter Guyot off Coffs Harbour is proposed for inclusion in a multiple use zone that prohibits bottom trawling. No protection is proposed for the Britannia and Queensland Guyots off Cape Byron-Brisbane, or the Recorder Seamount off Fraser Island. Both should be permanently protected from trawling, and the proposed inclusion of Britannia Guyot in a Marine National Park zone provides partial protection to this cluster, though further reservation to the north is still required.

2. MARINE BIOREGIONAL CONSIDERATIONS

All Australian Governments have committed themselves to establishing a National Representative System of Marine Protected Areas (NRSMPA) that is required to be comprehensive, adequate and representative. Put simply this means that within each bioregion, systems of Marine Protected Areas are required to be established that include a full range of ecosystems, reasonably reflect biotic diversity within those ecosystems, and have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

The Temperate East Marine Region covers 1,466,792 square kilometres of Commonwealth waters.

ANZECC (1998b) state that:

> ***The primary goal of the NRSMPA is to establish and manage a comprehensive, adequate and representative system of MPAs to contribute to the long-term ecological viability of marine and estuarine systems, to maintain ecological processes and systems, and to protect Australia's biological diversity at all levels.***

These three basic criteria of comprehensive, adequate and representative are defined as (ANZECC 1998b):

- ***Comprehensiveness:*** *The NRSMPA will include the full range of ecosystems recognised at an appropriate scale within and across each bioregion.*

- **Adequacy:** The NRSMPA will have the required level of reservation to ensure the ecological viability and integrity of populations, species and communities.

- ***Representativeness:*** *Those marine areas that are selected for inclusion in MPAs should reasonably reflect the biotic diversity of the marine ecosystems from which they derive.*

This process was taken further by the Task Force on Marine Protected Areas (TFMPA 1999) which established procedures for assessing comprehensiveness, adequacy and representativeness. For the establishment of MPAs the application requirements are given as:

> **Comprehensive:** *"Define and map the type, extent and location of marine ecosystems, habitats and communities at a suitable scale",* and *"Select an example of each ecosystem, habitat and community (i.e. a comprehensive set) to be included in the NRSMPA".*
>
> **Adequate:** *"Determine whether the 'proportion' of the ecosystem selected for the MPA is going to be adequate to ensure that the natural processes will persist through time. That is, how much of each ecosystem should be included in a protected area system in order to provide ecological viability and integrity of population, communities and species"*, and *"Factors to consider include reserve shape and size, population dynamics, reserve type or level of protection within the MPA as well as the management regimes in the surrounding area, replication of the ecosystem type and natural heterogeneity of the ecosystem".*
>
> **Representative:** "*Include examples of the variety of marine biodiversity at all levels within ecosystems (for example genetic, species, habitat diversity), as well as rare and threatened ecological communities/species and atypical areas (e.g. Spawning areas, nursery sites or breeding locations)".*

The ANZECC Task Force on Marine Protected Areas (TFMPA 2000) note:

> *For the NRSMPA comprehensiveness and adequacy are understood and applied at the scales of bioregions, ecosystems and habitats.*
>
> *Representativeness is applied at the finer scales of communities and individuals/species.*

DSEWPC (2011b) give more simplistic goals for implementation:

> ***Goals and Principles for the establishment of the NRSMPA in Commonwealth waters***
>
> ***Goal 1—****Each provincial bioregion occurring in the marine region should be represented at least once in the marine reserve network. Priority will be given to provincial bioregions not already represented in the National Representative System.*
>
> ***Goal 2****—The marine reserve network should cover all depth ranges occurring in the region or other gradients in light penetration in waters over the continental shelf.*
>
> ***Goal 3****—The marine reserve network should seek to include examples of benthic/demersal biological features (for example, habitats, communities, sub-regional ecosystems, particularly those with high biodiversity value, species richness and endemism) known to occur in the marine region at a broad sub-provincial (greater than hundreds of kilometres) scale.*
>
> ***Goal 4****—The marine reserve network should include all types of seafloor features. There are 21 seafloor types across the entire Exclusive Economic Zone. Some provincial bioregions will be characterised by the presence of a certain subset of features, such as continental slope or seamounts.*

In practice the Commonwealth relies upon a hierarchical classification scheme in lieu of ecosystems. The scheme is largely based upon provincial bioregions determined by modelling the distributions of fish species from the Australian continental shelf and slope. For application these bioregions are meant to be considered at lower levels of discrimination for design of the reserve network, though this does not appear to have been done in the Temperate East Marine Region.

Last *et. al.* (2010) identify 9 lower levels of discrimination:

> *The classification consists of 10 nested levels within realms, of which the first seven are primarily spatially nested and ecosystem based, and the lowest levels represent units of taxonomic inheritance: 1 – provinces, 2 – bathomes, 3 – geomorphological units, 4 – primary biotopes, 5 – secondary biotopes, 6 – biological facies, 7 – micro-communities, 8 – species, 9 – populations, and 10 – genes.*

Last *et. al.* (2010) identify the second level as bathomes, which are *"finerscale subdivisions of provinces that are characterised primarily by the bathymetric distribution of the biota ... The governing factors at this level are temporally evolving, depth-related processes (e.g., depth-layering of water masses), contemporaneous physiological constraints on species depth distributions, and depth-related differentiation in habitat distribution defined by geophysical constraints ...".* Last *et. al.* (2010) note:

> *Bathomes are important large-scale units of marine biodiversity because the composition and structure of their assemblages differ markedly within a province, and elements of the same bathome typically differ between provinces.*

Last *et. al.* (2010) identify the third level as comprising the differentiation within bathomes based on *geomorphological units,* noting:

> *Geomorphological units are mappable structures, which are usually easily identifiable from each other, and are assumed to be surrogates for distinctive biological assemblages responding to ecological niches provided by aspects of their physical environment.*
>
> …

In the Australian context, accurately identifying and mapping geomorphological units in each bathome of each province was found to be a critical initial step for identifying key elements of the region's biodiversity. This process identifies large-scale habitat diversity and its distribution which is ultimately essential for the protection of habitat specific biota.

Last *et. al.* (2010) next identify differentiation based on *primary biotopes (i.e.* soft, hard and mixed substrates)*,* then *secondary biotopes (i.e.* igneous, calcareous and sedimentary bedrock, silts, mud, sands, and gravels), before the identification of *biological facies, which* are mappable units characterised by groups or particular species of seagrasses, corals, sponges, or other macro-biotic groups. Facies are effectively the ecosystem surrogates which are meant to be the building blocks of the reserve system. Last *et. al.* (2010) note:

Knowledge of the distribution of facies in a bioregion is important in setting research, management and conservation priorities ... The identification of rare and threatened habitat at the facies-level is critical to the MPA selection process where protection of biodiversity is a major outcome.

Last *et. al.* (2010) note:

The characterisation of provincial (Level 1) and bathomic (Level 2) structure is a critical first step in biodiversity delineation at continental-scales. ... Non-representation of any of these bathomes for BRMP could result in the serious omission of potentially vulnerable stenobathic species from MPA protection or other management measures.

Last *et. al.* warn *"the approach fails when the hierarchical nature of levels is ignored; jumping erratically between levels can result in the inadvertent omission of elements of the biota"*.

Proposed Marine Reserves in Commonwealth waters of the Temperate East Marine Region (km^2)

NAME	Marine National Park Zone	Habitat Protection Zone	Recreational Use Zone	Special Purpose Zone	Multiple Use Zone	General Use Zone	TOTALS
Norfolk CMR	41661				117262		158923
Lord Howe CMR	10941	50584	1170	4683	42760		110139
Gifford CMR		3580					3580
Tasmantid CMR	10634				73712		84346
Clarence CMR					7714		7714
Solitary Islands MR	1	37				114	152
Cod Grounds CMR	4						4
Hunter CMR					3782		3782
Jervis CMR					2474		2474
Total Area	63241	54201	1170	4683	247704	114	371114
% region	4.3%	3.7%	0.08%	0.3%	16.9%	0.01%	25.3%

The Commonwealth is proposing reserves encompassing 25.3% of the Temperate East Marine Region, though only 4.3% of the region is proposed for inclusion in fully protected Marine National Park Zones.

This is one of the worst outcomes for Australian waters.

Marine Reserve proposals for Commonwealth Waters

Marine Region	% of region in and proposed for Reserves	% of region in and proposed for National Park zone
South East	24.3%	9.7%
Temperate East	25.3%	4.3%
Coral Sea	100%	51%
North	19.4%	3%
North West	35.3%	11.6%
South West	40%	21%

Note that the South-east is for existing reserves.

By its own admission DSEWPC (2011b) fail to achieve its own goals, of the 155 primary conservation features identified by the Commonwealth only 109 are represented in reserves, and only 49 are represented in multiple reserves. DSEWPC (2011b) state:

The Temperate East Commonwealth Marine Reserves Network proposal achieves the four Goals by representing:

- *seven of the 10 provincial bioregions in the Temperate East Marine Region (Goal 1—Each **provincial bioregion** occurring in the marine region should be represented at least once in the marine reserve network)*
- *seventy-three of 109 depth ranges within provincial bioregions (Goal 2—The marine reserve network should cover all **depth ranges** (15–6000 m) occurring in the region or other gradients in light penetration in waters over the continental shelf.)*
- *each of the key ecological features of the region relevant to Goal 35, three of four meso-scale bioregions, and five of nine biological seascapes. (Goal 3—The marine reserve network should seek to include examples of benthic/demersal biological features known to occur in the marine region at a broad sub-provincial (greater than hundreds of kilometres) scale*
- *fifteen of 17 seafloor features found in the region (Goal 4—The marine reserve network should include all **types of seafloor** features).*

Each of the broad scale surrogates utilised by the Commonwealth will encompass a diversity of ecosystems. So the omission of any surrogates will result in the omission of numbers of ecosystems. Even where these surrogates achieve minimal representation, but don't encompass the likely variation within the surrogate, this will mean that some of the ecosystems within that surrogate are likely to be excluded. So, by the Commonwealth's own admission their proposals do not include a full range of ecosystems or reasonably reflect biotic diversity within those ecosystems, it is therefore by definition neither comprehensive nor representative.

The Commonwealth makes no attempt to assess the adequacy of their proposed reserves. It is obvious that they have not provided the required level of reservation to ensure the ecological viability and integrity of populations, species and communities in most areas. Their proposal is far from adequate.

The available evidence suggests that a goal of including from 20% to 50% of each species, habitat, ecosystem, and bioregion in fully protected reserves is required to begin to reasonably sample the range of biodiversity, establish a hedge against species loss and provide a reasonable basis for fisheries management. This is the conclusion reached by many scientists and scientific groups who have assessed the issue.

In January 1998 in a statement entitled '*Troubled Waters: A Call to Action*' more than 1,600 marine scientists and conservation biologists from 65 countries called upon the world's citizens and governments *"to recognize that the living sea is in trouble and to take decisive action".* One of Trouble Waters' recommendations was to *"Increase the number and effectiveness of marine protected areas so that 20% of Exclusive Economic Zones and the High Seas are protected from threats by the Year 2020".*

America's National Research Council's Ocean Studies Board (NRC 1999) assessment of marine fisheries concluded:

> *Current theory and experience make clear that marine protected areas must be established over a significant portion of the fishing grounds to have significant benefits. Recent calls for protecting 20 percent of potential fishing areas provide a worthwhile reference point for future consideration, and emphasize the importance of greatly expanding the areas currently protected.*

Participants in the Marine Cross-Cutting Theme at the IUCN's Vth World Parks Congress, in Durban, South Africa (8-17 September 2003), called on the international community as a whole to:

> *1. Establish by 2012 a global system of effectively managed, representative networks of marine and coastal protected areas, consistent with international law and based on scientific information, that:*
>
> *a. Greatly increases the marine and coastal area managed in marine protected areas by 2012; these networks should be extensive and include strictly protected areas that amount to at least 20-30% of each habitat, and contribute to a global target for healthy and productive oceans;*

The Great Barrier Reef Marine Parks Authority's independent Scientific Steering Committee (Stewart 2002) noted:

> *"the protection of 20 - 40% of any fished grounds in no-take areas offers some fisheries the opportunity for better management, and permits no-take areas to maintain more natural population levels of harvested species and, consequently, more natural communities as a whole"*

For the National Representative System of Marine Protected Areas (NRSMPA) The Ecology Centre (2009) recommends:

> *1.4.1. **Individual conservation features** should all be represented in high protection zones at a **minimum** of 30% as a proportion of their distribution within each bioregion, although greater proportional representation within high protection zones will be required if only high level or indirect surrogates for biodiversity are used (Ward et al 1999, Airame et al 2003).*
> *…*
>
> *1.4.5 Where a physical structure/feature is incorporated into the MPA, the whole feature should be included.*
>
> *1.4.6 The final MPA network should consist of a minimum of 30% of the area of each bioregion.*

Musick (2011) notes that previous scientific recommendations were that 20-50% of the total of slope dogfish habitat should be closed to fishing off NSW and south-east Australia, stating that "*a reasonable goal for establishment of dogfish protected areas would be at least 35% of total suitable bathyal habitat".*

If the target is to enhance fisheries then similarly large areas have been identified as required. Stewart (2002) states:

> *Beverton and Holt (1957) are credited with first formulating the impact of harvest refugia (unfished areas) on the yield to a fishery. They found that an increased protected area led to increased survival and an age distribution skewed to older ages. When fishing effort is concentrated outside reserves, fishery yield increased with increasing reserve area when reserve area is low, but decreased when reserved area is high, generating an optimal reserve fraction … Thus, the majority of population models that investigate the optimal fraction of marine reserves employ fishery management techniques to predict how different levels of protection affect the extinction probability of exploited stocks … In general, these studies conclude that reserves are highly beneficial for the sustainable harvesting of a metapopulation, by providing a source for the replenishment of fished-out local patches and thus, preventing regional extinction of heavily exploited stocks. …*
>
> *...*
>
> *To summarise the target estimates identified … one would have to conclude that the optimal marine protected fraction required to maintain a sustainable population should be somewhere between 20% and 50% of the total area.*

Ward et. al. (2000) note *"The results of modelling studies have led several authors to suggest that protecting something like 20% of a population's range may be sufficient to achieve long-term sustainability. However, Clark (1996) suggested that sustainability will not be achieved unless more than 50% is protected, and Pollard (1993) concluded that the 'only long term solution' to overfishing may be in complete protection 'of very large areas of the marine and estuarine environment'. Walters (1998) used an analysis of cases of successful management of marine resources to propose boldly that sustainability will require that most of the marine environment be afforded protected status, with only a small proportion available for exploitation".*

Based on a review by the American National Research Council, the Marine Reserves Working Group (MRWG 2001) states:

> *If reserves are designed for fisheries enhancement and sustainability, the vast majority of studies done to date indicate that protecting 20% to 50% of fishing grounds will minimize the risk of fisheries collapse and maximize long term sustainable catches (NRC 2001,Table 1).*
>
> *…*
>
> *In 1990, the Reef Fishery Plan Development Team (RFPDT 1990) recommended protection of 20% of the continental shelf off the southeastern United States. In 2000, the U.S. Coral Reef Task Force (USCRTF 2000) recommended that 20% of coral reefs and associated habitats receive protection in reserves. Although the 20% figure is widely quoted, it is often criticized as being arbitrary and unscientific (NRC 2001). …*
>
> *Recent analyses suggest that stocks should be kept above 15-40% of their unfished population size (Hilborn, pers.comm.). Because of the uncertainty associated with these fisheries statistics, protecting 20% of a stock or habitat may not be sufficient to sustain exploited or bycatch species. Several studies suggest that stocks should be maintained at 60-75% of their natural population size if reserves are to be used as the primary*

> *management approach (Hannesson 1998, Lauck et al.1998). Without other management measures, highly mobile and migratory species will require very large closures (70-80%) (NRC 2001).*

Stewart (2002) cautions that "*most species-area curves suggest that the greatest losses of species richness will occur as remaining habitat declines below 20%".*

The intent of the reserve criteria is to allow for socio-economic considerations to be applied where alternatives exist, so as to achieve the least costly option for attaining reserve goals. Unfortunately the Commonwealth has used socio-economic rationale to over-ride the reserve criteria and both exclude areas required to achieve the promised Comprehensive Adequate and Representative reserve system, and to not provide the required level of protection for many vulnerable features that were included. DSEWPC (2011b) state:

> *Potential displacement of the majority of fisheries operating within the Temperate East Marine Region has been minimised by avoiding areas of high fisheries value or, where this is not possible, through zoning arrangements. Areas of shelf habitat where many of the most valuable fisheries operate have been zoned for Multiple Use to reduce the social and economic impacts on industry and associated communities.*

2.1. Provincial Bioregions

The proposed Tweed-Byron Marine Reserve occurs over three of Australia's identified provincial bioregions. Within each bioregion the Commonwealth should be ensuring the creation of a comprehensive, adequate and representative reserve system. The adequacy of the existing and proposed reserve system within each bioregion is reviewed in this section.

The bioregions have been further subdivided into bathomes by the Commonwealth, largely on the basis of geomorphic features and depth to more accurately reflect species distributions. These are intended to be used in relation to meeting Goal 2 of the NRSMPA Goals & Principles: "*The marine reserve network should cover all depth ranges occurring in the region or other gradients in light penetration in waters over the continental shelf*".

While these bathomes do not account for substrate and incorporate an unknown variety of ecosystems, they represent one surrogate for biodiversity and the only one available that accounts for depth related effects on fish and marine ecosystems.

In response to a request for justification as to why the Commonwealth did not consider that the Tweed Area for Further Assessment warranted creation of a marine reserve, the Temperate East Marine Conservation Marine Division responded:

> *Several areas were considered during the Areas for Further Assessment process which were not included in reserves. The Tweed Area for Further Assessment overlapped the Central Eastern Shelf Transition and Central Eastern Province provincial bioregions, both of which are represented either by proposed or existing reserves. Ecosystems of the Central Eastern Shelf Transition are currently represented in state marine reserves and the Great Barrier Reef Marine Park. Ecosystems of the Central Eastern Province are represented in the proposed Jervis, Hunter, Clarence, and Tasmantid reserves. These and other considerations, including potential socio-economic impacts, were taken into account when developing the Temperate East marine reserves network proposal.*

These claims do not stand up to scrutiny.

GIS reporting was used to assess the reserve adequacy of existing reserves and additional areas proposed for protection by the Commonwealth in relation to bathomes in each bioregion. Those areas which exclude fishing (IUCN categories I and II) were also considered as these fully protected areas represent the real level of protection applied. Please note that the bioregions are considered in their entirety, including where they extend outside the Temperate East Marine Bioregion. Also note that there are some discrepancies between the figures used here and those provided elsewhere due to the conversion and reporting process, though these are not significant

2.1.1. Central Eastern Shelf Transition

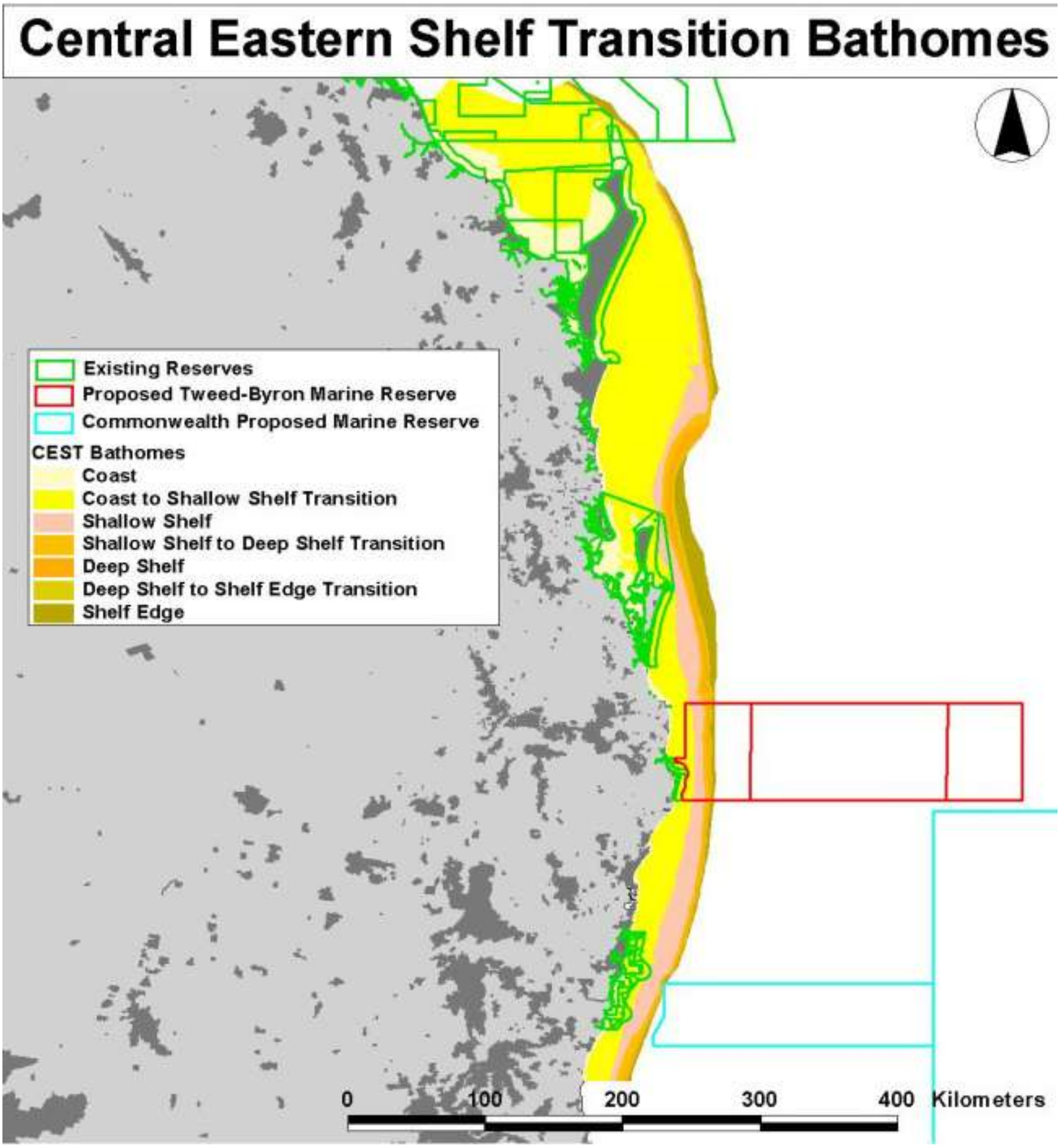
The Central Eastern Shelf Transition extends over the continental shelf from the southern Great Barrier Reef Marine Park (north of Fraser Island) south to Nambucca Heads, from the coast down to a depth of 240m. Please note that for completeness this assessment incorporates state waters and part of the Great Barrier Reef National Park, even though these are not included in the Temperate East Marine Region – with these excluded the reserve outcome is far worse.

This bioregion includes the existing reserves of Solitary Islands MP, Solitary Islands MR (Commonwealth), Cape Byron MP, Cook Island AR, Hervey Bay MP. Woongarra MP, Moreton Bay MP, Great Sandy MP, and parts of the Great Barrier Reef Coast MP and Great Barrier Reef MP. It also includes the Fish Habitat Areas of Elliot River FHA, Baffle Creek FHA, Kolan River FHA, Susan River FHA, Susan River FHA, Pumicestone Cgannel FHA, Moreton Banks FHA, Hay's Inlet FHA, Pimpana FHA, Coomera FHA, Burrum FHA, Kinkuna FHA, Kippa-Ring FHA, Maroochy FHA, Myora-Amity Banks FHA, Peel Island FHA, Deception Bay FHA, Pumicestone Channel FHA, Jumpinpin-Broadwater FHA, Beelbi FHA, Fraser Island FHA, Maaroom FHA, Kauri Creek FHA, and Tin Can Inlet FHA. It also includes the Hervey Bay-Tin Can Bay Dugong Protection Area. Taken together these "reserves" total 14,901 km^2, though only 1,889 km^2 is in the equivalent of Marine National Park Zones (IUCN classes I and II).

The only proposed new reserve is 3km^2 of the Clarence Marine Reserve that is intended as a Multiple Use Zone. The existing sanctuary zone of 0.8 km^2 in the Solitary Islands Marine Reserve is proposed to be expanded to 1 km^2 as a Marine National Park zone.

Central Eastern Shelf Transition Bathomes			Proposed and Existing Marine Reserves		Marine National Parks (IUCN 1&2)	
	Depth (m)	AREA (km2)	Area (km2)	%	Area (km2)	%
Coast	0-15	6892	5725	83.1	442	6.4
Coast to Shallow Shelf Transition	15-70	25237	8644	34.3	1436	5.7
Shallow Shelf	70-100	5113	235	4.6	4	0.1
Shallow Shelf to Deep Shelf Transition	100-120	1405	21	1.5	0.3	0
Deep Shelf	120-150	1540	24	1.6	0.2	0
Deep Shelf to Shelf Edge Transition	150-165	523	15	2.9	0	0
Shelf Edge	165-225	2293	236	10.3	1	0
TOTALS		43002	14901	34.7	1882	4.4

With the existing and proposed reserves, 35% of the province will be in marine reserves, though only 4.4% will be in the equivalent of Marine National Park Zones (IUCN classes I and II). At the bathome level the reserve status of coastal waters is good (but still deficient in fully protected areas), though this deteriorates dramatically for mid and outer shelf waters, with virtually none of the later included in any Marine National Park zones. For these deeper shelf waters this is one of the worst reserve outcomes in the region. Numerous shelf ecosystems can be expected to have been excluded.



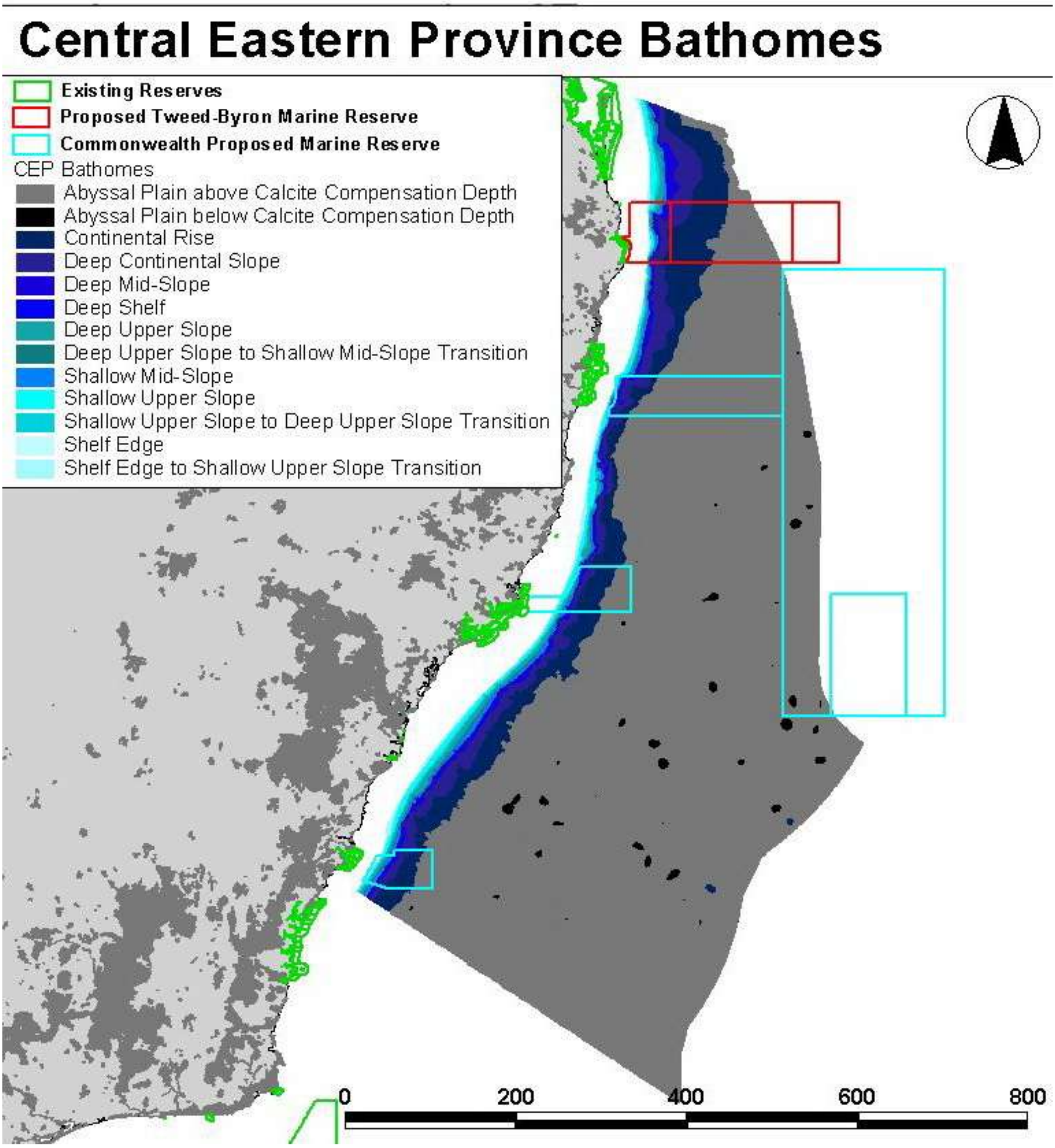
The proposed Tweed-Byron Marine Reserve includes 1,386 km^2 of the Central Eastern Shelf Transition, all of which is proposed for inclusion in Marine National Park Zones. This almost triples reservation of shelf waters below 70m depth from 532 km^2 (5%) to 1,520 km^2 (14%), and full protection of shelf waters below 70m depth in Marine National Park Zones from 5.5 km^2 (0.05%) to 988 km^2 (9%).

2.1.2. Central Eastern Province

The Central Eastern Province extends from the edge of the continental shelf offshore from Brisbane south to Ulladulla and down to 5100 metres depth. It encompasses the continental slope and part of the Tasman Abyssal Plain. There are currently no reserves within the province, though there are proposals for the Clarence, Hunter, Jervis and part of the Tasmantid CMRs within the province. The total of proposed reserves is 29,204 km^2, with a measly 27 km^2 in a Marine National Park zone.

The Commonwealth proposes to include 11% of the province in marine reserves, though only 0.01% is proposed for Marine National parks zoning. There is representation of all bathomes in the proposed reserves, though representation declines significantly in the shallower upper slope waters. Given that vulnerability to fishing pressures increases with accessibility it is evident that this bias in the reserves is worse than indicated. The representation of only one bathome in a Marine National Park zone is an extremely poor outcome.

Central Eastern Province Bathomes			**Proposed and Existing Marine Reserves**			
			Reserves		**Marine National Parks (IUCN 1)**	
	Depth (m)	**AREA (km2)**	**Area (km2)**	**%**	**Area (km2)**	**%**
Shelf Edge to Shallow Upper Slope Transition	220-280	1943	89	4.6		
Shallow Upper Slope	280-490	3140	130	4.1		
Shallow Upper Slope to Deep Upper Slope	490-610	1376	100	7.3		
Deep Upper Slope	610-830	2793	267	9.6		
Deep Upper Slope to Shallow Mid Slope	830-910	936	101	10.8		
Shallow Mid Slope	910-1080	1858	212	11.4		
Deep Mid Slope	1080-1500	4491	554	12.3		
Deep Continental Slope	1500-2500	11375	1358	11.9		
Continental Rise	2500-4000	19970	2439	12.2		
Abyssal Plain above CCD	4000-5000	216794	23669	10.9	27	0.01
Abyssal Plain below CCD	5000-6000	1815	285	15.7		
TOTALS		266492	29204	11.0	27	0.01



The proposed Tweed-Byron Marine Reserve incorporates 5,130 km^2 of continental slope waters, of which 1,565 km^2 is proposed for inclusion in a Marine National Park Zone. This doubles the area of the continental slope within the Central Eastern Province in reserves from 5,250 km^2 (11%) to 10,380 km^2 (22%), and results in 3.3% being fully protected in a Marine National Park zone.

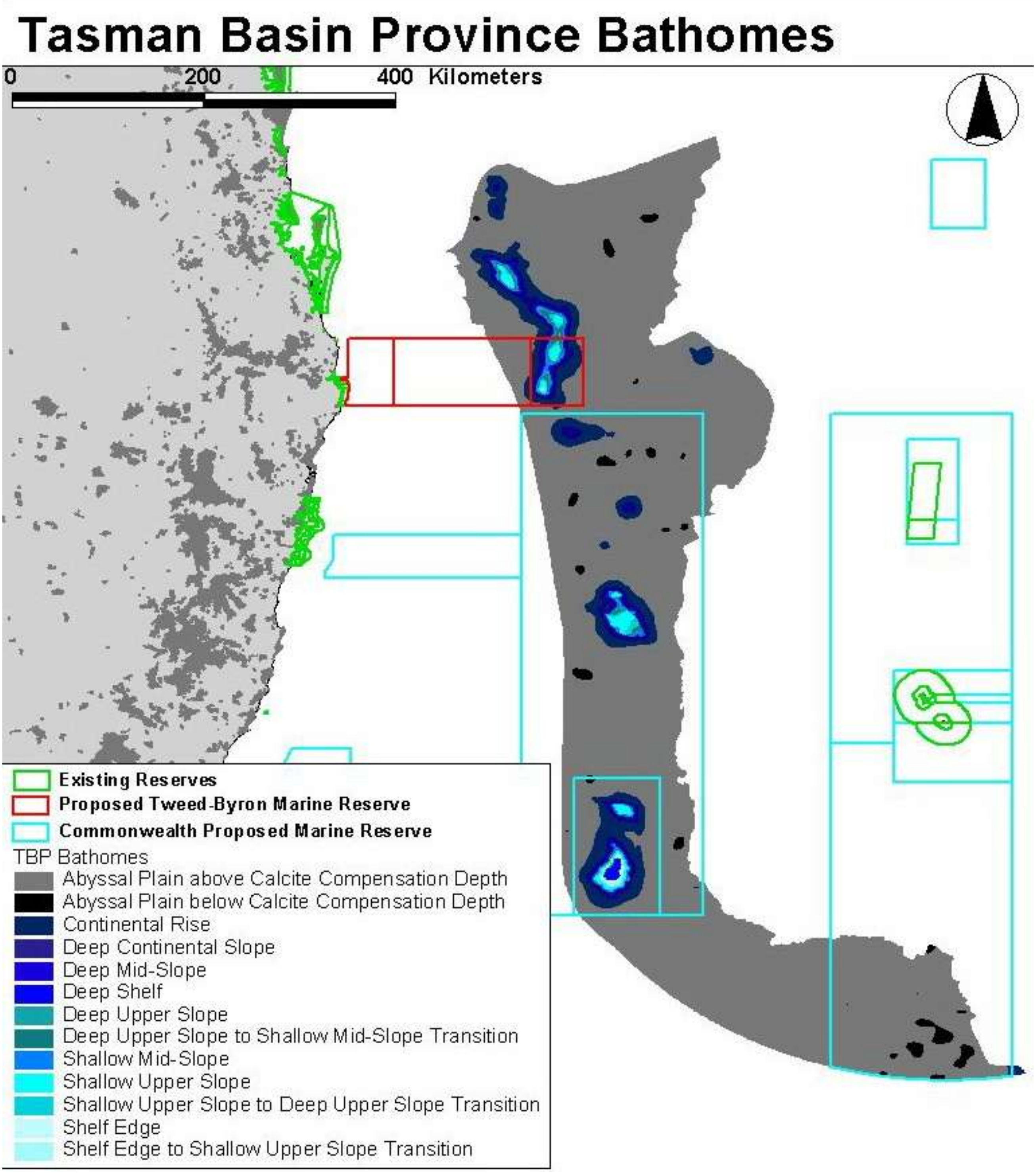
2.1.3. Tasman Basin Province

The Tasman Basin Province extends over the abyssal plains and seamounts of the Tasman Sea. It currently has no reserves, though is proposed to include parts of the Lord Howe and Tasmantid MPAs. In total 79,590 sq km of reserves are proposed, with 10,622 of this being Marine National

Park Zone. The proposal is to include 51 % of the province in reserves, with 6.8% of the province in Marine National Park zones.

Based on bathomes this would appear to be a reasonably good conservation outcome, though with a need for more fully protected areas. Though this does not take into account the latitudinal differentiation of seamounts and the need to reserve seamounts throughout their latitudinal range to achieve a comprehensive and representative sample.

Tasman Basin Province Bathomes			**Proposed and Existing Marine Reserves**			
			Reserves		**Marine National Parks (IUCN 1)**	
	Depth (m)	**AREA (km2)**	**Area (km2)**	**%**	**Area (km2)**	**%**
Shelf Edge	165-220	86	82	95.3	82	95.3
Shelf Edge to Shallow Upper Slope Transition	220-310	163	146	89.8	146	89.8
Shallow Upper Slope	310-520	1003	634	63.2	317	31.6
Shallow Upper Slope to Deep Upper Slope	520-650	438	211	48.1	60	13.7
Deep Upper Slope	650-775	741	263	35.5	106	14.3
Deep Upper Slope to Shallow Mid Slope	775-880	312	125	40.0	53	17.0
Shallow Mid Slope	880-1100	555	235	42.3	117	21.1
Deep Mid Slope	1100-1500	971	441	45.4	259	26.7
Deep Shelf	120-150	216	216	99.8	216	99.8
Deep Shelf to Shelf edge Transition	150-165	40	40	100.1	40	100.0
Deep Continental Slope	1500-2500	3372	1825	54.1	809	24.0
Continental Rise	2500-4000	10138	5623	55.5	2823	27.8
Abyssal Plain above CCD	4000-5000	136602	67917	49.7	5555	4.1
Abyssal Plain below CCD	5000-6000	2140	1831	85.5	37	1.7
TOTALS		156778	79589	50.8	10620	6.8



The proposed Tweed-Byron Marine Reserve includes 3,400 km^2 of the Tasman Basin Province for inclusion in a Marine National Park Zone, 2,631 km^2 of which represents bathomes above the Abyssal Plain (seamounts). This increases full protection of bathomes above the Abyssal Plain from 5,028 km^2 (28%) to 7,659 km^2 (42%). Most significantly it provides representative protection to an ecologically distinct cluster of seamounts over 400km away from those currently proposed for full protection.

2.2. Key Ecological Features

The Commonwealth data identifies 8 key ecological features (kefs) in the Temperate East Marine Bioregion. DSEWPC (2011b) state:

> *Key ecological features are elements of the Commonwealth marine environment that are of particular importance for ecological functioning, ecological integrity and biodiversity.*
>
> *...*
>
> *Areas of high conservation value based on their importance for the region's biodiversity or ecosystem function and integrity have been identified as key ecological features in the draft marine bioregional plan for the Temperate East region*

Those of relevance to the proposed Tweed-Byron Marine Reserve are Canyons on the eastern continental slope, Shelf Rocky Reefs, and the Tasmantid Seamount Chain.

These also represent *geomorphological units* as referred to by Last *et. al.* (2010) and should be used to differentiate within bathomes to better represent biodiversity in the reserve system. Though the Commonwealth obviously has failed to do so, and appears to have completely ignored some.

The Commonwealth's determination to exclude middle and outer shelf habitats has resulted in only 1.8% of Shelf Rocky Reefs being proposed for inclusion in reserves and none in Marine Park zones. These reefs are encompassed by 7 bathomes in the Central Eastern Province, 5 bathomes in The Central Eastern Shelf Transition, 4 bathomes in the Central Eastern Shelf Province, and 3 in the South-east Shelf Transition. It thus can be expected that these 19 bathomes encompass a larger number of ecosystems. Of these 19 bathomes only 5 are represented in proposed reserves.

The Commonwealth's allowance for some steep sections of the continental shelf to be included in reserves means that 17% of the area of canyons on the continental slope are proposed for inclusion in reserves, though none are proposed for inclusion in National park zones. These canyons incorporate 32 bathomes within 6 provinces, of which 16 in 3 provinces are proposed for limited protection. No canyons north of Coffs Harbour are proposed for protection.

The Tasmantid Seamounts fare better with 47% proposed for inclusion in reserves and 20% for inclusion in National Park zones. Though only the southern seamounts are proposed for inclusion in marine reserves, and only the southernmost are proposed for inclusion in a National Park zone. This is poor representation of their distribution and known diversity.

		Proposed and Existing Marine Reserves			
		Reserves		**Marine National Parks (IUCN 1&2)**	
	AREA (km2)	**Area (km2)**	**%**	**Area (km2)**	**%**
Canyons on the eastern continental slope	5869	985	17%	0	0%
Shelf Rocky Reefs	1,991	36	1.8%	0	0%
Tasmantid Seamount Chain	23604	11128	47%	4797	20%

2.3. Biologically Important Areas

The Commonwealth data identifies biologically important areas (BIA) for sharks (Grey Nurse and Great White), turtles (Green and Loggerhead), whales and dolphins, and seabirds. DSEWPC (2011b) state:

> *Biologically important areas are areas where aggregations of individuals of a protected species display behaviours such as breeding, foraging, resting and migration. Biologically important areas highlight those parts of the region that are particularly important for the protection and conservation of protected species.*

This data demonstrates that the waters within the Tweed-Byron proposal are important for Grey Nurse Shark, Great White Shark, Loggerhead turtles, Humpback Whales, Indian Yellow-nosed Albatross, Black-browed Albatross, Campbell Albatross, Wandering Albatross, Northern Giant Petrel, Southern Giant Petrel, Wilson's Storm Petrel, Black Petrel, Great-winged Petrel, and Flesh-footed Shearwater.

The failure of the Commonwealth to identify any biologically important areas for fish or marine invertebrates is a significant failing. Similarly their failure to include species (such as dogfish) and ecosystems that are known to have been decimated by fishing are major deficiencies. For the few species considered the modelling is simplistic and broad so does not provide an accurate identification of priority areas for reservation.

Only a subset of biologically important areas were considered priorities by the Commonwealth, and those of relevance to the proposed Tweed-Byron Marine Reserve are considered further. Coastal dolphins and Loggerhead Turtle nesting habitat are within State waters so are not considered herein.

The Grey Nurse Shark is predominately a species of shelf waters. Two separate populations of Grey Nurse Shark are identified in Australian waters, the east coast population is listed as critically endangered nationally. Major threats to the recovery of Grey Nurse Sharks have been identified (Environment Australia 2002) as including *"incidental capture by commercial and recreational fisheries".*

Julian Rocks and the surrounding reef in Cape Byron Marine Park is a recognised aggregation site. The nearby reefs, such as Windarra Banks, are also regularly used by Grey Nurse Sharks. The Commonwealth proposes creating small (1-3 km^2) Marine National Park zones over known aggregation sites at Pimpernel Rock in the Solitary Islands Marine Park and the Cod Grounds Marine Park. Though, as the Commonwealth has avoided protecting shelf ecosystems and species, the proposal is to only include 8.1% of their modelled distribution (its BIA) in existing and proposed reserves (mostly in state waters), with only 0.4% of their modelled distribution (already) included in fully protected zones.

The Grey Nurse Shark has been protected from fishing in NSW waters since 1984, as noted by NSW Fisheries (2002) *"As yet there is no evidence that this has succeeded in stopping or reversing the decline in their numbers. …They are still threatened by incidental capture by fishers and illegal fishing activities such as shark finning".* Now in 2011 Fisheries NSW are again saying "*modeling suggests that the population is likely to be declining under current levels of known fishing mortality*". There are estimated to be 500-1500 sharks left in the east coast population.

As noted by Environment Australia (2002) "*There is growing concern that legislative protection of Grey Nurse Sharks is not sufficient for their recovery and that strategies such as habitat protection are needed (Marsh 1995, Garbutt 1995). Habitat protection is of particular importance to Grey Nurse Sharks and particular areas where Grey Nurse Sharks aggregate, or particular habitats that are essential at different stages of their life history, should be provided with some effective form of protection (Otway and Parker 2000)".* Environment Australia concludes "*The primary response required to the impact of commercial fishing on the critically endangered east coast population is habitat protection".*

Environment Australia recommends: *"It is obviously necessary to protect key Grey Nurse Shark areas from the risk of incidental catch. This protection should include establishment of effective marine protected areas and seasonal or permanent closure to commercial and recreational fishers for these important sites"* (Environment Australia, 2001; p 10).

Both the Commonwealth Recovery Plan and the NSW Recovery Plan recommend the protection of the sharks' food source. The proposed Tweed-Byron Marine Reserve encompasses a priority area for reservation of Grey Nurse Shark habitat.

The Great White Shark is primarily a creature of deeper waters, with the most notable exception being an aggregation site for juveniles inshore in the Port Stephens area. The proposal is to incorporate 4.8% of their modelled distribution (its BIA) in existing and proposed reserves, with only 0.2% of their modelled distribution (already) included in fully protected zones.

Five marine turtles (loggerhead, green, leatherback, hawksbill and flatback) have been identified in NSW's waters, with resident groups of hawksbill, loggerhead and green turtles in the waters of northern New South Wales. Loggerhead turtle is listed as endangered and green and leatherback turtles are listed as vulnerable under the NSW Threatened Species Conservation Act 1995.

The proposed Tweed-Byron Marine Reserve is near the southern limit of the distribution of both breeding and inter-breeding habitat for the Loggerhead Turtle. Given that breeding occurs on beaches the breeding habitat is within State waters. Therefore, for GIS analysis only inter-nesting habitat was considered. Currently no existing or proposed Commonwealth reserves include inter-nesting habitat for loggerhead turtles. Though 7.3% of inter-nesting habitat is already included in State reserves, with next to nothing fully protected. This in effect means that there is no protection for inter-nesting habitat of Loggerhead Turtles.

Environment Australia (2003a) identify that turtles are threatened by *"increasing mortality through marine debris, boat strike in waters popular for recreational boating, habitat loss, predation of eggs by feral animals, noise, oil pollution, and the continuing harvest in Australia".* One of the most significant sources of mortality to adults is trapping and drowning in trawling nets, though they are also killed in other net, longline and trap fisheries, as well as shark meshing. Environment Australia (2003a) report that *"There is sufficient information to identify a decline of 50 – 80 per cent over 10-15 years in the eastern Australian loggerhead population (Limpus and Reimer 1994). Limpus (1995) has found that in the 1976 and 1977 nesting seasons approximately 3500 loggerhead females nested on the Queensland coast, whereas 300 nested in 1997".*

Turtle exclusion devices are not mandatory in NSW ocean trawl nets. Prawn Trawlers in the Tweed-Byron area apparently regularly catch turtles, though this is not reported to NSW Fisheries (T. Puglisi pers. comm.). The Ocean Trawl Fishery EIS (DPI 2004) notes:

> *... the eastern population of Loggerhead turtles are estimated to be only able to withstand 100 human induced deaths per year (C. Limpus, Qld EPA, pers. comm., 2003). ... Whilst one fishery, such as OTF, may only encounter these turtles a few times and as a result the turtles die, these deaths may push the human induced mortality over the threshold of 100 and hence impair the recovery of this species. Therefore, it is not sufficient protection for some threatened species to rely solely on the minor incidences of encounters and conclude that no action should be taken to minimise the risks.*
> *...*
> *Turtle exclusion devices (TEDs) set in prawn trawl nets in Queensland are effective at allowing turtles to escape from nets but these devices are not used in NSW.*

Environment Australia (2003a) considers that *"Ideally marine turtle habitats should be free from human influences that can kill, injure or disable a turtle"*. Habitats critical for the survival of marine turtles are mating sites where turtles aggregate for breeding, the natal beaches on which they lay their eggs, internesting habitat that is inhabited between nesting events, and high quality feeding habitat (Environment Australia 2003a). There is a need to incorporate critical habitats for marine turtles into reserves.

The Commonwealth identify four Albatross that utilise the continental shelf for foraging and reach their northern limits of distribution off Tweed-Byron: Indian Yellow-nosed Albatross, Black-browed Albatross, Campbell Albatross, and Wandering Albatross. The existing and proposed Commonwealth reserves include 13.8% of modelled habitat for these four albatross, though do not propose any habitat for inclusion in National Park zones. This in effect means that there is no protection for these surface feeding birds.

It appears that the Commonwealth paid no heed to its Biologically Important Areas when designing its reserve system.

		Proposed and Existing Marine Reserves			
		Reserves		**Marine National Parks (IUCN 1&2)**	
	AREA (km2)	**Area (km2)**	**%**	**Area (km2)**	**%**
Grey Nurse Shark	205129	16568	8.1%	776	0.4%
White Shark	48850	2365	4.8%	90	0.2%
Loggerhead Turtle (inter-nesting)	14702	1067	7.3%	1	0%
Shelf Albatross	50455	6977	13.8%	0	0%

3. CURRENT CONSIDERATIONS

Ocean currents play a major role in shaping the geomorphology of the region, having a significant influence on water temperatures, nutrient availability, larval dispersal, and thus biological patterns. Of particular relevance for the proposed Tweed-Byron Marine Reserve are the East Australian Current and the inferred abyssal currents affecting the deep waters of the lower continental slope and abyssal plain.

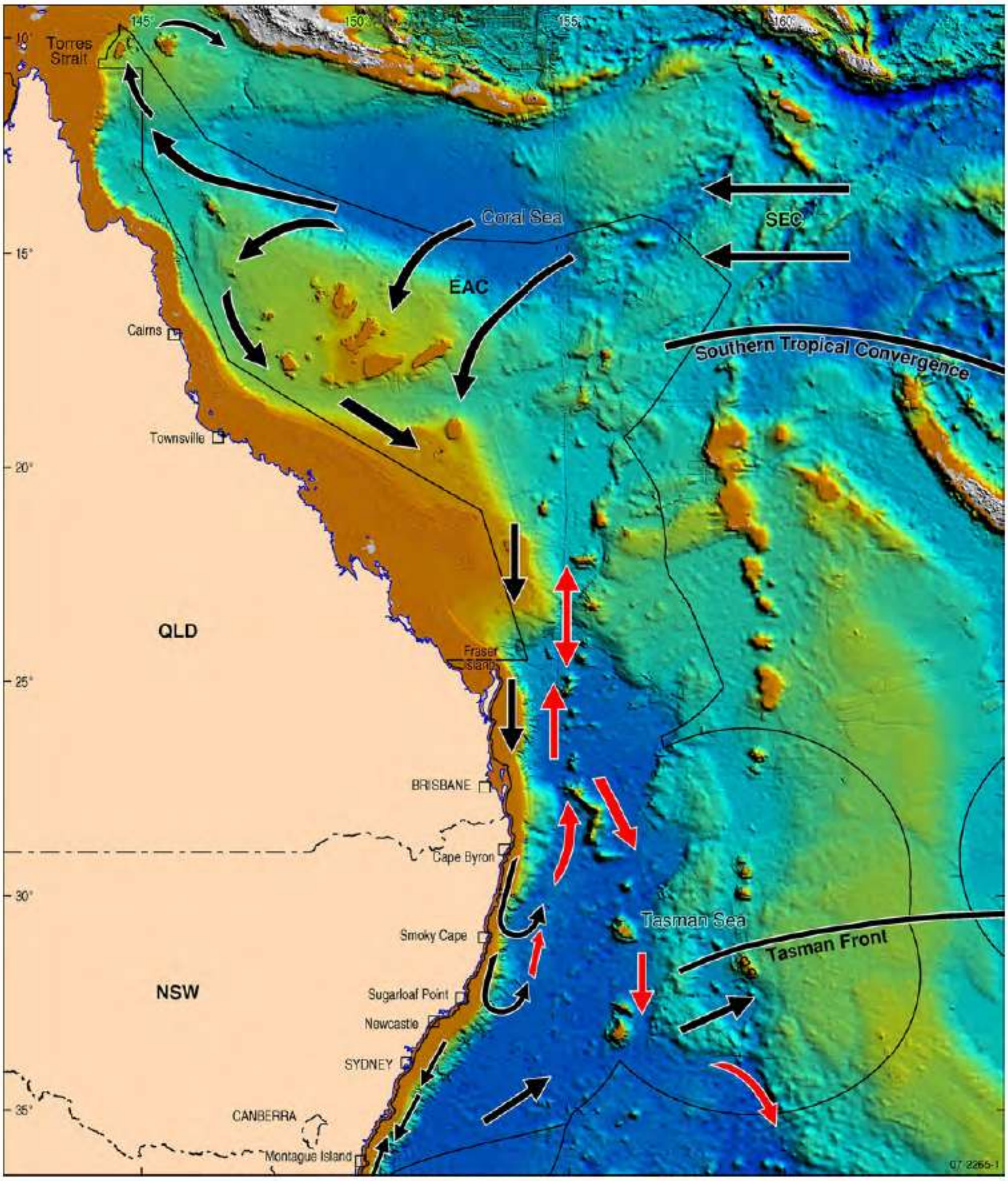


Figure 3.10. Physical oceanography of the EMR, showing the main water masses influencing the region: the East Australian Current (EAC), South Equatorial Current (SEC), West Wind Drift (WWD) and inferred abyssal currents. (CSIRO; Jenkins, 1984; Kawagata, 2001).

DEWHA (2007) note that:

> *The interaction of currents with geomorphic features such as reefs, atolls, seamounts and canyon heads creates areas of enhanced productivity. The vertical mixing of waters as*

> *currents move around prominent geomorphic structures brings nutrient rich deeper waters into the photic zone. Typically, sharks, tuna and billfish are resident top predators in some of these consistent areas of enhanced productivity.*

The East Australian current is the predominant influence on the north of the area, affecting waters down to 1,000 m depth, and even further. The interaction of the EAC with the colder waters of the Tasman Sea, as the Tasman Front, has affects across the whole region.

DEWHA (2007) note that:

> *Underlying the East Australian Current, beyond a depth of approximately 500 m, is a cool and generally northwards-moving sub-Antarctic water mass. The exact path of this current is not known, although there is evidence of scouring along the base of the continental slope, the Tasmantid Seamounts and the Lord Howe Rise .This suggests that there is a northward flow of water across the floor of the western Tasman Basin and a southerly flow along the eastern margin.*

The inferred abyssal currents likely play a significant role at greater depths. For example cold-water corals are associated with strong near-seabed currents, which help them maintain food supply, disperse eggs, sperm and larvae, remove waste products and avoid being smothered by sediments. Corals also appear to benefit from flow acceleration, and some of their patterns of distribution can be explained by current flow conditions (Secretariat of the Convention on Biological Diversity 2008). It's cold sub-Antarctic waters will represent a change in ecosystems and species, compounded by depth changes.

3.1. East Australian Current

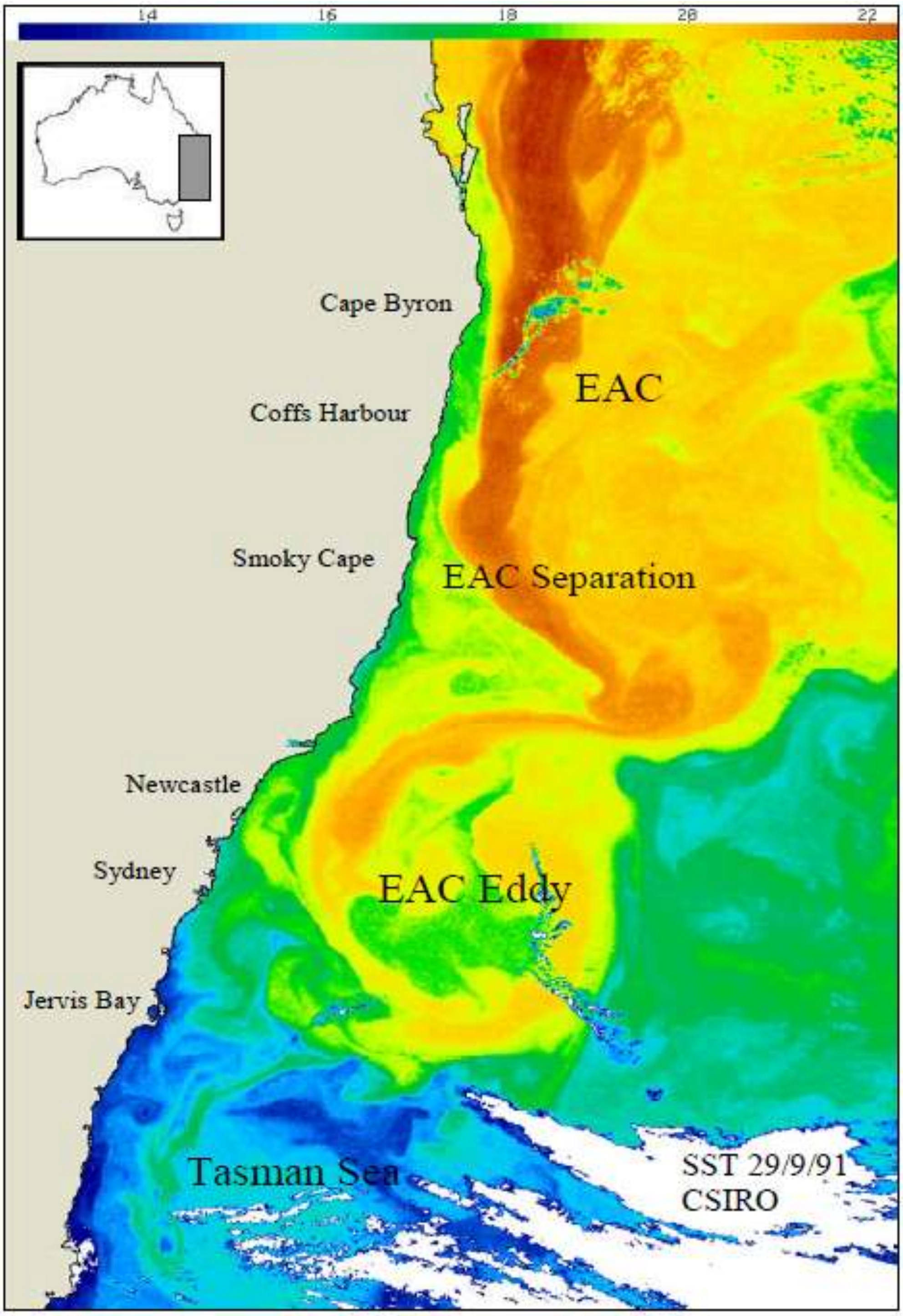
The surface water circulation in the Temperate East is dominated by the East Australian Current (EAC). The EAC is Australia's largest current and is typically 30 km wide, 200 m deep and traveling up to 4 knots (2 ms^{-1}), though may also extend up to 100km wide and 500m deep. The core of the EAC is centred over the continental slope, although its coastal presence is regularly felt close to shore off Cape Byron. This current arises in the tropics and is nutrient poor. Its warmth means that it may be up to a meter higher than the surrounding sea. The current can modify the sediment down to water depths of 1,000 m and its influence may be felt down to 2,000 m. The current is strongest in summer, peaking in February at up to five knots, and weakest in winter.

South of Sugarloaf Point (32°S) the strength of the current decreases rapidly and the current breaks up into anticyclonic gyres or eddies which can be up to 200 km across and one kilometre deep, rotating at up to four knots at the edge and lasting for up to a year.

On the outer continental shelf the effect of the EAC dominates, with current strength increasing towards the outer edge of the shelf at about 200 m producing a zone of coarse sand and scours and exposing the Shelf Rocky Reefs (Avery 2000). Long shore drift and wave action move sand north along the inner shelf, while further offshore, sediment on the shelf is carried southwards by the EAC.

Upwellings around Cape Byron, Smoky Cape and Sugarloaf Point are caused by the EAC crossing the continental shelf and drawing up nutrient-rich waters from depths, though the prevailing wind pattern means that upwelling of deeper nutrient rich water is not a regular phenomenon. As noted by Bax and Williams (2001), at places along the continental margin there *"is this deep upwelling of nutrient-rich slope water that contributes to the productive habitat and fishing grounds along the shelf-break, and especially at canyon heads"*.

Part of the EAC is deflected offshore at around 30°S along the Tasman Front (Subtropical Divergence) forming a warm subtropical anticyclonic gyre. The Tasman Front forms the interface between the warm waters of the Coral Sea and the cooler waters of the Tasman Sea and it moves north and south with the seasons.



Sea Surface Temperatures along the east coast of Australia showing the influence of the EAC, an EAC eddy and the Tasman Sea (From Roughan *et. al.* 2008).

DEWHA (2007) note that:

> *The East Australian Current and its eddies create the primary process whereby warm low-nutrient waters are delivered to cool southern coastal waters (and to the outlying Lord Howe and Norfolk islands) as well as being the primary driver of abundance, distribution and dispersal of pelagic and shelf-slope demersal organisms.*

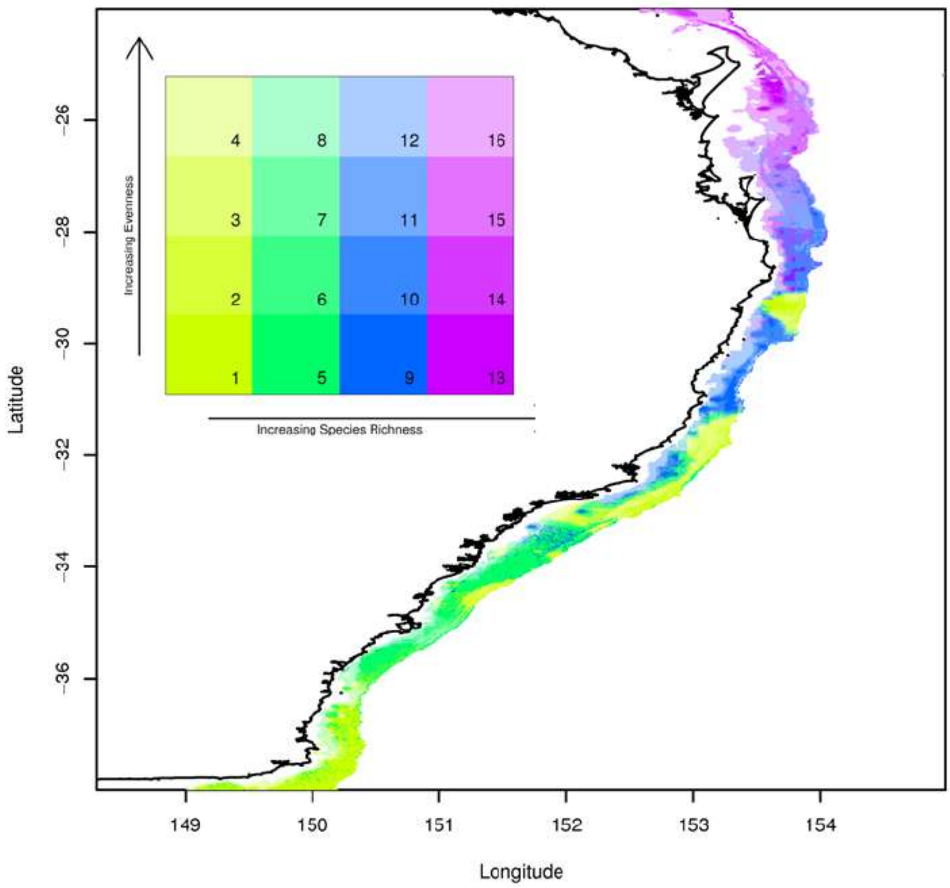
TFMPA (2000) note that *"Ocean current and various physico-chemical properties also have an application for the recognition of relationships among pelagic communities and mapped habitats, which would in turn assist in the classification of mapping units at the ecosystem level".*

SCBD (2008) consider:

> *Species richness of pelagic fish predators and zooplankton are suggested to be correlated with sea surface temperature (SST), SST gradients and dissolved oxygen concentrations. The diversity of pelagic fish predators and zooplankton consistently peaks at intermediate latitudes (20–30°N and S), where ranges of tropical and temperate species overlap.*

Williams and Bax (2001) found that strong latitudinal patterns in fish species distributions existed in all three depth groups, coinciding with an overlap of temperate currents and subtropical *"eddy flows associated with the warm East Australian Current"*. They found that these patterns persisted *"despite marked seasonal shifts in water masses"* and identified the prevailing hydrodynamic climate as *"an important structural component of fish habitat"*. They note:

> *"… these patterns suggest that strength of water currents and levels of current-borne food are structural attributes of habitats that help shape shelf fish communities. … Water currents can be modelled as a quantitative attribute of habitat for mapping purposes and can be rapidly measured during surveys with research vessels."*



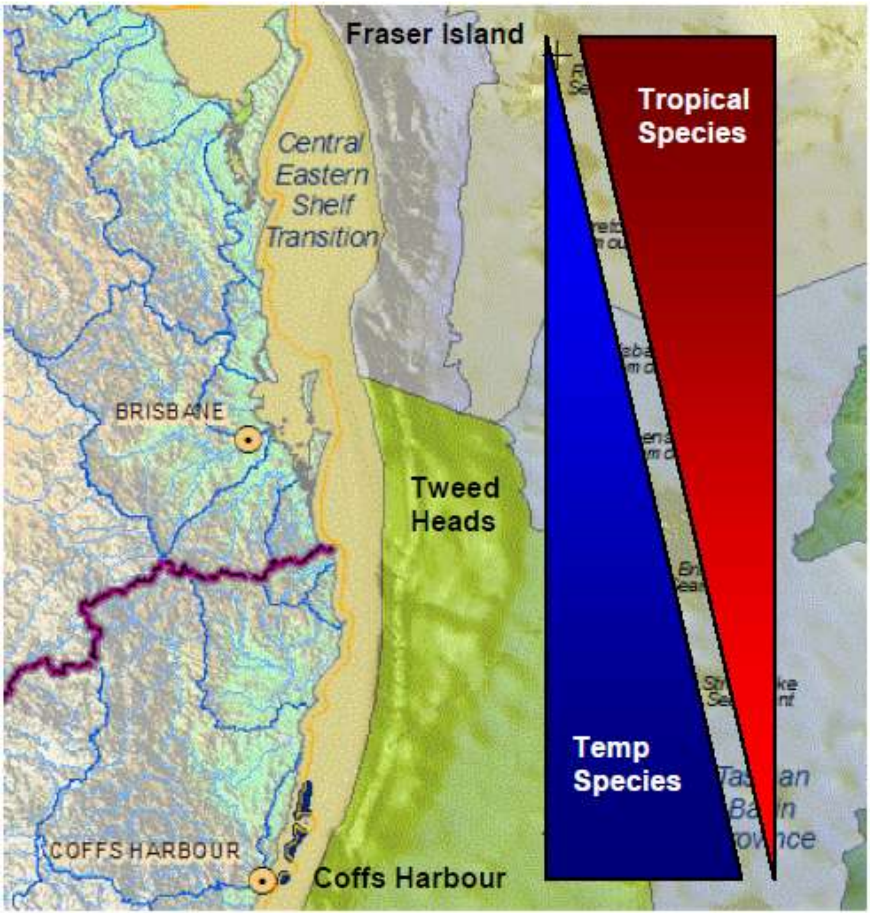
Map and interpretive key showing distributions of 16 categories of unique combinations of species richness and evenness for demersal fish in the East Marine Region. Note the increasing species richness with decreasing latitude.

There is a consistent variation in fish communities along the shelf and slope with latitude (Williams and Bax 2001, Graham 2007). There is also consistent variation in seamount fauna with latitude off the east coast of Australia (Richer de Forges 1993, Tracey et. al. 2005, NORFANZ 2006). These changes are in part due to the influences of the Coral and Tasman seas as mediated by the EAC.

From their review of bycatch of bony fish (teleosts) Graham (2007) also identifies a significant change with latitude:

> *Geographically, teleost diversity on inshore and shelf depths decreased with increasing latitude. Almost twice as many teleost species were recorded on the Queensland grounds compared to southern NSW .... On the inshore grounds, more than 30% of the Queensland species were not found in NSW and, for both depth zones, only about 20% of the species were distributed between Queensland and southern NSW. There were no comparable data for continental slope depths.*

The tweed is central to the temperate/tropical overlap and thus represents a distinct biota, as noted by the Commonwealth *"The continental shelf off Tweed Heads, NSW is a major tropical/temperate divide for the East Marine Region"*. Few tropical benthic species are found south of Coffs Harbour and few temperate benthic species are found north of Fraser Island. This effect, to varying extents, can be expected to be present across the whole of the continental shelf, upper slopes and seamounts across the region, though will become less pronounced with depth.



From DEWHA 2007.

DEWHA (2007) note that the influence of the EAC is felt across the Tasman Basin:

> *Ecological connections in a north - south direction are influenced by the southerly flowing East Australian Current and associated eddies that move waters across the Tasmantid seamounts.*

These changes with biota in relation to latitude emphasises the need to sample a range of latitudes in the proposed reserve system in order to fully sample the biota and ecosystems. While the bioregions utilised by the Commonwealth take into account latitudinal changes in biota and ecosystems, there is still significant latitudinal variations within the bioregions that needs to be accounted for. The Commonwealth's refusal to include any reserves north of Coffs Harbour is a significant failure.

The need for dispersal between reserves and in response to global warming emphasises the need for reserves to be spread along the coastline. Currents play a significant role in the distribution of eggs, larvae and young of a variety of marine organisms. An important consideration with reserve design is the spacing of reserves to allow for dispersal of species between them (NRC 2001, Stewart 2002, Gaines *et. al.* 2003, Shanks *et. al.* 2003, Roughan et. al. 2008).

America's National Research Council (NRC 2001) state *"Connectivity refers to the capacity for one site to 'seed' another location through the dispersal of either adults or larvae to ensure the persistence and maintenance of genetic diversity for the resident protected species".*

Gaines *et. al.* (2003) found "*that advection can play a dominant role in determining the effectiveness of different reserve configurations. Two of the most important consequences are: (1) with strong currents, multiple reserves can be markedly more effective than single reserves of equivalent total size; and (2) in the presence of strong currents, reserves can significantly outperform traditional, effort-based management strategies in terms of fisheries yield, and do so with less risk".*

Harriott *et. al.* (1999) state *"The role of the East Australian Current in southward dispersal of tropical marine larvae has previously been described in relation to many taxa …The southern separation point of the East Australian Current coincides with the southernmost extensive coastal coral communities in coastal eastern Australia (Fish Rock and Black Rocks), and also with the southern distribution limit of giant tropical sea-anemones"*. Harriott and Banks (2002) note *"Currents deliver both warm water and tropical larvae, so that currents, water temperature … and larval dispersal patterns … are inextricably linked".*

Shanks *et. al.* (2003) in their review of propagule dispersal conclude that there are *"two evolutionarily stable dispersal strategies: dispersal <1 km or >~20 km. We suggest that reserves be designed large enough to contain the short-distance dispersing propagules and be spaced far enough apart that long-distance dispersing propagules released from one reserve can settle in adjacent reserves. A reserve 4–6 km in diameter should be large enough to contain the larvae of short-distance dispersers, and reserves spaced 10–20 km apart should be close enough to capture propagules released from adjacent reserves".*

The Scientific Steering Committee for the Great Barrier Reef Marine Park (Stewart 2002) recommends that *"The network of areas should accommodate what is known about migration patterns, currents and Connectivity among habitats. The spatial configurations required to accommodate these processes are not well known and expert review of candidate networks of areas will be required".*

This emphasizes the need for well spaced marine reserves at periodic spacings along the east coast and the Tasmantid Seamounts chain.

4. INDEPTH CONSIDERATIONS

In the marine environment, ocean currents, water depths and substrates generally have the most significant affect on species distributions and thus the distribution of ecosystems. The closest the Commonwealth comes to identifying a surrogate for marine ecosystems are a combination of provincial bioregions and bathomes derived from biotic responses to depth. Each bathome will contain a variety of ecosystems.

The affect of currents and the resultant need to reserve samples of features throughout their latitudinal distribution to represent ecosystems and the diversity within them is considered previously in section 3.1. The existing and proposed protection for depth related “bathomes” in the 3 provincial bioregions represented in the proposed Tweed-Byron Marine Reserve is considered previously in section 2.1. This section considers further information on the effects of depth on species, and thus ecosystems, and their vulnerability to fishing threats.

The density of water means that light decreases rapidly with depth, pressure increases rapidly and disturbances generally decline. For these and many other reasons, depth is a primary determinant in the distribution of many species. Increasing habitat stability and declining food resources with depth leads to species having longer lives and lower reproduction, which makes them increasingly vulnerable to increases in mortality due to fishing and habitat degradation due to trawling. This emphasizes the distinctiveness and vulnerability of deep sea species and ecosystems and the need to ensure that adequately sized representative samples of these deep ecosystems are included in fully protected Marine National Park zones.

For the deeper waters along the edge of the continent in the Temperate East region the Commonwealth proposes

- Increasing reservation of the shelf waters it controls to 1.6%, with a mere 0.01% proposed for inclusion in Marine National Park Zones
- Creating reserves to include only 8% of the continental slope (reducing to 6.7% of the mid and upper slope) in three reserves, all within Multiple Use Zones that only limit some bottom fishing, and with no areas protected north of Coffs Harbour.

Existing NSW Marine Reserves are mostly restricted to the shallower waters of the inner shelf. For example only very small parts of the Cape Byron and Solitary Islands Marine Parks extend below 60m depth. The Commonwealth cannot rely upon them to represent the distinct ecosystems and species only living in deeper waters.

The Commonwealth has intentionally avoided protecting the middle and outer continental shelf, and has only provided token protection to southern parts of the continental slope, so as to not affect the fishing industry. This means that most ecosystems of these deeper waters have not been represented in the proposed reserve system. This intentional avoidance of adequate representation of deeper ecosystems contravenes the principles that are meant to underlie the creation of the promised Comprehensive, Adequate and Representative marine reserve system. The ecosystems occurring here are largely unseen and their ecosystems poorly understood (Williams et. al. 2005). A precautionary approach should mean that they are provided with a higher level of protection, not less.

It is important to recognize that within the constraints of latitude and depth, substrate type is the most significant physical determinant of the distribution of sessile organisms (i.e. algae and colonial invertebrates) and the fauna that utilise them for food and shelter. Substrate type is thus an important determinate of ecosystem distribution. As noted by Bax and Williams (2001) *"At a resolution of 10s of kilometres, the seascape of the south-eastern Australian continental shelf can be visualised as a series of massive sediment flats ('soft-grounds') with reefs, bedrock and consolidated sediments ('hard-grounds') cropping out in dispersed patches".* Williams and Bax (2001) found that of their 61 species of relatively abundant fish species, 61% showed an association with either rock/reef or soft-sediment substrata. There are a variety of other attributes that also influence ecosystem distribution.

This means that the smaller a sample of a bathome is the more likely it is to not sample the variation within that bathome, and thus the more likely it is to exclude or inadequately sample ecosystems. For example the only substrate type mapped by the Commonwealth is Shelf Rocky Reef which represents 19% of the bathome Shallow Upper Slope in the Central Eastern Province. The Commonwealth proposes reserving 4.1% of this bathome yet manage to totally exclude Shelf Rocky Reefs and the species and ecosystems they support.

4.1. The Depth Effect

Depth has a profound effect on species distributions in marine environments. This is supported by numerous studies and is accepted by the Commonwealth who have taken depth into account in their "bathomes". Unfortunately the Commonwealth have failed to adequately account for depth in designing their proposed reserves. This section seeks to reinforce the importance of depth in delineating fish communities and ecosystems, and the need to adequately sample it in order to establish a CAR reserve system.

From their study of the south-eastern Australian continental shelf Bax and Williams (2001) note *"Generally, inner-shelf sediments (≤40 m) are less stable, more sorted and rippled by water currents and storm events. Outer shelf sediments (≥80 m) are more stable, have higher levels of bioturbation and are less rippled by water currents; mud is present in localised areas*." They go on to state *"Physical factors that cause changes in sediment size and bottom ripples with depth also affect the distribution of invertebrates and fish. Both show distinct trends with depth …"*

Williams and Bax (2001) delineated seven fish communities based primarily on depth and latitude, noting *"Consistent groups were formed by samples from inner-shelf depths 1 and 2 (25 and 40 m), outer-shelf depths 3 and 4 (80 and 120 m), and the shelf break depth 5 (~150-200 m) with very few 'cross-overs' between groups"*.

Gray and Otway (1994) studied variations in assemblages of demersal fishes occurring in different depths of water (30, 60 and 100 m) on the inner continental shelf off Sydney and found:

> *Classification analyses showed that assemblages of demersal fishes at 30 and 60 m depth were most similar to each other and that they consistently differed from those at 100 m depth. This difference may reflect a change in the demersal ichthyofauna from a nearshore to an offshore assemblage. The depth-delineated differences between assemblages agree with those found in similar studies on demersal fishes in coastal waters elsewhere. The distributions and relative abundances of many species differed markedly among depths, but such differences were not always consistent between localities or throughout time. Despite this, some species showed some temporal affinity with a particular site and/or depth.*

DPI and CSIRO (2009) developed a model for their assessment of NSW Fisheries; vertically it was based on the zonation of water properties and pelagic organisms, with depth breaks of 20m, 50m, 100m and 200m used.

Zooxanthellate corals are generally limited in their depth distribution by light and thus are usually found in depths of less than 30–50 m in relatively clear water.

From their review of bycatch of bony fish (teleosts) in the Eastern Marine Region (EMR) Graham (2007) consider:

> *Analyses of the trawl data for teleosts showed that species diversity and assemblages varied geographically and with depth, and that most species were depth-dependent. Of the 306 species of non-commercial bycatch teleosts recorded in survey trawls off central and southern NSW (K. Graham, unpublished data), almost 27% were caught exclusively on the inshore grounds (< 90 m) and nearly 30% were endemic to the midslope zone (650–1200 m); less than 25% of the total number of species was caught in two or more of the depth zones and only a single species (Apogonops anomalus) was recorded in all depths .... Data for the Queensland trawl grounds (Courtney et al. 2007) showed that about 40% of bycatch teleosts were confined to the inshore depths, 25% were caught only in depths greater than 90 m and the remainder spanned both depth zones.*

	NSW			Queensland		
Depth zone(s)	**T**	**N**	**% of total**	**T**	**N**	**%**
Inshore (0-90 m)	126	82	26.8	182	103	42.1
Shelf (90-200 m)	74	23	7.5	142	63	25.7
Upper slope (200-650 m)	77	36	11.8			
Mid-slope (650-1200 m)	116	91	29.7			
Inshore – shelf		33	10.8		79	32.2
Inshore - shelf - upper slope		10	3.3			
Inshore - shelf - upper slope - mid-slope		1	0.3			
Shelf - upper slope		6	2.0			
Shelf - upper slope - mid-slope		1	0.3			
Upper slope - mid-slope		23	7.5			
Total number of species		306			245	

Depth distributions of bycatch teleosts on NSW and Queensland trawl grounds, from Graham (2007). T: total no. of species in each depth zone; N: no. of species exclusive to depth zone or across two or more zones.

Graham (2007b) identified the depth ranges for 200 species of sharks and rays (chondrichthyans) found in the EMR.

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

Distribution of depth preferences for chondrichthyans found in the EMR, from Graham (2007b).

The above tables illustrate that reserves only sampling the inshore waters (i.e. less than 90m depth) of the continental shelf and slope totally excludes the habitats of 60% of bony fish species (caught as trawl bycatch) and 50% of sharks and rays.

For the Temperate East region the Commonwealth relies on Australian continental scale shelf provinces to identify bathomes for fish of the shelf:

- Coast 0-15m
- Coast to shallow Shelf Transition 15-70m
- Shallow Shelf 70-100m
- Shallow Shelf to Deep Shelf Transition 100-120m
- Deep Shelf 120-150m
- Deep Shelf to Shelf Edge Transition 150-165m
- Shelf Edge 165-225m

The Coast and Coast to shallow Shelf Transitions occur predominately in State waters, while from the Shallow Shelf to Shelf Edge are predominately within Commonwealth waters. The bathomes of the shelf waters over 70m deep cover 28,003 square kilometres of the continental shelf within the Temperate East Marine Region. Of this, 441 km^2 (1.6%) are in existing State reserves, with 46 km^2 (0.16%) fully protected in sanctuary zones. The Commonwealth is now only proposing to include an extra 557 km^2 (2%) of theses within reserves, and these are all Multiple Use Zones which equate to IUCN class VI reserves. None of the shelf bathomes north from Coffs Harbour, and the distinct ecosystems that occur there, are proposed for protection.

Multiple Use Zones are proposed to allow a variety of commercial fishing gears and methods, though are proposed to exclude:

—demersal gillnet
—demersal longline
—danish seine
—demersal trawl

This means that they provide partial protection to bottom-dwelling (demersal) species but none to species that utilise the water column (pelagic species).

The low survival rate for released fish that have been caught in water depths greater than 40 m demonstrates that the traditional use of legal minimum sizes to increase survival to spawning sizes and hence maintain stocks is not a viable management option.

The Shelf Edge encompasses the boundary of the epipelagic zone, up to around 150-200m depth, where there is sufficient light for photosynthesis. This extends across the open ocean. SCBD (2008) note:

> *The most pronounced depth-related change in faunal composition occurs at the transition from continental shelf to continental slope (shelf-slope transition), and is probably due to differential adaptation by species to increasing environmental predictability on the upper slope.*

The Deep

Many deep-sea species are widespread (albeit often disjunctly), and others are endemic, restricted to small areas such as isolated seamounts, submarine ridges, or canyons of the slopes. Many of the deepwater species have biological characteristics (slow growth, long lives, low rates of natural mortality, episodic recruitment, late maturation, aggregating behaviours, etc.) that make them particularly vulnerable to overexploitation. Deepwater sharks have been found to be particularly vulnerable species with low resilience to fishing and slow replacement rates. A variety of deep-sea fish have maximum ages of at least 100 years, and can take over 30 years to mature.

Williams et. al. (2005) note:

> *Depth is the strongest environmental correlate of fish community structure in the deep temperate Australian marine environment ... and the southeastern upper slope ... has a distinct demersal fish community that differs markedly to those at the adjacent shelf-break and the mid-slope.*

For individual species there are considerable differences in their depth ranges from a few hundreds of metres to more than a thousand metres. The juveniles of many species of demersal fish tend to live at shallower depths than adults.

The source of food for deepwater fishes is almost entirely derived from primary production in the euphotic zone and thus the composition and density of deepwater fish is related to the productivity of surface waters. Food availability also decreases with depth. The notable exception being the specialized fauna associated with hydrothermal vents.

The mesopelagic zone (approximately 200m to 1000m) extends down to the limit of light. Many of the creatures that inhabit these waters undergo daily migrations to the surface to feed at night, returning to deeper water during the day to avoid predators. Mesopelagic fishes are the main consumers of zooplankton, larval and juvenile fishes, and are important prey for the higher producers, such as tunas, squids and marine mammals (SCBD 2008).

Graham (2007, 2007b) identifies distinct zonation for some fish and sharks with depth, with peaks in diversity in mid-slope waters (300-1,200m) and inshore waters. Gordon (2005) considered that there was not any pronounced zonation of deepwater demersal (bottom dwelling) fishes, but rather a gradual replacement of species, with zonation usually associated with physical phenomena. Although he does note that the number of species in any given depth zone changes with depth, usually decreases rapidly below about 1500 m. and that the rate of change in species tended to be greatest at around 2000 m depth. At some locations populations and biomass can peak at around 1,000 to 1,500m depth.

From their sampling of the West Australian continental slope, Williams et. al. (2001) found:

> *Off western Australia, bathymetric boundaries were distinct in the slope fish fauna, and zones were defined. Delineation was most distinct between shelf-break and upper-slope communities at about 250 to 350 m, and between upper-slope and mid-slope communities at about 700 to 800 m; shallow and deep communities were also evident on both the upper-slope and mid-slope, with boundaries at about 500 m and 900 to 1000 m.*

NORFANZ (2006) found that the distribution of fauna as a whole was primarily influenced by depth (<500m, 500-1,000m and >1,000m) and latitude, even at these depths there were apparent influences from the tropical Coral Sea and temperate Tasman Sea.

For the Central Eastern Province the Commonwealth relies upon an analysis of demersal fish to identify depth related breaks to define bathomes for deeper fish of the continental slope down to 1500m depth:

- Shelf Edge to Upper slope Transition 225-265m
- Shallow Upper Slope 265-485m
- Shallow Upper Slope to Deep Upperslope Transition 490-610m
- Deep Upper Slope 610-830m
- Deep Upper Slope to Shallow Mid-slope Transition 830-910m
- Shallow Mid-slope 910-1080m
- Deep Mid-slope 1080-1500m

These bathomes encompass 21,723 km^2 of the whole of the continental slope in the Temperate East Marine Region. The Commonwealth proposes including 1,452 km^2 (6.7%) of the mid and upper slopes in reserves and all of these are to be Multiple Use Zones with an IUCN class of VI. This will only limit some bottom fishing. None of the slopes north from Coffs Harbour, and the distinct ecosystems that occur there, are proposed for any level of protection.

The Commonwealth utilises a series of depth related breaks to identify the deepest bathomes throughout the region:

- *The 1,500m depth break is the apparent faunal break in fish communities; consistent with transition of the Antarctic Intermediate Water mass, other upper/intermediate water masses, and Deep Water masses; approximates the depth of the aragonite saturation horizon (ASH) which affects the distribution of faunal with calcium carbonate skeletons (e.g. stony corals).*

- *The 2,500m depth break is the approximate depth of continental slope-continental rise boundary; upper bound of Deep Water; roughly coincident with possible emergence of a barnacle/anemone/gorgonian based deep water community associated with deep rocky sea floor.*

- *The 4,000m Abyssal plain depth break is a traditional geological boundary point.*

- *The 5,000m depth break is the calcite compensation (oceanographic) boundary point.*

There can be no doubt that the bathomes identified by the Commonwealth reflect real changes in the distribution of biota and ecosystems. It is also apparent that within each bathome there will be significant changes in the distribution of biota and ecosystems in response to latitude, substrate and a variety of other influences on the distribution of species. This means that each bathome will encompass a variety of ecosystems. If the intent is to reserve a full range of ecosystems, reasonably reflect biotic diversity within those ecosystems, and have the required level of reservation to ensure the ecological viability and integrity of ecosystems, this will require the reservation of substantial areas of each bathome from throughout its range. For adequacy the goal should be to fully protect at least 20-50% of each bathome.

4.2. Trawling through the debris

Twenty-one commercial fisheries can operate in the Temperate East Marine region. Fishing effort is relatively concentrated along the continental shelf and slope and in state waters adjacent to the region. This review focuses on bottom (demersal) trawling as this is the most destructive method used, though other fishing methods are having significant impacts on fish, including demersal species. It also focuses on deeper waters as it is the species of the deep that are most vulnerable to fishing.

Deep-sea fisheries are generally considered to be fisheries conducted for bottom dwelling species below 400 m. Many deepwater fish species are highly vulnerable to overfishing because of their unique biology and adaptation to deep-sea environments.

Three major gear types used in deep-sea bottom fishing: gillnets, longlines, and bottom trawls. Bottom trawling is most commonly used and is the most destructive. With current technology bottom trawling is limited to slopes less than 20-30^o and depths less than 2,000 metres. Longlines can extend down to 3,000 metres.

Gianni (2005) considers:

> *The environmental or ecosystem impacts of bottom fishing in the deep-sea are characterized as two-fold. One is the impact of the removal of large quantities of biomass (fish populations) from the food web of 'food-poor' or low energy environments characteristic of the deep-sea. The other is the physical impact of fishing on ocean-bottom ecosystems, primarily coral, sponge and other filter feeding species that often provide the basic structure of seamount and other ecosystems and which are also found along continental slopes, canyons and ridges throughout the world's oceans.*

There is increasing commercial development of deep-sea fisheries as traditional inshore stocks decline and boats move further offshore and into deeper water in attempts to sustain or increase catch levels.

Deep-sea fisheries are often characterized as 'serial' or 'sequential depletion' fisheries because fishing vessels find and deplete a stock, then move on and repeat the practice (Gianni 2005). Most deepwater fisheries around New Zealand and Australia have a history of rapid development and then rapid decrease after several years of high catches (Annala and Clark 2005). As noted by Bax *et. al.* (2005) *"Deepwater fisheries seem particularly prone to a boom and bust cycle".*

Pitcher et. al. (2010) identify:

> *Collapse and depletion of many historical inshore and shelf groundfish stocks in the late 1900s encouraged fisheries to expand into deeper water and, in particular, to seamounts. Since the 1970s, advanced gear technology has enabled fishing in increasingly compromised overfished shelf waters, in deeper water, and on small, steep, and rough seamount flanks that previously could .not be trawled.*
>
> *...*
>
> *However, few of these large-scale seamount fisheries have proven sustainable. Both within and among regions, serial depletion is evident as the fishing fleets moved on from one seamount to the next ...and often to another target species as the initial stocks were overexploited.*

The Secretariat of the Convention on Biological Diversity (SCBD 2008) note:

> *Rapid increase in catches of primary seamount species in the mid-1970s resulted from the availability of technology to find and explore deeper and distant fishing locations, such as seamounts. Catches of primary species appear to have peaked overall by the early 1990s, by which time it is likely that almost all productive seamounts were accessible to fisheries. It has been suggested that the apparent increase in catch was sustained by serial depletions of previously unexploited and inaccessible stocks. Serial expansion and depletion of seamount fisheries is also suggested by an increase, since the 1970s, in the catches of non-pelagic fishes from seamounts that are highly intrinsically vulnerable to fishing.*

Koslow *et. al. (*2001) note:

> *Trawl fishing has not only intensified, it has also expanded into a range of hard rocky and reefal environments not previously accessible to this gear, based on the development of*

> *strong synthetic net fibres, rockhopper gear—large rubber bobbins and metal discs along the footrope—and precise electronic positioning systems both for the vessel and to monitor net performance.*

Trawling is a major threatening process in the marine environment. Its indiscriminate nature is a major threat to most marine ecosystems, aside from those too rugged to be trawled or at depths too deep to reach. There are a variety of marine seabed habitats that have also been identified as particularly vulnerable to fishing, including soft corals, polychaetes hummocks, sponge beds and reefs, bryozoan reefs, deep-sea coral communities and stable sediments of deeper waters. In general, vulnerability of ecosystems to trawling increases with depth and habitat complexity. There is an increased need to protect adequate areas of those ecosystems and species most vulnerable to trawling.

The NSW Ocean Trawl Fishery (OTF) extends from the Queensland border in the north to the Victorian border in the south. North of Barrenjoey Point (Sydney) the boundaries extend from the coast to the 4000 m depth contour. The fishery targets prawns and fish by dragging a demersal trawl net along the sea floor. More than 300 species of fish and about 80 species of mobile invertebrates were recorded in fish and prawn trawl catches from NSW waters during the 1990s. Of those caught, at least 120 species of fish and 30 species of invertebrates are sold. Prawn trawlers off the northern half of NSW target mainly prawns, cephalopods and whiting (Graham 2007).

There are three components to the Ocean Trawl Fishery which use a common type of fishing gear (the demersal trawl net):

1. A prawn trawling sector targeting school prawns, school whiting, and eastern king prawns in depths down to 200m, mostly north of Newcastle.

2. A deep water prawn trawling sector targeting royal red prawns depths of 400 - 600 m, mainly off the central and lower north coasts, between 29°S and 35°S.s

3. A fish trawling sector targeting fish species on the continental shelf and slope grounds down to 1,100 metres between Smoky Cape (approx. 31°S) and the Victorian border

The apparent exclusion of the continental slopes in the vicinity of the Tweed-Byron Marine Reserve from trawling makes this area a high priority for conservation on the assumption that the complex and vulnerable ecosystems on the seafloor are <u>relatively</u> undisturbed.

NSW Department of Primary Industries' (DPI 2004) Ocean Trawl Fishery (OTF) Environmental Impact Statement identifies the profound ignorance that management of the industry is founded on:

> *The risk assessment conducted on the existing ocean trawl fishery found that almost all activities of the fishery are likely to pose a risk to most components of the environment. In particular, trawling, harvesting and discarding pose the greatest risk to the components of the environment including primary and key secondary species, non-commercial bycatch species and habitats. Although not all aspects of the activity were found to affect all components of the environment, it was apparent that inappropriate gear selectivity, lack of stock assessments of the primary and key secondary species, poor understanding of discard composition and magnitude, knowledge gaps of biology and ecology of species and ecological interactions, lack of knowledge about the distribution and types of marine habitats with respect to trawling activities all pose a risk to the environment.*
>
> *...*
>
> *There are a number of substantial knowledge gaps that hinder the ocean trawl fishery from being managed and fished in an ecologically sustainable manner. Specific knowledge is needed on the location of trawl grounds for each sector of the fishery, the frequency the grounds are fished and by how many fishers. There is little to no knowledge on the ecology and basic biology of many of the primary and key secondary species. Research on the interactions among fish species and non-target species, interactions of fish with the*

> *environment and habitats, stock and community structure, and spatial and temporal complexity of fish stocks has received little attention in the ocean trawl fishery.*

In their review of the East Marine Region, the Australian Museum (Keable 2007) identify trawling as a primary threat to crustaceans; demersal fish; echinoderms; marine snakes; molluscs; seabirds; sharks and rays; sponges; and syngnathids. Also for turtles where Turtle Exclusion Devices are not used.

Turtle exclusion devices are not mandatory in NSW ocean trawl nets. Prawn Trawlers in the Tweed-Byron area apparently regularly catch turtles, though this is not reported to NSW Fisheries (T. Puglisi pers. comm.). DPI (2004) note:

> *... the eastern population of Loggerhead turtles are estimated to be only able to withstand 100 human induced deaths per year (C. Limpus, Qld EPA, pers. comm., 2003). ... Whilst one fishery, such as OTF, may only encounter these turtles a few times and as a result the turtles die, these deaths may push the human induced mortality over the threshold of 100 and hence impair the recovery of this species. Therefore, it is not sufficient protection for some threatened species to rely solely on the minor incidences of encounters and conclude that no action should be taken to minimise the risks.*
>
> *...*
>
> *Turtle exclusion devices (TEDs) set in prawn trawl nets in Queensland are effective at allowing turtles to escape from nets but these devices are not used in NSW.*

Examples of the impacts of trawling and its management on bycatch, pipefish, dogfish, orange roughy, deep water corals and sponges are provided in following sections. For their 2004 EIS DPI assessed the risk posed by the OTF to the 40 species primarily caught, noting:

> *Five species of finfish were at the highest level of risk, all of whom were elasmobranchs – fiddler, angel and saw sharks and greeneye and Endeavour dogfishes. These species are at highest risk due to their low resilience and factors such as low refuge availability, poor selectivity of fishing gear and inadequate stock assessments.*
>
> *Seven species of finfish and two species of shellfish had moderately high levels of risk. Silver trevally and redfish have relatively high resilient biological characteristics but are growth overfished (Rowling and Raines, 2000) indicated by declining catch trends and small sizes of landed fish, have aggregations that are targeted by fishers, and low availability of refuges from fishing mortality. The remaining finfish species in this category of risk all have inadequate stock assessments, declining catch trends and poor gear selectivity. The total stocks of eastern king and school prawns are growth overfished (Montgomery, 1999).*
>
> *Eight species of finfish and four species of shellfish are at intermediate risk of becoming unsustainable primarily because of their declining catch trends. Species of greatest concern in this category are the three elasmobranchs, gummy and carpet sharks and stingrays, because of their low resilience.*

DPI and CSIRO (2009) modelled the effects of 8 fishing scenarios, with existing State marine parks excluded from fishing, to identify vulnerable species groups. Under all scenarios the deep demersal fish group was overfished, with skates, rays and dogsharks particularly vulnerable to overfishing. The deep demersal fish group included: Mirror dory, king dory, other dories, hapuku, cucumber fish, painted gurnard, long-finned gemfish, silverside, Whiptails, Beryx, Cardinalfish, spiny flathead and Ribaldo. Surprisingly the identified plight of these species was not discussed.

Koslow *et. al* (2000) state:

> *Exploited deepwater (>500 m) species generally exhibit clear "K-selected" life-history characteristics markedly different from most shelf species: extreme longevity, late age of maturity, slow growth, and low fecundity. Many also aggregate on restricted topographic features such as seamounts, and as a consequence are notably unproductive, highly*

> *vulnerable to overfishing, and have potentially little resilience to overexploitation... Most deepwater stocks are today overfished or even depleted. Depletion of species from deep-sea environments that dominate mid to upper trophic levels may have long-term ecological implications, but the risks of reduced stock size and age structure to population viability, the potential for species replacement, and the impacts on prey and predator populations are not generally known. However, trawl fisheries have been shown to have potentially severe impacts on the benthic fauna of seamounts, where these fish aggregate. This fauna, dominated by suspension feeders, such as corals, is typically restricted to the seamount environment and is characterized by high levels of endemism, which suggests limited reproductive dispersal. The ability of the benthic community to recover, following its removal by trawling, is not known.*

Many species inhabiting seamounts are endemic or have restricted distributions, which when combined with slow growth rates and recruitment, makes many particularly vulnerable to human impacts and the risk of extinction (Koslow *et. al* 2000, Koslow *et. al.* 2001, Gianni 2005). Bottom-trawl fishing poses a major threat to the biodiversity of vulnerable deep-sea habitats and ecosystems (Gianni 2005).

In their 2004 EIS for OTF, DPI recognises that trawling can cause fundamental shifts in species compositions:

> *Trawling is a relatively non-selective fishing method that catches a variety of species with a range of life-history characteristics. Such non-selective removal can cause increases in the relative abundance of species with shorter life histories, because species that are larger, slower growing and late maturing (e.g. elasmobranchs) will decline to a greater extent than smaller, faster growing species (Gislason, 2002; Link et al., 2002; Kirkwood, et al., 1994; Jennings et al., 1999). Major changes in demersal fish assemblages consistent with this scenario have occurred off the NSW coast in SEF trawl grounds (Andrew et al. 1997). These changes included a major reduction in the total fish biomass and a marked decline in the relative abundances of larger/older fish, and major reductions in the abundance of species with longer life histories, and were attributed to harvesting by the SEF over the past 20 years. There is no equivalent data specifically for the NSW Ocean Trawl fishery, however similar changes are likely to have occurred.*

DPI (2004) emphasise the need to establish substantive trawling exclusion areas, noting:

> *The trawl fishery has expanded its operations onto hard-ground low reef habitats by using modified trawl gear that are equipped with large bobbins/rollers as indicated by the reef fish species being recorded on the fishers returns. This expansion is likely to be causing major impacts on these habitats. If this degradation continues it is likely that productivity will decrease and the sustainability of some species may be threatened.*
>
> *Adequate refuge areas from trawl fishing are needed to conserve habitats. In particular there is currently limited protection for soft-sediment habitat, low reef and habitat forming animals and plants that live in these habitats from the impacts of fishing. There is a need to protect representative areas of these habitats if risks are to be mitigated.*
>
> *…*
>
> *Because habitats are critical for maintaining species assemblages, sustainable ecological processes and biodiversity, habitat loss and fragmentation are the greatest threats to these components becoming unsustainable. Substantial efforts must be made in a number of areas to conserve and, where appropriate, restore lost habitats due to the activities of the fishery. Until the spatial and temporal extent of trawl grounds, species assemblages, interactions between trawling and ecological processes and the level of intensity of trawling on these grounds are known, refuges will be needed to protect species biodiversity, species assemblages and ecological processes.*

They go on to identify a variety of management responses to reduce the impact of trawling, including 1.1b *" Implement a series of closures to trawling to protect the range of ocean habitats and associated biodiversity, including closure of all reefs and depths greater than 1100 metres".* They note:

> *Establishment of refuge areas – as a precautionary measure a series of closures to will be implemented to protect a range of habitats until more information about the different types and spatial extent of habitats is gathered, including closing all waters beyond the 1,100 metre depth contour*
>
> *Closure of all reefs – the closure of all reefs (i.e. all hard rock) is a firm step to reducing the risk on these habitats and will have flow on effects to fish productivity and ecological sustainability*

DPI (2004) identifies fishing closures as the most important single management response for all the species identified at highest risk from trawling:

> *Implementation of closed areas ... and establishment of refuge areas ... would have a significant affect in reducing the fishery impact on these species provided they are appropriately designed. There are three purposes for the proposed closures – habitat protection, refuges for adult/juvenile populations and protection of spawning areas. Closures to protect habitats will benefit species at moderately high (and intermediate) risk by reducing the indirect effects of fishing on them. Protecting habitat will potentially allow ecological processes, such as food webs and species interactions, to occur with minimal impairment. It will also protect the sources of food of primary and key secondary species. These indirect benefits will contribute to the reduction of risk of all species at high, moderately high and intermediate risk.*
>
> *...*
>
> *... This would require the application of a precautionary approach to the detailed design of the closures, with a subsequent adaptive approach for further refinement. Such an approach should include closures that cover continuous areas of habitat across a range of depths, such as several strip closures that extend from the coast out to the lower continental slope. Only closures that demonstrate a high level of precaution until the necessary information required for specific designs is obtained will adequately contribute to reduction in risk to the primary and key secondary species.*
>
> *...*
>
> *The establishment of refuge areas is the most effective means of reducing risk to species diversity, assemblages and ecological processes in the information poor environment of the OTF. ...Implementing closures specifically to protect a range of marine habitats, including some oceanic waters outside three nautical miles, will have a positive affect on helping to maintain species diversity and assemblages ...*

DPI (2004) identified sharks and rays as being most at risk from trawling, calling for *"immediate action to reduce the high risk"* that *"will need to entail such things as providing adequate refuges from fishing mortality and protecting pupping and nursery areas"*. From his review of dogfish management Musick (2011) concluded "*perhaps a reasonable goal for establishment of dogfish protected areas would be at least 35% of total suitable bathyal habitat".*

With existing reserves, the proposed Commonwealth reserves increase the protection of Continental shelf waters >70m deep from bottom trawling to 3.6%, with numerous ecosystems totally excluded from proposed reserves. Similarly the Commonwealth proposes including 6.7% of the mid and upper slopes in reserves that will exclude bottom trawling, again excluding numerous ecosystems. This is a grossly inadequate response to a severe threatening process and does not provide adequate protection to vulnerable ecosystems.

ANZECC (1999) note that *"The principle of representativeness implicitly requires that the MPA system also includes those marine ecosystems that are rare, vulnerable or endangered"*. Action 4 is given as *"Assessments and mapping of rare, vulnerable and endangered marine ecosystems will be carried out, in association with an analysis of threatening processes".*

The vulnerability of habitat to threatening processes is an important indicator of both the urgency to protect a habitat and the extent to which it should be protected. Roberts *et. al.* (2003) note that *"The presence of intact habitats that can easily be damaged or changed by human activities increases priority of an area as a reserve. Vulnerable habitats often contain structures that are biologically generated rather than the result of physical processes."*

Pressey and McNeill (1996) consider that "*If priority is defined at least partly in terms of vulnerability, or the need for reservation, then reserves can be focused more effectively to pre-empt the loss of features, thus maximising the persistence of biodiversity in a region, whether it is reserved or not.*

Many species of deeper waters have characteristics that make them particularly threatened by fishing. The Commonwealth's failure to responsibly manage Orange Roughy and other deep sea fisheries, and its ongoing failure to take adequate action to protect decimated populations of marine predators, highlight the need for adequate reservation of outer shelf and upper slope waters, along with seamounts.

Given the known vulnerability of ecosystems and species in these deeper waters to the impacts of trawling and the identified necessity of creating fishing exclusion areas to mitigate impacts of the Ocean Trawl Fishery, the Commonwealth's proposals are grossly inadequate. Not only have they failed to protect a comprehensive or representative sample of ecosystems, it is obviously not an adequate sample.

Given the profound ignorance of these waters and their inhabitants a precautionary approach requires greater protection, not less. The Commonwealth must act decisively to ensure that adequate protection is afforded to shelf and slope habitats and that large representative samples of all ecosystems are fully protected from trawling. Conservation of vulnerable fish species requires the establishment of substantial areas from which fishing is excluded so as to allow recovery of natural processes, healthy substrates and fish stocks, and to protect against recruitment overfishing.

4.2.1. Bycatch

Trawling is an indiscriminate fishing method. Aside from trawling's impact on targeted commercial species, there is the problem of bycatch that is discarded and killed. Kennelly *et. al.* (1998) assessed by-catch from oceanic prawn trawling from four ports in NSW (including Ballina) and found:

> *In catching an estimated 1 579t of prawns during the two-year survey, the oceanic prawn trawlers from the four ports were estimated to have caught approx. 16 435t of by-catch (a by-catch-to-prawn ratio of 10.4 : 1). Of this by-catch, 2 952t were estimated to have been retained for sale and 13 458t were discarded – including several million individuals of commercially and recreationally important species (e.g. snapper, eastern blue-spot flathead, red-spot whiting).*
>
> *The weights of discarded by-catches per trip … were greatest for Ballina …*
>
> *...Ballina's total retained catch to discard ratio was 1: 5.14.*
>
> *… with stout whiting, red-spot whiting, cuttlefish, snapper, smooth bugs, eastern blue-spot flathead and small toothed flounder all estimated to have more than 1 million individuals discarded during the two-year period for all four ports.*

> *… other studies have shown that a small but variable proportion of the discarded by-catch can survive.*

For their 2 year period Kennelly *et. al.* (1998) estimated that for a prawn catch of 166.4 tonnes at Ballina the bycatch was 2,667.6 tonnes, of which 2,370.7 tonnes (89%) was discarded. The total discards of fish from Ballina's oceanic prawn trawlers was estimated to be 5,976,100 individuals, most notably including: 3,296,800 Stout whiting, 732,100 Red-spot whiting, 554,400 Eastern blue spot flathead, 288,500 Smooth bug, 223,900 Balmain bug, 216,900 Small-toothed flounder, 214,400 Cuttlefish, 199,400 Red mullet, 56,100 Snapper, 37,900 Spikey flathead, 30,200 Three spot crab, 20,000 Northern sand flathead, 19,700 Bruce's bug, 18,700 Marble flathead, 13,800 Shovelnose ray, 12,600 Large-toothed flounder, and 12,500 Mulloway.

DPI (2004) cites a similar assessment for fish trawlers:

> *Fifty percent of the total catch (over all years and ports) was discarded by fish trawlers and 54 % of the discarded catch consisted of non-commercial species (Figure B2.8). The quantity of non-commercial bycatch discarded from fish trawls varied little between or within years ....*

Graham (2007) identifies that overall discard rates of non-commercial species on NSW grounds fished by trawlers in the 1990's ranged between 30% of the total catch weight by offshore fish-trawlers to more than 60% of catch weight by prawn trawlers. From their assessment of the risk posed by trawling to bycatch in the Ocean Trawl Fisheries (OTF) , DPI (2004) considered that:

> *Ninety five percent of the non-commercial bycatch species (fish and invertebrates) had a high or moderately high level of risk .... Clearly, the majority of the non-commercial bycatch in OTF appear to be at substantial risk from the activities of the OTF.*

Bycatch reduction devices (BRDs) were subsequently introduced into the NSW Offshore Prawn Trawl (OPT) fishery to reduce discarding rates. They are not considered appropriate for fish trawling.

In their 2004 EIS DPI notes:

> *While the use of bycatch reduction devices by all ocean prawn trawlers were made mandatory in July 1999, there has been little work done to assess the effectiveness of the devices under normal commercial trawling conditions. There has been no onboard monitoring of ocean prawn trawlers since the compulsory introduction of bycatch reduction devices.*
>
> *...*
>
> *... Internal studies done by NSW Fisheries (Ashby, 1999; Broadhurst, 2001) suggest that the BRD fitted to ocean prawn trawlers are ineffective under some conditions. Research is required to determine whether the range of BRD actually used by fishers whilst trawling do reduce the bycatch of unmarketable commercial species.*

Graham (2007) assessed trawling bycatch of bony fish, noting that "*most bycatch teleosts are small, lower-order carnivores feeding on smaller fish and invertebrates while, in turn, being prey for the larger carnivorous fish.*", and stating:

> *Continued fishing pressure is likely to have the greatest impact on bycatch species and the high levels of discarding in trawl fisheries has generated worldwide and local concern (e.g. Andrew & Pepperell 1992; Buxton & Eayrs 1998; Kennelly et al. 1998). Studies of shallow water trawling showed that 80–90% of teleosts do not survive when discarded (Hill & Wassenberg 1990; Wassenberg & Hill 1989), and this mortality figure is probably closer to 100% for deepwater trawl bycatch which are exposed to severe barotrauma and water temperature changes during capture. The Environmental Impact Assessment for the NSW OTF concluded that 95% of bycatch species (fish and invertebrates) on NSW trawl grounds were at a high or moderately-high level of risk (DPI 2004).*

The Commonwealth (DSEWPC 2011) identifies bycatch as a threat to most important protected species and key ecological features:

> *Bycatch from commercial fishing activities has been assessed as of concern for inshore dolphins, killer whale, marine turtles (green, loggerhead and leatherback), the grey nurse shark and foraging seabirds (selected petrel, albatross and shearwater species). It is considered of potential concern for sea snakes, hawksbill turtle, white shark, eastern gemfish, syngnathids, foraging seabirds (selected shearwater, albatross and petrel species) and a number of key ecological features (Tasman Front and eddy field, upwelling off Fraser Island, Norfolk Ridge, Tasmantid and Lord Howe seamount chains, shelf rocky reefs and canyons).*

4.2.2. Seafloor

Bottom trawling and dredging have been identified as the most destructive and widespread forms of disturbance to marine seabed habitat, and thus one of the most significant threatening processes to the marine environment (Probert *et. al.* 1997, ASEC 2001, Jackson 2001, Bax and Williams 2001, Koslow *et. al.* 2001, Kaiser *et. al.* 2002, Ponder 2003, Avery 2003, Gianni 2005, Hooper 2007, Graham 2007, Keable 2007, SCBD 2008, Pitcher et. al. 2010). As noted by Avery (2003) bottom trawling *"is analogous to vegetation clearing in terrestrial environments"* and *"may result in temporary to permanent decrease in habitat complexity and biodiversity".*

Inshore sedimentary substrates are naturally subject to severe disturbances from wave and storm action and thus relatively resilient to disturbances within the realm of natural disturbance regimes. It is the more stable sediments of deeper waters and hard substrata that are particularly vulnerable to alteration and modification by trawling (Turner *et. al.* 1999, Bax and Williams 2001, ASEC 2001, Kaiser *et. al.* 2002, DPI 2004, Gianni 2005, SCBD 2008).

Turner *et. al.* (1999) consider:

> *Fishing activities, such as trawling and dredging for fish and shellfish, where mobile fishing gear is towed across the sea bed, have the capability of altering, removing or destroying the complex, three-dimensional physical structure of benthic habitats by the direct removal of biological (e.g. sponges, hydroids, bryozoans, amphipod tubes, shell aggregates and seagrass) and topographic (e.g. sand depressions and boulders) features. These impacts are in addition to documented effects of fishing on sediment dynamics (e.g. sediment suspension and deposition), sediment chemistry (e.g. alteration of the sediment chemistry and changes in the availability of toxic contaminants) and benthic/pelagic nutrient fluxes ...*

DPI (2004) note

> *The activity of trawling has the potential to have the greatest impact on species diversity because it has a direct affect on habitats that contribute to this diversity. Gray (1997) cites habitat loss as the greatest threat to species diversity. It can both decrease the number of species in a particular habitat type and change the composition of the species in a habitat. For example, trawling over low profile rocky reef can reduce the diversity of sessile species by destroying and removing entire assemblages of these species over a relatively short space of time, particularly if areas are trawled repeatedly in a season or year (e.g. Sainsbury, 1988). Because these sessile species, such as sponges and gorgonians, often provide habitat to other species, such as fish, molluscs and crustaceans, their removal from an area can lead to lower species diversity for a number of taxa and change the composition of other taxa (Gray, 1997).*

The impacts of trawling increase with trawling frequency. Jackson (2001) considers *"Mechanized bottom fishing reduces abundance of echinoderms, mollusks, and worms by 10–90% each time the bottom is fished …Most areas are dredged many times per year, thereby flattening the bottom*

…Large sponges, bryozoans, corals, worms, or bivalves that provide important habitat for commercially important fishes and numerous smaller invertebrates are virtually eliminated …Large species that form these habitats grow so slowly that they cannot recover for decades to centuries".

Kaiser *et. al.* (2002) refer to a study on the Great Barrier Reef that found that, without accounting for individuals detached and not caught, *"each trawl removed and caught between 5 and 20% of the available biomass of sessile fauna, with 70-90% removed after 13 trawls".* Kaiser *et. al.* (2002) state *"Contrary to the belief of fishers that fishing enhances seabed production and generates food for target fish species, productivity is actually lowered as fishing intensity increases and high-biomass species are removed from the benthic habitat".*

ASEC (2001) note *"The impact of trawling depends on the combination of trawl frequency and intensity, and the susceptibility of the habitats and species being trawled. Nonetheless, even infrequent trawls may still cause ecological damage in habitats that are slow to recover".*

The loss of sessile species increases with trawling frequency, and recovery of trawled habitats can take a very long time, particularly in deeper waters. As noted by DPI (2004):

> *When slow growing species are lost from an area, species diversity may stay permanently depleted of these taxa because regrowth and recolonisation is so extremely low. For example, some sponges may take >100 years to regrow (Leys and Lauzon, 1998).*

Kaiser *et. al.* (2002) note *"There is no doubt that as habitat stability increases the relative effects of fishing will also increase as will the longevity and severity of its ecological effects. … hard substrata are also likely to be vulnerable owing to the generally higher abundance of encrusting and erect biota that are damaged by trawls."*

Bax and Williams (2001) state *"even small physical modification to habitats at greater depths than those where storm events penetrate may persist over long periods of time, making those habitats more vulnerable. The time to recovery of ecosystem functions following modification will vary …* [being] *on the order of decades or centuries for slow growing biota (e.g. deep sea corals), and on the order of millennia for structural habitat required by sessile biota for anchorage"*.

As noted by Bax and Williams (2001) *"Recovery of hard-ground habitats is so long term as to be effectively zero, causing any hard-ground habitats with low resilience to modification to be classified as highly vulnerable"*, and *"Productivity in the fishery is likely to decline if the hard-grounds that provide physical refuges are reduced over time"*.

Major threats to sponge reefs and fields include destructive fishing practices such as bottom trawling and other bottom-contact fishing (SCBD 2008). Hooper (2007) notes:

> *But because sponges are generally slow to recruit, slow growing and long lived, they are very vulnerable to anthropogenic and natural disturbances (Roberts et al. 2006). Bottom trawling remains a significant threat to sponges and other sessile invertebrate communities, with some commercially fished areas, such as those based over a soft substrates dominated by organisms like sponges, more susceptible than others. The limited quantitative data currently available shows that each pass of a trawl net along the seabed removes about 5 to 25% of the biota. This effect is cumulative with successive trawls removing an increasingly higher proportion of organisms. Different species have different levels of vulnerability, with especially large sponges particularly susceptible to trawling (Poiner et al. 1998).*
>
> *In addition to the physical alteration or destruction of the seabed by trawling activities, over-fishing also has a highly significant impact upon bycatch species, including sponges. Wassenberg et al. (2001) suggested that most sponges torn from the seafloor and damaged*

by trawl nets probably do not survive after being discarded, and that this bycatch is often a significant component of the bottom trawl fisheries in northern Australia. ...

Bottom trawling is the biggest threat to cold-water coral reefs, causing mechanical breakage of the reef structure. Corals on Tasmanian seamounts were substantially damaged by bottom trawling for orange roughy and oreos (Koslow *et. al.* 2001, SCBD 2008), Koslow *et. al. (*2001) note *"data suggest that virtually all coral aggregate, living or dead, was removed by the fishery, leaving behind bare rock and pulverized coral rubble"*. Once a cold water reef has been extensively damaged by trawling, it is estimated to take decades to centuries for a reef to regain ecological function owing to their very slow growth rate (SCBD 2008).

The New Zealand Ministry of Fisheries placed observers on NZ vessels fishing the newly-discovered South Tasman Rise orange roughy fishery in October 1997. Nevill (2009) cites Anderson (2004) as stating:

Sea floor communities are easily damaged in orange roughy seamount fisheries because they tend to be fragile, erectile, slow growing and susceptible to damage by the heavy fishing gear used.

Between October 1997 and August 2000 observers examined and recorded the contents of 545 trawls, covering 10-22% of the annual New Zealand plus Australian catch. They collected a wide range of specimens, corals in particular.

The most notable outcome of this analysis was the large amount of coral trawled up from the seamounts. Observers recorded coral in the catch of almost 40% of trawls. A hundred kilogram or more of coral was recorded in 12% of trawls and one tonne or more in 5% of trawl, with one catch of 15 t recorded.

Over time, as the coral was gradually removed from the area and fishing effort eased due to declining catch rates, both the bycatch ratio and estimates of total annual bycatch diminished, the latter from about 1750 t to 100 t per year.

From their study of Tasmanian seamounts Koslow *et. al. (*2001) found

The impact of trawling on complex seamount reefs appears to be dramatic, with the coral substrate and associated community largely removed from the most heavily fished seamounts. ...virtually complete loss of this community from the shallow heavily fished seamounts.

…

The substrate of heavily fished seamounts in the area now consists predominantly of either bare rock or coral rubble and sand, features not seen on any seamount that was lightly fished or unfished. The abundance and species richness of the benthic fauna on heavily fished seamounts was also markedly reduced.

The Secretariat of the Convention on Biological Diversity (SCBD 2008) note:

Seamount trawl fisheries also have severe impacts on the benthic communities on seamounts, including fragile habitats, such as cold-water corals and other invertebrates. Comparative surveys of benthic macrofauna community structure at four seamounts found intact coral cover only on the un-fished and very lightly fished seamounts. The substrate of heavily fished Tasmanian seamounts was predominantly bare rock (>90% at most depths), while the existing coral material was either rubble or sand. Data suggest that virtually all coral aggregate, living or dead, was removed by the fishery, leaving behind bare rock and pulverized coral rubble. The results showed that the impact of trawling on complex coral reefs appears to be dramatic, with the coral substrate and associated community largely removed from the most heavily fished seamounts.

Bax and Williams (2001) consider *“Some of the most vulnerable habitats are shelf-break bryozoan reefs …that are soft and lightly attached, have minimal vertical relief (<30cm) and exist in small patches (1-10s of sq. m.). Bryozoan reefs may be completely removed by fishing gear”.*

Stocks (2004) notes:

> *Damage to corals, sponges, anemones, etc., is of special concern because these species provide habitat for rich assemblages of other organisms. Studies have shown that gorgonians (sea fans) provide food, habitat, or shelter for a variety of crinoids, brittlestars, seastars, basketstars, anemones, molluscs, fishes, and crabs (Risk et al., 1998; Krieger and Wing, 2002). A study that examined stalks of glass sponges in one area found 139 associated species (Beaulieu, 2001) and 866 species have been recorded in association with Lophelia pertusa beds (Rogers, 1999). These structure-building species are the same species that are most damaged by trawling; damage to them will likely cause a cascade of disturbance effects throughout the associated communities.*

SCBD (2008) also warn:

> *Ocean acidification presents a potentially serious future threat. Increase in atmospheric carbon dioxide (CO2) can increase the acidity of seawater through increased CO2 dissolution. Acidic water de-saturates aragonite in water, making conditions unfavourable for corals to build their carbonate skeletons. Current research predicts that tropical coral calcification would be reduced by up to 54% if atmospheric carbon dioxide doubled. Because of the lowered carbonate saturation state at higher latitudes and in deeper waters, cold-water corals may be even more vulnerable to acidification than their tropical counterparts.*
>
> *Also, the depth at which aragonite dissolves could become shallower by several hundred metres, thereby raising the prospect that areas once suitable for cold-water coral growth will become inhospitable in the future. It is predicted that 70% of the 410 known locations with deep-sea corals may be in aragonite undersaturated waters by 2099.*

This emphasizes the need to allow deep-water corals to recover from past disturbances to better enable them to cope with the coming changes due to human CO_2 emissions.

4.2.3. Seahorses

Syngnathids include seahorses, pipefishes, pipehorses and sea dragons. Aside from their looks, they are distinguished by the males providing sole parental care by incubating the eggs in pouches or on its body. Their restricted diet, specific habitat requirements, low mobility and low reproductive output make them vulnerable to disturbances.

Syngnathids are a component of the bycatch for trawl fisheries operating off the NSW coast. They are valuable as curios and aquarium fish, and dried specimens are highly sought after in the Traditional Chinese Medicine trade. More than 98% of Australia’s exports of dried syngnathids for use in the TCM trade are the pipehorses *Solegnathus dunckeri* and *S. hardwickii* sourced largely from trawling bycatch on the east coast.

Duncker’s Pipehorse *(Solegnathus dunckeri)* is an endemic Australian species, it is one of four species from the East Marine Region on the IUCN Redlist and one of seven identified as protected in NSW. Duncker’s Pipehorse is the most commonly caught Syngnathid species from the central to the far north coast of NSW. It is trawled from depths between 30 m and 140 m. In an assessment of risk to bycatch species caught in the NSW OTF (DPI 2004) Duncker’s Pipehorse was one of four species of syngnathids identified as being at medium to high risk from fishing operations.

The IUCN Red List of Threatened Species states that for Duncker's Pipehorse:

> *The designation of suitable non-trawl protected areas with bottom structure suspected to support pipehorses in the northern New South Wales and southern Queensland region*

would be a suitable precautionary approach, until the impact of trawling both in terms of direct capture as well as the indirect effects of habitat damage can be established.

4.2.4. Sharks

Around 200 species of sharks and rays occur in the waters off New South Wales and eastern Queensland. The IUCN Redlist includes more than 140 of these, with three species listed as critically endangered, one as endangered and 23 as vulnerable. (Graham 2007b).

Off Queensland and northern NSW there is significant commercial exploitation of whaler and hammerhead sharks for meat and fins. In NSW, several species of demersal sharks are important components of the landed catch as primary or key secondary target species. Many sharks and rays are also caught and discarded as bycatch in trawl fisheries with most, particularly from deepwater, not surviving capture. Their slow growth rates and conservative reproductive strategies make sharks and rays particularly vulnerable to overexploitation. (Graham 2007b).

NSW Department of Primary Industries' (DPI 2004) Ocean Trawl Fishery Environmental Impact Statement assed the risk to sharks and rays (*elasmobranchs)* from the OTF, concluding:

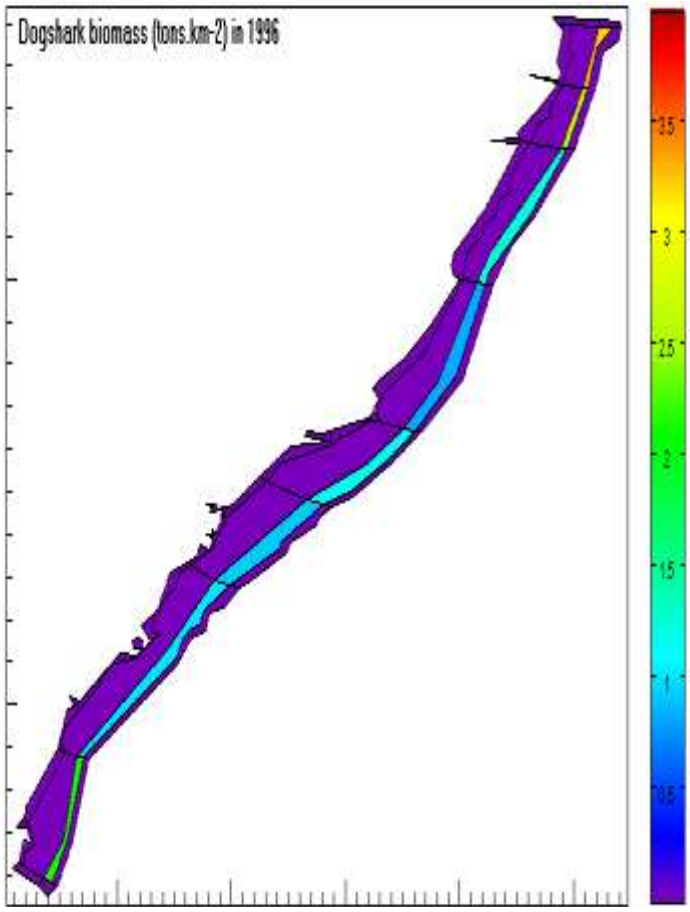
> *All the species with the highest level of risk were elasmobranchs. This group of species is recognised both nationally (Graham et al., 2001; AFFA, 2003a) and internationally (Cavanagh et al., 2003; IUCN, 2002) as being at risk from commercial fishing. Elasmobranchs are particularly vulnerable to trawling because their slow growth rate, long life span and life history strategy is not conducive to rapid recovery after populations have been depleted (Walker, 1998). Specific and immediate action should be implemented to reduce the high risk on these species. Their large size and body shape means they will not respond to changes in gear selectivity as for some species of teleosts. Consequently, management strategies will need to entail such things as providing adequate refuges from fishing mortality and protecting pupping and nursery areas.*
>
> *...*
>
> *... if adequate attention is given to the design requirements and level of protection needed for elasmobranchs at high risk then this would be a very effective means of reducing the fishery impact, and therefore risk, on these species. The risks to elasmobranchs otherwise will not be reduced effectively*

The Commonwealth Government has been preparing an Upper-slope Dogfish Management Strategy with the objective *"to reduce the ecological risk of fishing on each species identified and to maintain the viability of populations in the wild"*. It is particularly targeted at the Harrison's dogfish which inhabits waters 300-600m south from northern NSW, Southern Dogfish which inhabits waters 210-700m deep south from Forster and the Endeavour Dogfish which inhabits waters 125-820m deep along the east coast.

Australian Fisheries Management Authority (AFMA 2010) note *"Dogfish and all deepwater sharks in general, have been described by the International Union for Conservation of Nature (IUCN) Shark Specialist Group as being more vulnerable to overexploitation than perhaps any other marine species group"*. Surveys from 1976 to 1996 recorded declines in relative abundances of Harrison's and Southern and Endeavour dogfish of 98.4-99.7%, and Greeneye Spurdog of 95.8%. The IUCN has listed Harrisson's Dogfish as Critically Endangered and Endeavour Dogfish as Data Deficient. The three dogfish have been nominated for threatened species listing under the EPBC Act

In Australia, deepwater dogfishes are a major bycatch of commercial trawlers, and drop and longliners, though at least 11 species are increasingly being marketed for flesh and liver oil (Irvine et. al. 2005). For over a decade serious declines in upper-slope dogfish stocks off southeastern Australia have been well documented (Irvine et. al. 2005) and for almost as long the Commonwealth have been procrastinating about listing some species as threatened.

Musick (2011) identifies that the deep-water dogsharks are typified by slow growth, late maturity, and low fecundity which makes them particularly vulnerable to overfishing and stock collapse. Trawling and longlines have been identified as primary threats, though they are also caught by droplines.



Dogshark (excluding spiky dogshark) biomass along the NSW shelf (after CSIRO 2009) note its concentration along the outer shelf/upper slope and off the Tweed.

Musick (2011) states:

> *Graham et.al. (2001) showed that other top-level bathyal predators such as sevengill sharks and skates (Ebert and Bizzaro 2007) had the same order of population decline as the dogfish. Although detailed trophic interactions in Australian bathyal ecosystems have not been studied, it would be astounding if a >90% reduction in the apex predators has not caused major disruptions in ecosystem structure and function.*

In 2010 the Commonwealth prepared its Draft Upper-Slope Dogfish Management Strategy (AFMA 2010), it documents attempts to manage the sharks by reducing fishing pressures since 2001, introducing partial closures since 2005 and prohibiting shark gill netting and shark longlining deeper than 183m. One proposal is to establish a partial closure somewhere off northern NSW on the basis of "*Possible Harrisson's Dogfish and other dogfish species. This area is believed to have had only relatively light fishing pressure historically with the benthic habitat likely to be more intact compared to further south".*

Musick (2011) reviewed AFMA's draft Upper-Slope Management Strategy. In 2010 the total of slope dogfish habitat (43,846 km^2) closed to fishing was increased to 8.5%, as noted by Musick (2011) "*This value is far lower than the 20-50% recommended by Wilson et.al. (2009) after exhaustive review of the problem*".

Musick (2011) notes that he concurs with CSIRO in that:

> *CSIRO analyses further suggest that the Sydney area closure would be effective in conserving Southern Dogfish, and that an area ("Hunters," not yet fully defined) off northern NSW would be effective for Harrisson's and perhaps for Endeavor Dogfish (Daley et. al. 2010, Williams et. al. 2010).*

Though he identifies a number of reservations, and emphasises the need to establish substantial areas free from fishing, stating:

> *The solution to these potential problems is to protect more areas and make the existing ones larger. The closed area actions taken in stages one and two of the Strategy may prevent total extinction of Harrisson's and Southern Dogfish, but are likely too limited in area to contribute to these species' recovery. It is extremely important that AFMA resolve negotiations with NSW, so that NSW fishers no longer fish in the Sydney closed area, and that a new closed area of sufficient size (see discussion above) is established off northern NSW.*
>
> ...
>
> *Marine Protected Areas (MPAs) developed by DSEWPaC could contribute significantly to conservation of upper-slope dogfish if designed properly. Existing MPAs off southern Australia provide little protection for dogfish, because even though some areas are quite large, they are so shaped that they "pinch in" where they intersect the slope, thus protecting only small snippets of dogfish habitat. If future MPAs are to be effective in protecting dogfish and the ecosystems in which they live, the MPAs must be designed to maximize their width parallel to slope isobaths, and some should be located adjacent to closed areas where concentrations of dogfish are known to survive.*
>
> *... In addition to establishing a small number of protected areas to prevent extinction of these relict populations--the Strategy should seek to establish a sufficient number of closed areas of sufficient size to allow these species to recover their ecological function over significant portions of their original ranges. Making the analogy with population modeling where Bmsy is usually set at 50% K (virgin biomass), and Blim (the limit below which the population should never be allowed to drop) is usually set from 25%-40% K), perhaps a reasonable goal for establishment of dogfish protected areas would be at least 35% of total suitable bathyal habitat.*

The Commonwealth should have included dogfish as target species and should have made a meaningful attempt to include adequate and representative samples of deeper shelf and slope ecosystems in their proposed reserves.

4.2.5. Orange Roughy

The most well known case of over-exploitation of a deep sea fish species is the long-lived Orange Roughy (maximum age of 150 years). Orange roughy is a deepwater species, occurring at depths between 500 m and 1,500 m. Commercial fishing for orange roughy first began in New Zealand in 1979 and now trawl fisheries for orange roughy occur in Australia and around the world.

Annala and Clark (2005) note:

> *Orange roughy can form dense aggregations for spawning or feeding, which enables high commercial catch rates even as stock size is declining. This makes the species vulnerable to overexploitation. In addition, roughy are slow-growing and long-lived and sustainable exploitation rates are low. Hence recovery from overfishing should take a long time.*

The gross mismanagement of the Orange roughy by the Australian Fisheries Management Authority (AFMA) provides a clear example of the abysmal failure of regulation to manage fish stocks in a sustainable manner. Bax *et. al.* (2005) document the faltering and failing efforts to establish stock targets and regulate catches for the orange roughy fisheries. The target recommended by scientists was a minimum of 50% of the pre-fishery biomass. By 1992 the Eastern Zone biomass was estimated to be 25–30 percent of pre-fishery biomass. Overfishing (above recommended yields) continued, some under the guise of a failed "adaptive management experiment". In 1994 the AFMA developed a target reference point of 30 percent pre-fishery biomass, and a limit reference point of 20 percent, for the orange roughy fishery. When the 20 % limit was reached the fishing did not stop. The 2002 eastern zone biomass was estimated at 7–13 percent of the pre-fishery biomass (Bax *et. al.* 2005).

Bax *et. al. (*2005) state:

> *At the start of the fishery, scientific advice was clear that biomass should not be reduced below 50 percent of prefishery biomass (DPFRG 1990b). This limit was soon passed and in 1994, AFMA, acting on advice from the assessment group, determined that 30 percent of prefishery biomass was the target, which was subsequently endorsed by international reviewers (Deriso and Hilborn 1994) and a timeframe to reach it was established (for fisheries already below 30 percent). Following revised scientific advice and the failure to manage to this target level, a rebuilding target of 40 percent of initial biomass was put forward by the assessment group and again endorsed by international reviewers (Francis and Hilborn 2002). This target has yet to be accepted by AFMA.*
> *...*
> *Total allowable catches have been consistently set at, or above, the highest levels recommended by scientists and estimated catches consistently exceeded the TAC at the start of the Eastern Zone fishery. In addition, and despite DPFRG concluding that the "greatest danger to the resources and industry is… from a build up of catching power during the transient period of high catches" (Anon. 1988), there seems to have been no restriction on permits given to develop the orange roughy fishery and the number of shots trebled between 1986 and 1990 (Tilzey 1994). Scientists expressed their concern that their advice was often seen as overconservative, while Australia's record on managing fish resources at the time did not seem overly conservative given that most resources were maximally exploited and some had collapsed (Kearney 1989).*

From his review of the Orange Roughy fishery Nevill (2009) concluded:

> *The story of Australia's orange roughy fishery is a classic story of overfishing under regulation. The fishery is also a destructive fishery, associated with a substantial but un-quantified amount of benthic damage to ancient and diverse coral ecosystems.*
>
> *... many fishers showed that they were quite prepared to breach their legal responsibilities regarding catch limits when they perceived licence compliance was not being enforced – also in the knowledge that the productivity of the stock was very low. Koslow (2007) has argued that there was an un-written understanding amongst fishers that the stock should be 'mined out' – which in fact is exactly what occurred.*
>
> *Although AFMA had clear responsibilities to apply the precautionary and ecosystem approaches in management of the fishery, and in spite of statements that precautionary catch limits would be set, the reality showed that AFMA either promoted the 'mining' of the stock, or were too weak to resist the pressures of their vocal clients.*

Nevill (2009) highlights a number of cases of deliberate misrepresentation by the AFMA, including:

> *AFMA, in an accreditation report provided to the minister responsible for the Environmental Protection and Biodiversity Conservation Act 1999 (AFMA 2002a:184), in discussing setting orange roughy total allowable catch (TAC) limits, stated that:*

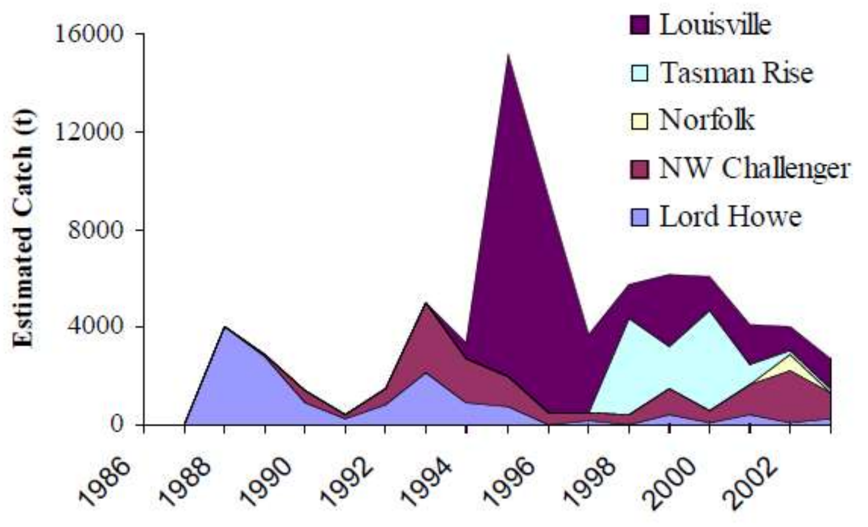
> *..“current TACs for the southern and eastern sectors are considered precautionary using the best available scientific advice and have a good chance of meeting the recovery strategy.”*

The TACs referred to were 1600 tonne for the eastern stock and 420 tonne for the southern stock.

The relevant CSIRO stock assessment (Wayte & Bax 2002) had been commissioned by AFMA, and had recommended a total allowable catch of zero for the eastern stock and zero for the southern stock. The stock assessment report had also pointed out that there was no chance of either stock meeting the recovery strategy.

Orange roughy was belatedly recognized as overfished in 2006 and is now listed as Conservation Dependant under Australia’s Environment Protection and Biodiversity Conservation (EPBC) Act. The gross mismanagement of the orange roughy fishery is a classic example of the failure of regulation, and the need for fully protected marine reserves as a safeguard against fisheries collapses and species extinctions.

FIGURE 2
Estimated catches of orange roughy from the high seas fisheries in the New Zealand region
Data are primarily from the New Zealand Ministry of Fisheries and Australian Fisheries Management Authority. 1988 on the x-axis, e.g. is the 1987–88 fishing year.



Graph depicting high initial yields and rapid declines in stock of Orange Roughy. From Annala and Clark 2005.

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