National Environmental Research Program
MARINE BIODIVERSITY hub

Oceanic Shoals Commonwealth Marine Reserve – a guide

This guide has been developed for policy makers and managers to communicate the key findings of the three recent surveys of the Oceanic Shoals Commonwealth Marine Reserve, and its relevance to decision making and management. The document is a synthesis designed to transfer relevant knowledge from scientists to managers and decision makers and will continue to evolve in response to further discussion with researchers and managers and as new information becomes available.

Why surveys of the Oceanic Shoals Commonwealth Marine Reserve were needed

Background: The broad continental shelf of northern Australia is characterised by extensive areas of carbonate banks, terraces and isolated pinnacles that provide hard substrates for sponge gardens and associated benthic fauna (*Przeslawski et al., 2014*). The conservation values of these seabed features is recognised in marine bioregional plans through their assignment as Key Ecological Features (KEFs) of regional significance (Commonwealth of Australia, 2012a, b) (*Fig 1*). These KEFs include: the carbonate banks and terraces of the Van Diemen Rise (North Marine Region); the carbonate banks and terraces of the Sahul Shelf (Northwest Marine Region), and; the pinnacles of the Bonaparte Basin (North and Northwest Marine Regions) (Table 1). The Oceanic Shoals CMR that includes these KEFs covers an area of approximately 72,000 km2 and is designated as a Multiple Use Zone (IUCN VI).

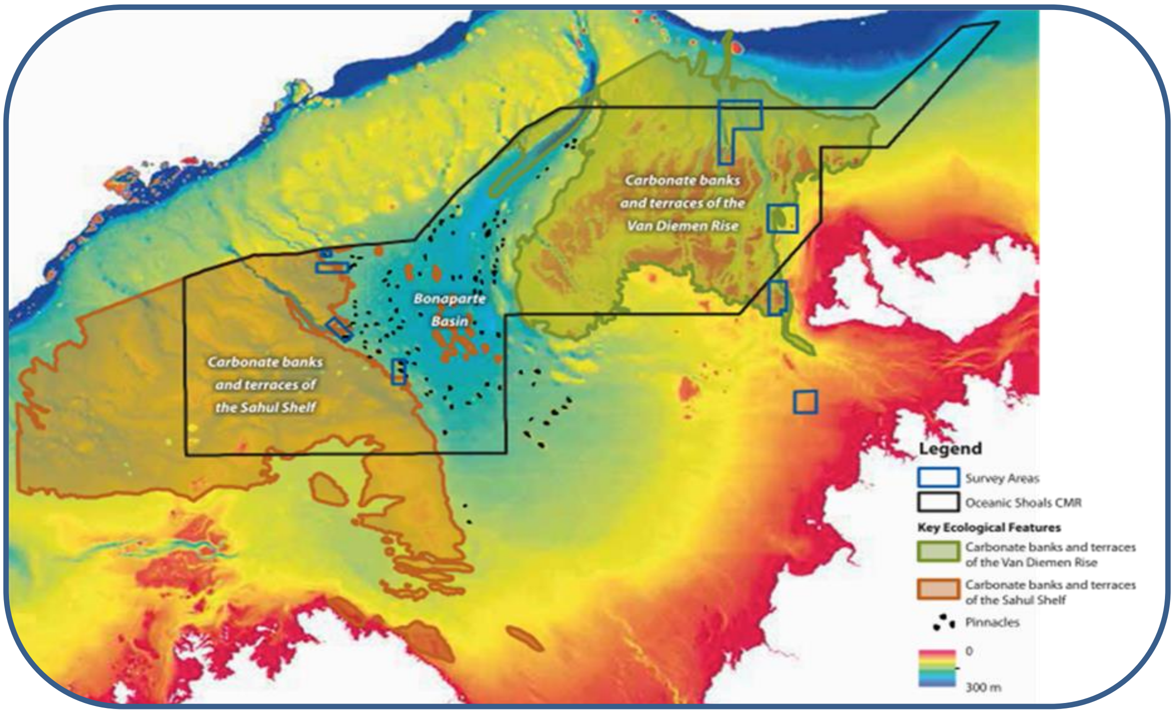


Figure 1: Carbonate banks, terraces and pinnacles in the Timor Sea region, showing the intersection with the Oceanic Shoals Commonwealth Marine Reserve. Areas surveyed during voyages in 2009, 2010 (Eastern CMR) and 2012 (Western CMR) voyages are also shown.

Table 1: Key Ecological Features in the Timor Sea that are characterised by hard ground with the potential to support sponge and coral communities, listing total area and proportion of that area within the Oceanic Shoals Commonwealth Marine Reserve.

Marine Region	Key Ecological Feature (KEF)	Area	Area in Oceanic Shoals CMR	
		km^2	km^2	%
North	Carbonate banks and terraces of the Van Diemen Rise	31,278	25,697	82
North-west	Carbonate banks and terraces of the Sahul Shelf	41,157	18,950	46
North & North-west	Pinnacles of the Bonaparte Basin	530	450	85

Key ecological features within Oceanic Shoals CMR

The three KEFs found within the Oceanic Shoals CMR, carbonate banks and terraces and pinnacles, have similar carbonate parent material and differ primarily in size and shape (*Fig 2*).

These three nominated types of KEFS appear to operate in similar ways with respect to their relationship to the benthic and pelagic biodiversity in this region (see below).

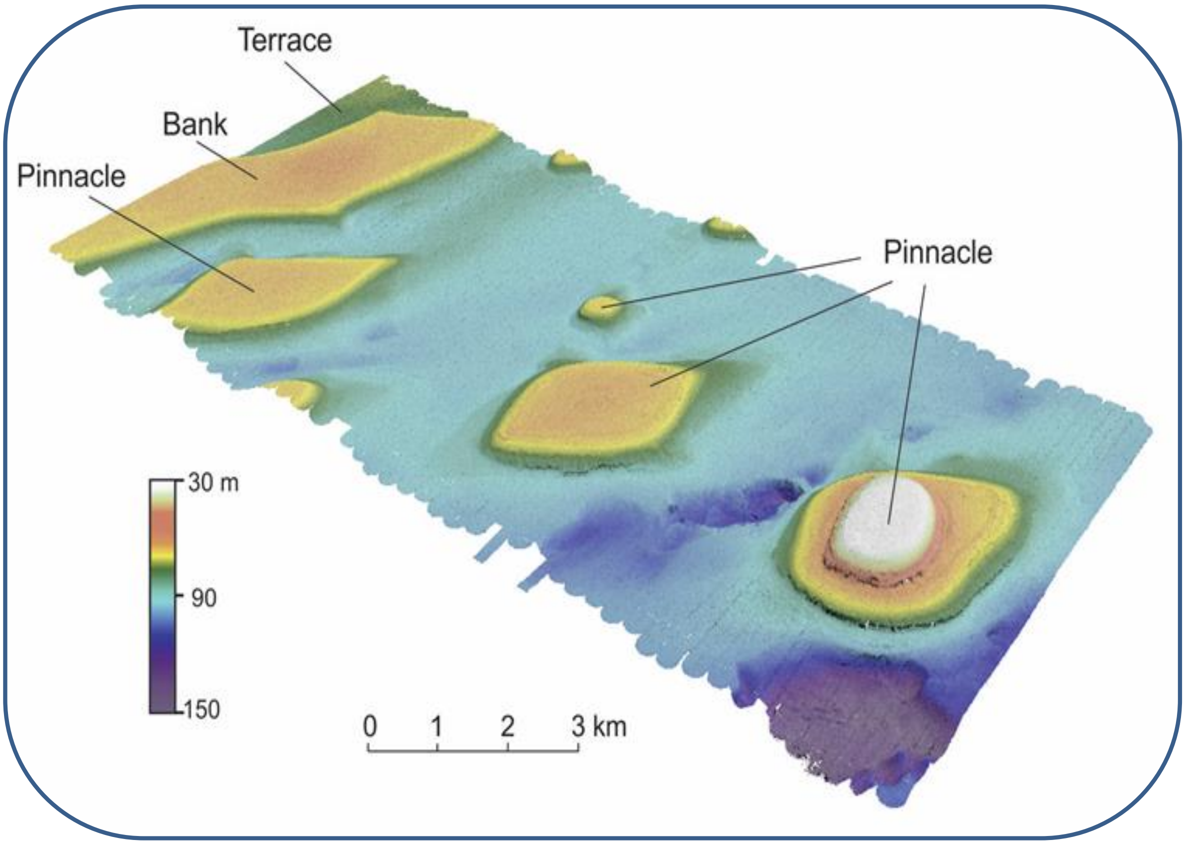


Figure 2: Examples of carbonate banks, terraces and pinnacles mapped by high resolution multibeam sonar in the Oceanic Shoals Commonwealth Marine Reserve.

Previous research in the Region – what we knew

Previously published research on seabed habitats and biological communities in the Timor Sea region is limited to studies on the Big Bank Shoals (outside the EEZ*; Heyward et al., 1997*), a single carbonate bank on the outer Sahul Shelf (Pee Shoal; *Wienberg et al., 2010*) and targeted mapping and sampling by Geoscience Australia and AIMS in 2009 and 2010 in the eastern part of the Oceanic Shoals CMR on the Van Diemen Rise (summarised in *Przeslawski et al., 2011*). There is also a body of geological literature documenting sub-seabed structure, seabed character and evolutionary history of the Sahul Shelf (e.g. *Van Andel and Veevers, 1967; Hovland et al., 1994; Yokoyama et al., 2001; Bourget et al., 2013; Nicholas et al., 2014; Saqab and Bourget, 2015*).

These geological studies provide context for understanding the origin and distribution of modern benthic habitats within the Oceanic Shoals CMR. These benthic habitats are best characterized as a spatially complex system of raised hardground features (banks, terraces, pinnacles), separated by incised channels and expansive areas of soft muddy seabed originating from processes of carbonate production over geological time scales overprinted by major fluctuations in sea level and regional tectonics.

Together, these earlier studies provided valuable insights into the physical complexity of this area and the importance of the hard ground provided by these carbonate banks, terraces and pinnacles to the biodiversity in this area. In particular, banks and terraces consistently support rich sponge and octocoral (i.e. soft corals) gardens. However, prior to the 2012 voyage scientific understanding of marine biodiversity in the CMR was based on limited number of observations of benthic habitats of the Sahul Shelf (one of the three KEFs in the CMR).

Consequently, significant questions remained regarding the continuity of this pattern in the western part of the Oceanic Shoals CMR, where a largely unexplored expanse of carbonate terraces, banks and pinnacles exists, and the relationships of geographic and physical correlates to these biological communities.

This paucity of information is perhaps best exemplified by the previous failed attempt to construct the most basic of qualitative models for the carbonate terraces, banks and pinnacles because sufficient basic information was lacking (see below for more information).

Addressing this information gap was recognised as a priority for the Department at the beginning of the NERP Marine Biodiversity Hub.

New Discoveries from the 2012 survey

In 2012, a voyage of discovery was undertaken to the western part of the Oceanic Shoals CMR by the Marine Biodiversity Hub under the National Environmental Research Program (NERP). This 2012 voyage was designed to complement the findings and discoveries of the two previous surveys completed by GA and AIMS in 2009 and 2010, and provide better understanding of east-west gradients in the physical environments of the CMR and their relationships to patterns of biodiversity in the region.

The 25-day voyage on *RV Solander* involved Hub partners - AIMS, Geoscience Australia, and the University of Western Australia - and targeted previously unsampled carbonate terraces, banks, and pinnacles. The survey was designed to collect information to generate high-resolution seabed maps, gather samples of benthic biological material, and observe communities of fishes and other vertebrate species.

Key findings from the 2012 survey of the western Oceanic Shoals

- There are more banks and pinnacles than previously thought. High resolution mapping in four survey areas revealed 41 additional banks and pinnacles covering an area of 152 km2, an increase from 105 km^2 (*Fig 3*) indicating that hard substrate, which is important to benthic biodiversity is more extensive than previously thought.

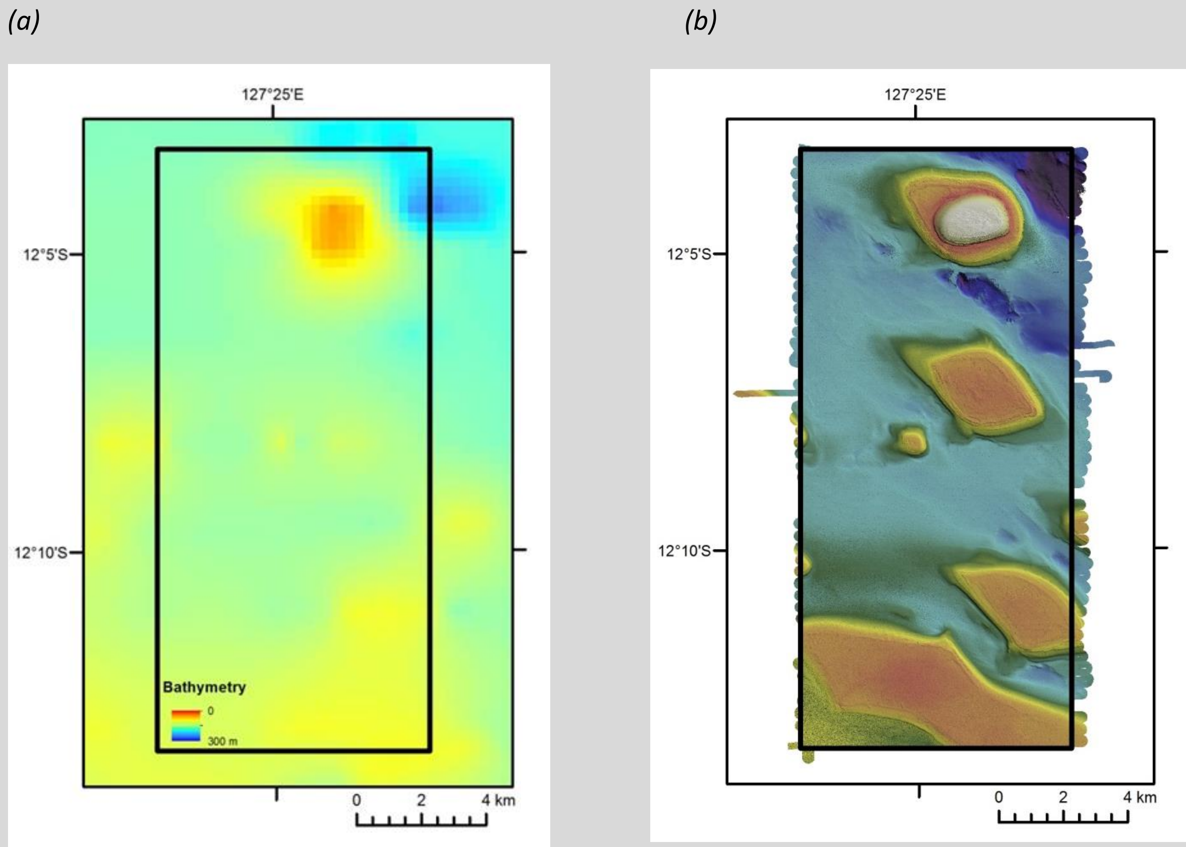


Figure 3: *Bathymetry maps for survey grid 1 in the Oceanic Shoals CMR, showing:*

(a) Bathymetry map before the 2012 survey with a spatial resolution of 250 m; and

(b) Newly mapped pinnacles at a spatial resolution of 2 m.

Key findings from the 2012 survey of the western Oceanic Shoals

- Benthic biodiversity of invertebrates on banks and pinnacles decreases with water depth and across the transition from the hard substrate of banks to soft sediment plains (*Fig 4*);
- Banks that rise to at least 45 m water depth support more invertebrate biodiversity including isolated hard corals, most likely because of greater light penetration at these shallower depths,
- Tidal currents play an important role in shaping the seabed by scouring holes into soft sediments around the base of banks and pinnacles and by extending the length of these pockmarks; Typically, a more complex physical environment will host more species but such a relationship has not been confirmed in this case;
- Levels of suspended sediment (turbidity) appear higher in the western part of the Oceanic Shoals CMR than the eastern part with some smaller pinnacles partly buried by sediment indicating both ongoing dynamic sedimentary processes and environmental gradients which are likely to be responsible for some of the differences between the structure of invertebrate communities observed at these locations. This high turbidity precluded the analysis of video collected using demersal baited cameras. Understanding of the local fish communities in the survey area remains a gap;
- The surveyed area supports a wide range of pelagic vertebrates with 32 species observed, including 11 shark species, black marlin, barracuda, Olive Ridley turtle, sea snakes and orca.
- At least 350 species of marine sponge occur within the Oceanic Shoals CMR, with modelling indicating there may be as many as 900 sponge species - almost twice the number estimated for the Ningaloo CMR;
- Twenty-nine sponge species collected have been described and are new to science, with as many as 100 potential new species yet to be confirmed;
- Four species of hard corals found growing in the Oceanic Shoals CMR are IUCN-listed as Vulnerable or Near Threatened and one species is Endangered;

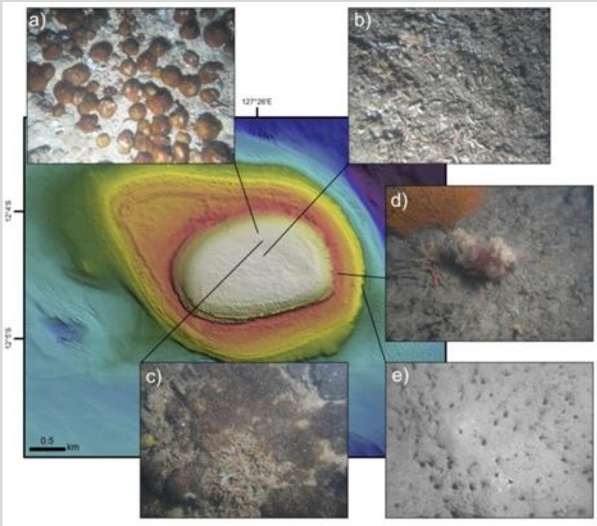
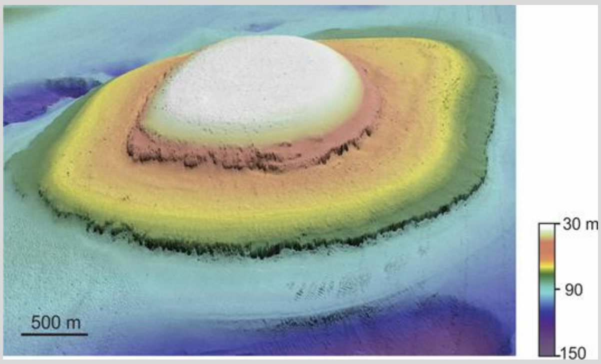


Figure 4: *Examples of species sampled along the depth transition from the top of a pinnacle to the surrounding plain, including: (a) mushroom corals; (b) coral remains; (c) sponges; (d) gorgonians and sponges; (e) burrows in soft sediment (above); and (f) Perspective view of the same pinnacle (below)*



Key findings from the 2012 survey of the western Oceanic Shoals

- Sediment dwelling invertebrates are also highly diverse with 266 species collected, including newly discovered species of sea spider (*Fig 5*), squat lobster, and worm;
- Among all observed and/or sampled biota, 57 species are first-time observations for the Sahul Shelf and NT, seven are first-time records for Australia, and 13 are new for the Indo-Pacific region;
- The voyage confirmed that this area supports large numbers of marine species and that many of these species rely on the KEFs that are present.

Figure 5: *Newly discovered species of sea spider (Cordylochele Sp.) collected from 80 m water depth on the flank of a carbonate pinnacle (11º 53.14S, 127º 05.60E).*

Relevance to IMCRA

The three surveys of the Oceanic Shoals CMR (2009, 2010, 2012) targeted discrete areas of the banks, pinnacles and terraces, covering a combined area of almost 2200 km^2. While these samples represent only 3% of the ~73,000 km^2 of KEFs included in the Oceanic Shoals CMR, the knowledge of these KEFs gained from these surveys is likely to be typical for these features within and adjacent to the reserve. In particular, because these seabed features provide hard substrata for sponge and coral communities, similar patterns at the spatial scale of these features can be expected to occur across the reserve wherever hard raised substrata exists. Moreover, as shown by the high-resolution bathymetry mapping, it can be expected that there are many more unmapped banks and pinnacles in the CMR, especially in the transition from the carbonate terraces to the deeper Bonaparte Basin in the central part of the CMR.

The Oceanic Shoals CMR incorporates approximately ~45,000 km^2 of carbonate banks, terraces and pinnacles, the largest area of these features among all reserves in the North and North-West marine regions. By comparison, the Kimberley CMR has 40,000 km^2 of terrace and bank features and only four isolated pinnacles have been mapped. Along with the large area of KEFs in the Oceanic Shoals CMR, the potential importance of this reserve is underscored by its location straddling an east-west environmental gradients influenced by the Indonesian Through-flow, strong tidal currents, and cyclones. Further sampling and analysis will be required to build a more comprehensive understanding of the uniqueness of this CMR is a broader regional context.

Much of the new information gathered during these surveys will underpin more extensive analysis in support of updating IMCRA 4. With respect to biological data, IMCRA 4 relied exclusively on fishes for the bio-regionalization of both the benthic and pelagic realms.

These voyages have provided further information on both the benthic and pelagic communities of the Oceanic Shoals CMR. Information for the benthic communities in this area was richest for the sponge communities of this area before the voyages. Nonetheless, these voyages have provided new information about the extent of the biodiversity on this group (~ 350 sponge spp. and many new to science) and patterns of regional differentiation in community composition and levels of endemism. Much additional information on other species associated with both the hard and soft bottom substrata of the CMR was also collected.

This additional information creates the possibility that, at least for this area, the bioregionalisation of IMCRA 5 may be able to move beyond a sole reliance on fishes. Similarly for the pelagic environment, new information has been provided both for fishes and other pelagic vertebrate species.

Collection of this new information was made possible through the development of baited pelagic video cameras. In addition, these surveys change our understanding of the number and distribution of seabed features and the distribution and regional context for a vast array of species including pelagic vertebrates, benthic invertebrates that preferentially associate with hard ground and infauna species associated with soft sediments. This information includes many new species, threatened and endangered species, and significant shifts in the community structure in space (see New Discoveries section above and Biodiversity Patterns below for further details).

Biodiversity Patterns

Drawing upon the collective information available from multiple surveys of the Oceanic Shoals CMR, the following key points emerge:

- Banks in the Oceanic Shoals CMR are biodiversity hotspots for sponges, with more species and different communities than the surrounding seafloor;
- Sponges are most common on raised geomorphic features (banks, pinnacles, ridges, terraces) compared to subdued features (plains, valleys);
- Sponge communities are different between the eastern and western sides of the Oceanic Shoals CMR, with the west showing higher sponge species richness and biomass than the east. These differences are likely related to differences in the environmental conditions (e.g. greater turbidity in the west) animals would experience at these locations, and to a lesser extent, the presence of regional differences in the species pools from which these communities can be assembled;
- Sponge communities may be different among individual banks. However, some banks showed much more variation than others and low sample sizes mean this pattern remains to be confirmed;
- Polychaete communities did not differ between eastern, central and western areas of the CMR, although species-level identifications are still pending;
- For infaunal communities, temporal patterns may over-ride spatial ones, with significant differences observed in polychaete family composition between surveys one year apart.
- Pelagic species were preferentially associated with raised geomorphic features.

Understanding connections between reserves

From modelling of potential connectivity between this reserve and other reserves in the North and North-West marine regions, the following key points emerge (Note: these modelling results are based on brittlestars and assume a maximum 90 day larval period. As such the model generates hypotheses that require validation with field data):

- Based on a narrow subset of species and passive dispersal, the Oceanic Shoals CMR may be to a large extent self-seeding with respect to larval dispersal (i.e. 77% chance of a larva being retained in its area of origin);
- The model suggests that the Oceanic Shoals receives larvae from the Argo Rowley Terrace, Mermaid Reef, Kimberley, Ashmore Reef, Cartier, Joseph Bonaparte Gulf, Arafura, Arnhem, Wessel and West Cape York CMRs (*Fig 6*).
- The model also suggests that the Oceanic Shoals contribute larvae to the Montebello, Argo-Rowley Terrace, Mermaid Reef, Kimberley, Ashmore Reef, Cartier, Joseph Bonaparte Gulf, Arafura and Arnhem CMRs.
- Analysis of modelled connectivity among CMRs suggests that the Oceanic Shoals CMR is a keystone of the north and northwest network because it links to the Kimberley, Arafura and Arnhem CMRs.

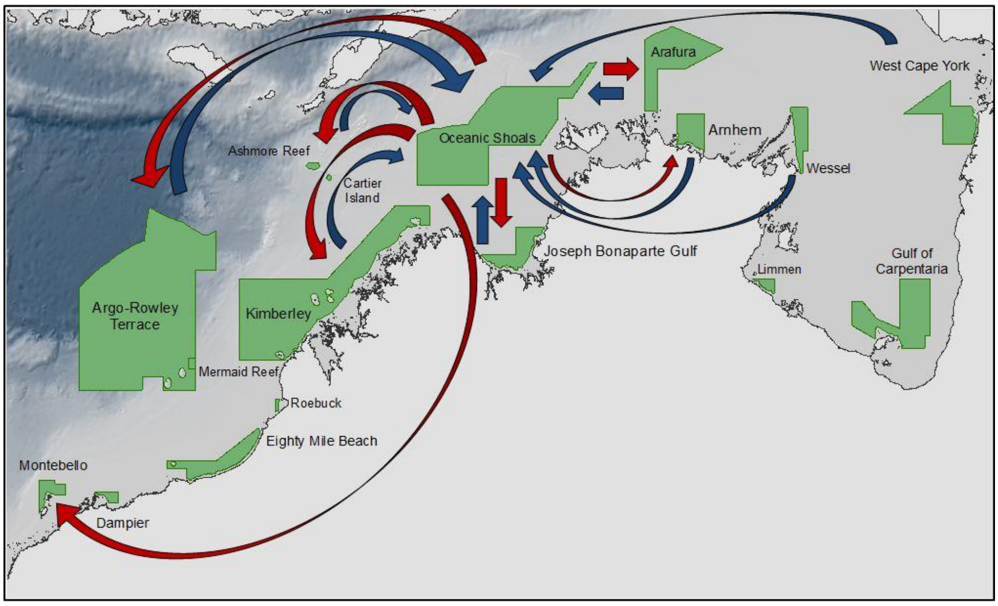


Figure 6: *Modelled connectivity to and from the Oceanic Shoals CMR. Red arrows indicate export of larvae from the Oceanic Shoals to other CMRs, blue arrows indicate import of larvae to the Oceanic Shoals from other CMRs.*

Understanding ecosystem structure and function in the Oceanic Shoals CMR

Prior to these surveys of the Oceanic Shoals, an attempt was made to build a qualitative model of the KEFs contained in it. At that time, it was decided that insufficient information was available to allow even such a basic model to be constructed. Following these recent surveys, a second attempt was made to model these KEFs. Based on the increased knowledge gained from these surveys it was possible this time to build such a model (*Fig 7*).

This model was developed to identify ecological indicators most likely to be useful for management. No fundamental differences were found between the communities associated with terraces, banks, or pinnacles. There were differences, however, in how organisms were positioned relative to physical factors such as water clarity and depth and current stress associated with cyclones and storms. The model also identified five plausible threats to the functioning of these KEFS over the next fifty years including: oil and gas spills, illegal fishing, ocean acidification, increased storm intensity, and increased agricultural run off.

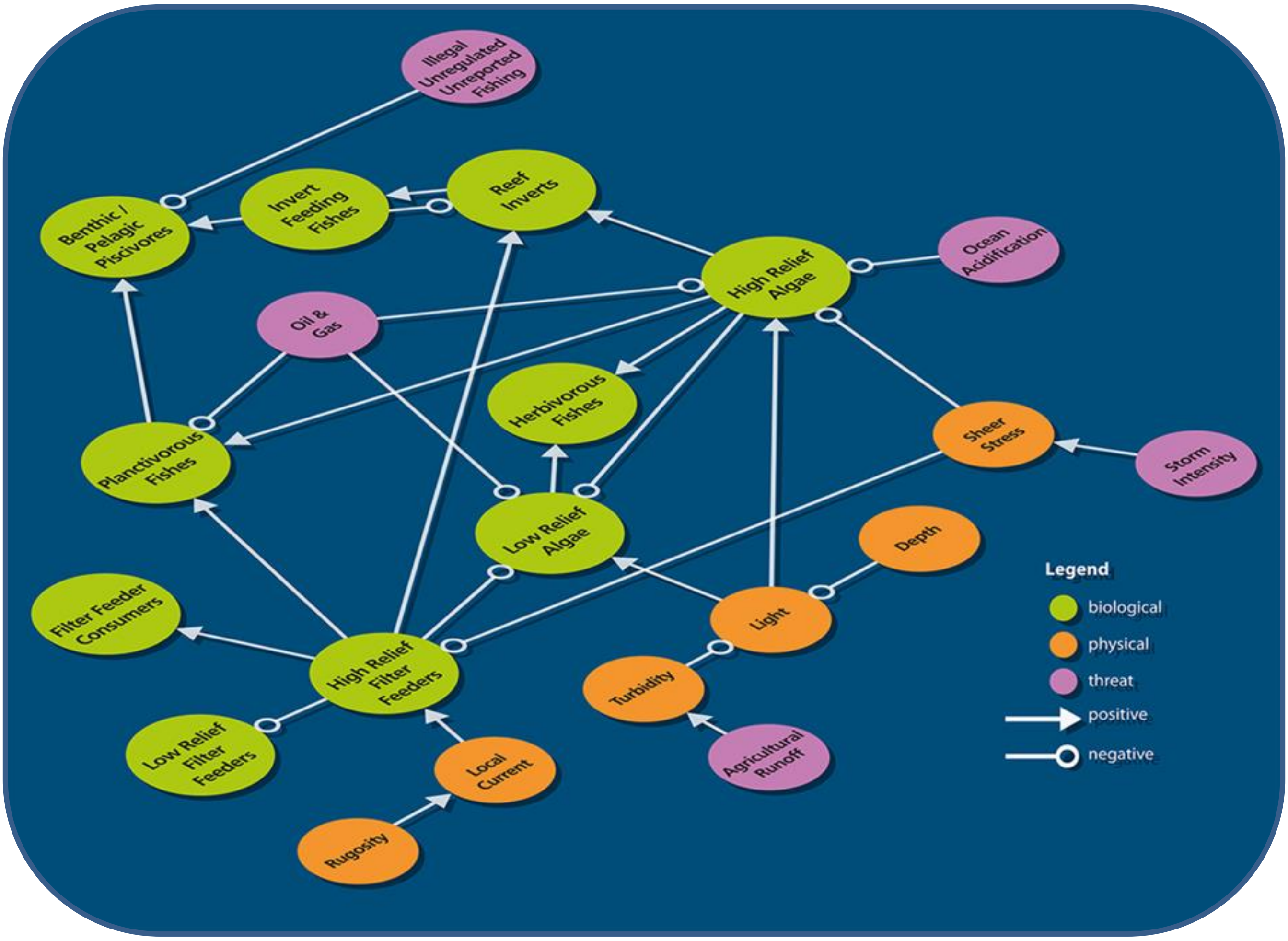


Figure 7: A qualitative model of the Key Ecological Features (KEFs) of the Oceanic Shoals Commonwealth Marine Reserve. The same model was deemed by experts to be appropriate for all three KEFs: the carbonate terraces, banks, and pinnacles.

Summary of Survey Datasets and Information Provided

Data Type	Coverage/Number		Information Provided
	Western Shoals 2012 Survey	Eastern Shoals 2009/10 Surveys[1]	
Multibeam sonar	507 km^2	1,938 km^2	Detailed maps of seabed geomorphology and habitats
Sediment samples	121	183	Composition of seabed and sediment infauna
Video transects	65 km	~62 km	Composition and distribution of seabed biota
Benthic sleds	22	85	Samples of benthic biota for taxonomic identification
Baited video - benthic	56	0	Composition and distribution of demersal fish communities
Baited video - pelagic	120	0	Composition and distribution of pelagic fish communities
CTD casts	63	85	Physical properties of the water column (temp, conductivity, turbidity)
Ocean drifters	10	0	Regional patterns of ocean surface currents
Sub-Bottom profiles	143 km	935 km	Images of sub seabed geological structure

Note:

1. *Includes one survey grid (261 km^2) located outside the Oceanic Shoals CMR and carbonate terraces KEF (see Fig 1.)*

Support for Decision Making

As a result of these surveys, many new resources are now available to support decisions making required for the management of the CMR network. These resources include:

- Improved understanding of conservation values
  - The survey provided new understanding for three key ecological features identified in the North and North-west marine bioregional plans, all three of these features are included in the Oceanic Shoals CMR.
  - A connectivity model that provides insights into the levels and patterns of connection between the Oceanic Shoals CMR and other CMRs in the network.
  - Identification of rare and endangered species in the CMR including those listed as Vulnerable, Near-threatened, and Endangered.
- Assessment of proposed activities – the survey provides new knowledge (e.g. descriptions, models, and maps) to inform the assessment of proposed activities in, or nearby, the survey area (e.g. proposed activities that trigger the need for an assessment in accordance with the EPBC Act).
- Environmental reporting on status and trends of biodiversity – new ecosystem models were developed that can be used to identify ecosystem indicators and predict how these are likely to change in response to current pressures and over the next 50 years.
- Communicating conservation values - new Imagery and maps of the physical and biological components of the Oceanic Shoals CMR:
  - Imagery http://nerpmarine.edu.au/hub-imagery/search
  - Maps http://www.nerpmarine.edu.au/maps/
- Additional information regarding the biodiversity values of the Oceanic Shoals CMR including:
  - New observations of known species at the scales of shelf, region and ocean basin.
  - http://data.aims.gov.au/metadataviewer/faces/view.xhtml?uuid=f9b98dad-6816-4715-aecb-7ffbee0f7ab5
  - Link to GA data http://www.ga.gov.au/search/index.html#/ (search term: oceanic shoals)
  - https://researchdataonline.research.uwa.edu.au/handle/123456789/1621

Gaps in understanding of the biodiversity in the Oceanic Shoals CMR

The main geographic gap in our understanding of the benthic communities within the Oceanic Shoals CMR is the Bonaparte Basin that separates the carbonate banks and terraces of the west and east. The existing bathymetry data and geomorphic features map shows isolated pinnacles across the basin. Further high resolution mapping and sampling of these features would confirm their true form and likely lead to the discovery of new pinnacle features and associated communities. Similarly, the infaunal communities of the deep basin sedimentary environments are poorly documented. Our understanding of the local scale oceanography across the banks and pinnacles is also rudimentary and if improved would strengthen our summary models of connectivity and relationships between tides, turbidity and biodiversity patterns.

During the last of these three surveys, a new approach to the non-destructive sampling of pelagic species using baited cameras was tested and provided new insights into how these species associate with the KEFs in the Oceanic Shoals CMR. While some information is now available regarding these pelagic species in this CMR, no comparable data are currently available for any of the other CMRs thereby precluding any possibility of comparing this aspect of the biodiversity values among CMRs. This lack of data for other CMRs constitutes a significant knowledge gap given the predominance of pelagic habitat throughout the national network of Commonwealth Marine Reserves.

Links to supporting information

- Marine bioregional plan for the North Marine Region
- Marine bioregional plan for the North-west Marine Region
- Oceanic Shoals Commonwealth Marine Reserve (Timor Sea) Biodiversity Survey – Post Survey Report
- Seabed habitats and hazards of the Joseph Bonaparte Gulf and Timor Sea, northern Australia
- Sponge biodiversity and ecology of the Van Diemen Rise and eastern Joseph Bonaparte Gulf, northern Australia
- http://fish.ala.org.au/
- http://www.nerpmarine.edu.au/rv-solander-blog

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