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18E The management of the Coral Sea reefs and sea mounts

Australia's Coral Sea - how much do we know?

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Abstract. Recent efforts to implement management zoning to Australia's portion of the Coral Sea have highlighted the need for a synthesis of information about the area's physical structure, oceanography and ecology. Current knowledge is hampered by large geographic and temporal gaps in existing research, but nevertheless underpins the determination of areas of ecological value and conservation significance. This review draws together existing research on the Coral Sea's coral reefs and seamounts and evaluates their potential function at a regional scale. Only four coral reefs, out of a potential 36, have been studied to the point of providing information at a community level; this information exists for none of the 14 mapped seamounts. However, the research volume has increased exponentially in the last decade, allowing a more general analysis of likely patterns and processes. Clear habitat associations are emerging and each new study adds to the' Coral Sea species list'. Broader research suggests that the reefs and seamounts serve as dispersal stepping stones, potential refugia from disturbances and aggregation hotspots for pelagic predators.

Key words: Isolated reefs, Dispersal, Community structure, Refugia.

Introduction

Australia's Coral Sea lies to the east of the Great Barrier Reef (GBR) within the Australian EEZ boundaries. Geologically, it is dominated by large plateaux that rise from the abyssal plain and cover approximately half of the seabed area (Harris et al. 2003). The northern end of the Tasmantid seamount chain, which includes the oldest seamounts in the chain, extends into the southern and eastern Coral Sea (Keene et al. 2008).

The reefs and shoals of the Coral Sea are formed on the structural high points of the major plateaux and on the summits of the highest seamounts (Davies et al. 1989). There are 36 mapped reefs and shoals, and 14 seamounts (Fig. 1; D. Beaver, pers. comm.), and together they make up approximately 1.3% of its surface area (Harris et al. 2003). However, given the overwhelming diversity of life that coral reefs host (Knowlton et al. 2010), it is likely that they represent concentrations of species diversity in the Coral Sea. They are also the best-studied ecosystem in the Coral Sea, as the other ecosystems are less accessible due to their depth and remoteness. Despite this, ecological information beyond simple species collections or observational studies exists for only four of the major reef systems. Differences between these systems imply that it is not possible to define a 'typical' Coral Sea reef.

The aim of this paper is to review the status of existing information about the Coral Sea's reefs and seamounts, to infer the potential ecological functions of these habitats and to highlight critical research gaps.

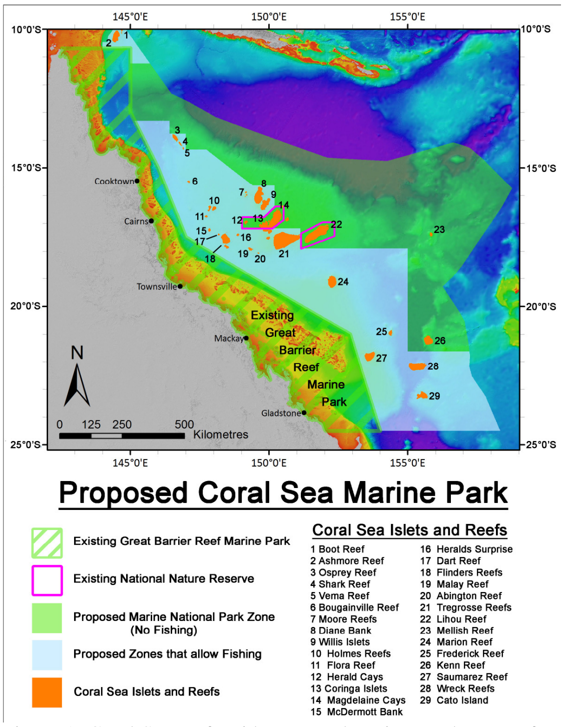

Figure 1: Coral Sea reefs with proposed zoning. Bathymetry from Beaman (2010).

Benthic Communities

To date, only four reef systems have been subject to rigorous, community-level ecological research that has quantified the major benthic components (corals, algae, sponges and other sessile benthos). Results indicate that on these isolated, highly exposed coral reefs, physical structure, the extent of sheltered habitat and the presence and area of a lagoon are major determinants of the abundance, diversity and taxonomic composition of ecological communities (Mellin et al. 2010). Smaller, more isolated reefs without lagoons (e.g. the Coringa-Herald group) appear relatively depauperate, with low coral cover and structural complexity, while large reef systems with lagoons and sheltered areas (e.g. Osprey Reef, Lihou Reef) host higher coral cover and diversity (Fig. 2).

Low-lying turf algae form the highest percentage of much of the Coral Sea's reef benthic cover, and many of the reef crests are cemented by crustose coralline algae (Done 1982). *Halimeda* is also abundant, providing much of the sand in lagoons and on cays (Byron et al. 2001). Large macroalgae on surveyed Coral Sea reefs are sparse and restricted to a few species (primarily *Caulerpa* and *Halimeda* spp.) growing in sheltered or lagoonal habitats (Ceccarelli et al. 2009).

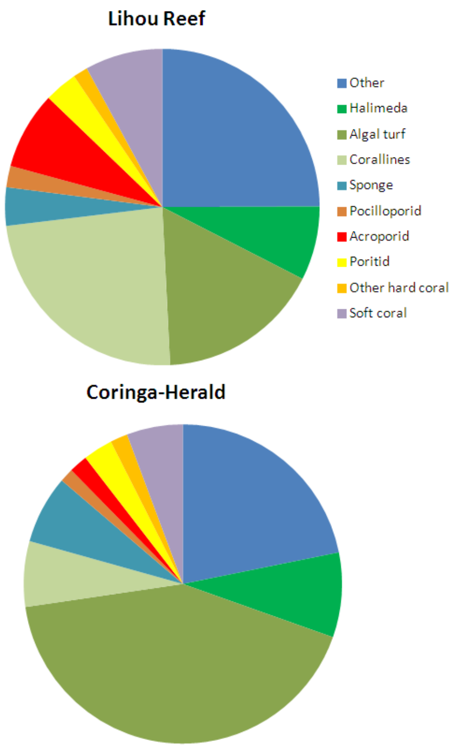

Figure 2: Differences in proportions of benthic categories on two Coral Sea reefs, Coringa-Herald and Lihou Reef. 'Other' includes taxa that individually make up less that 5% cover such as hydroids, ascidians and molluscs. Adapted from Ceccarelli et al. (2009).

Coral species richness tends to be reduced on the smaller reefs, and the Coringa-Herald reefs were noted for the absence of the coral genera *Pavona* and *Psammocora*, and the rarity of *Montipora*, *Porites*, *Turbinaria* and Fungiidae (Oxley et al. 2003). Despite a high level of relatedness to GBR coral communities, there are also unique assemblages (Done 1982). Coral communities also show affinities with the Central and Western Pacific. Recent surveys have extended the ranges of some species previously unrecorded in Australian waters (e.g. *Pocillopora linguata* and *Siderastrea savignyana*) (Ceccarelli et al. 2008).

Marine surveys in the Coral Sea have documented the aftermath of at least two major bleaching events. In 2004, Lihou Reef suffered bleaching across 65% of the hard coral cover, with subsequent recovery seen in 67% of bleached colonies (Oxley et al. 2004). The Lihou Reef system therefore demonstrates a high capacity for recovery, but it is unknown to what extent this is applicable to other reefs in the Coral Sea.

Sponges and sponge gardens are a feature of shallow, deep reef and seamount environments (Wilkinson and Cheshire 1989, Hooper et al. 1999; Williams et al. 2006; Woerheide et al. 2011). Coralline, colonial sponges discovered in caves at Osprey Reef appear to be 'living fossils' that once formed the primary building blocks of reefs (Woerheide et al. 2000). Due to their rarity and cryptic habitat, species of coralline sponges in different regions have become genetically distinct. Their rigid skeleton still plays an important role in cementing the framework of reef caves and overhangs (Woerheide and Reitner 1996). Species richness of sponges was found to be related mostly to the size and types of available habitats, and to collection efforts (Hooper and Ekins 2004). The Coral Sea was not identified as having particularly high sponge diversity, but there were reasonably high levels of endemism, with Wreck Reef showing 46% endemism (Hooper et al. 1999). The Coral Sea sponge fauna forms a distinct group of its own, with some links to the GBR and western Pacific (Hooper and Ekins 2004).

Reef Fish Communities

Coral Sea reef fish communities were first described in the 1960s (Whitley 1964), but new species are still being discovered, especially cryptic, deep-dwelling or nocturnal species (Randall and Nagareda 2002; Watson and Walker 2004; Randall and Walsh 2010). It has long been apparent that despite broad similarities with the GBR, there is a set of reef fish species that are unique to the Coral Sea reefs (e.g. the damselfishes *Pomachromis richardsoni*, *Chrysiptera taupou* and *Pomacentrus imitator*), and other taxa that are common on the GBR, but absent from the Coral Sea, such as many *Epinephelus* spp. *Neopomacentrus* spp. and *Dischistodus* spp. (Oxley et al. 2003).

Some Coral Sea reef fish use the enclosed lagoons of some of the atolls as nurseries. For instance, Leis (1994) found high concentrations of some reef fish larvae in plankton tows in the lagoons of Osprey and Holmes Reefs, but very few oceanic fish larvae. Those reef fish that displayed closed populations, with a lagoonal, rather than an oceanic, larval phase, were also highly abundant on those reefs. This suggests that those fish species would not rely on dispersal from external sources to replenish local populations. Species with low dispersal capabilities have shown genetic differentiation between the Coral Sea and the GBR (Planes et al. 2001).

Surveyed Coral Sea habitats have revealed both species-poor and depauperate fish faunas (e.g. Coringa-Herald), and areas of richer communities, with higher densities of predatory fish (e.g. Lihou Reef; Ceccarelli et al. 2009). Osprey Reef appears to have very high densities of sharks (Dunstan 2008). The high grazing rates measured on this reef (Hutchings et al. 2005) suggest that populations of grazing fish are also healthy.

Reef Predators

Sharks associated with the Coral Sea's reefs include grey reef sharks, blacktip and whitetip reef sharks, tawny nurse sharks and to a lesser extent silvertip sharks. Despite their high site fidelity, they can undertake long-range movements, with at least one grey reef shark tracked between Osprey Reef and the GBR (Heupel et al. 2010). Densities of reef sharks are often used as an indicator of general ecosystem health, and although the usefulness of this is debated, there is a significant increase in reef sharks with protection from fishing (Ayling and Choat 2008).

Habitat structure and prey availability are most probably equally important, as highlighted by the large difference in shark densities between the small isolated reefs of Coringa-Herald (Ceccarelli et al. 2008), and the larger and more networked complex of Lihou Reef (Ceccarelli et al. 2009). Coringa-Herald had very low densities of sharks despite strict protection from fishing, whereas Lihou Reef and Osprey Reef boasted densities similar to 'no-go' Pink Zones of the GBR (Fig. 3).

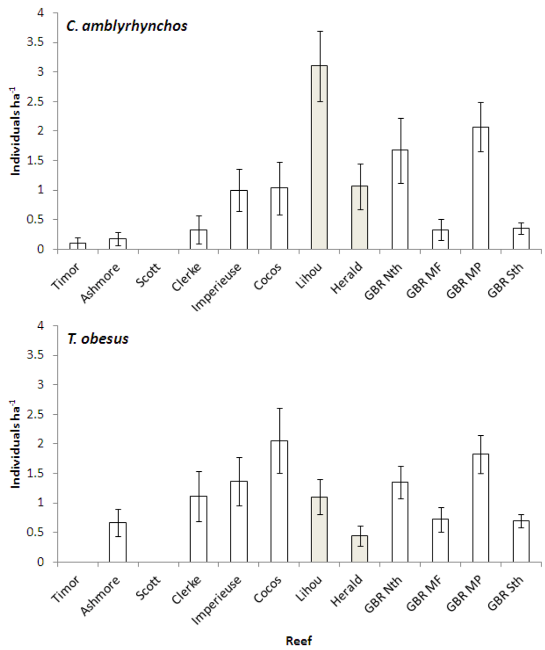

Figure 3: Density of reef sharks (grey reef shark *Carcharhinus amblyrhynchos* and whitetip reef shark *Triaenodon obesus*) on Indian Ocean, Coral Sea and GBR reefs (+/- 1 SE). GBR estimates are for: GBR Nth: GBR northern reefs, GBR MF: GBR midshelf fished reefs, GBR MP: GBR midshelf protected reefs, and GBR Sth: GBR southern reefs. The two Coral Sea reefs are highlighted in grey.

Seamounts

The northern portion of the Tasmantid Seamount Chain extends into the southern half of the Coral Sea in a series of emergent reefs, cays and submerged guyots. The most notable seamounts are Cato Seamount, the Wreck Seamount and the Kenn Seamount (Exon et al. 2006); however, these are practically unexplored and their ecological function and value must be inferred from knowledge of other seamounts. Seamounts tend to host vulnerable ecological communities made up of sponges, cold-water corals and other sessile invertebrates, which provide food and habitat for a rich demersal fauna that is, in turn, preyed upon by deep-diving pelagic species (Clark et al. 2010). On isolated seamounts, species assemblages are often unique to individual seamounts (Richer de Forges et al. 2000).

Billfish and other large pelagic predators are known to aggregate around the seamounts (Morato et al. 2010). The highly migratory species typically attracted to such high-productivity patches provide significant connectivity pathways as they migrate between adjacent regions (Brewer et al. 2007). Levels of connectivity between the reefs of this sub-region and those of adjacent sub-regions or the GBR are unknown.

Discussion

Despite the onset of research on the Coral Sea's reefs and seamounts in the 1950s, knowledge of these environments remains in its infancy. Community-level ecological information exists to some degree for four coral reefs, but none of the seamounts. Therefore it is not possible to map distributions of species, determine levels of biodiversity, or draw conclusions about connectivity within the Coral Sea and between the Coral Sea and adjacent regions. This makes the management of the region and the setting of monitoring targets challenging.

Overall, however, the trend is for an increasing volume of research, especially in the last decade, with grey and peer-reviewed documents increasing exponentially since 2000. While this trend encompasses a range of research disciplines, ecological research has increased most rapidly (Fig. 4). About 36% of this research has taken place on coral reefs, as opposed to deep-sea, open ocean or structural geological research, but there has yet to be a dedicated "Coral Sea reefs and seamounts expedition" that contributes more widely to the knowledge of the area. Despite these severe knowledge gaps, existing research on Coral Sea reefs and seamounts suggests that they have more than just localised ecological value.

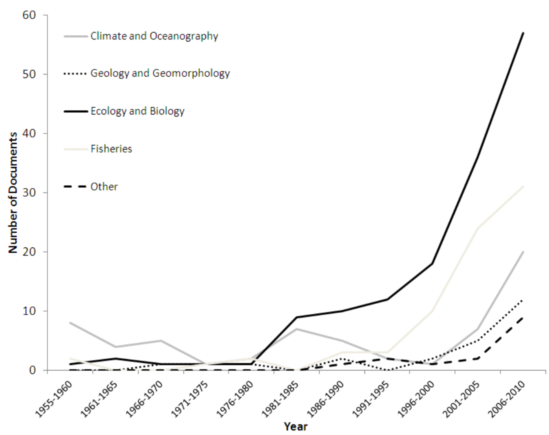

Figure 4: Research trends between 1955 and 2010 in the Coral Sea (Australian EEZ), split by major disciplines.

Various studies have found links between the Coral Sea reefs and the wider Pacific, and have suggested mechanisms of dispersal, larval retention and connectivity linked to the Coral Sea's major currents. Coral Sea reefs may function as dispersal stepping-stones between the west Pacific and the GBR (e.g. van Herwerden et al. 2009). Research on invertebrates suggests that the westward-flowing South Equatorial Current, while assisting dispersal from the Pacific towards the GBR, also creates a barrier between reefs to the north and south of the main current stream (Benzie et al. 1994). Coral reefs and seamounts in the southern Coral Sea may also act as stepping-stones for organisms whose ranges will extend southward in response to climate change (Noreen et al. 2009).

Surveys at depths of 30-150m have documented a rich mesophotic coral community that combines both deep-water specialists and shallow-water corals. The authors suggest that deep Coral Sea reefs may provide refugia from disturbances such as heavy wave action from storms and cyclones and thermal and UV bleaching (Bongaerts et al. 2011). Studying the patterns of larval connectivity between the Coral Sea and GBR may provide insights into whether the Coral Sea reefs may serve to replenish downstream GBR reefs after disturbance events.

Australia's Coral Sea is currently being assessed for management zoning, and scientific and conservation groups are calling for the entire area to be declared a no-take marine park. A draft zoning plan currently proposes a no-take zone in the eastern half of the Coral Sea, with recreational and game fishing still envisaged for the western half (Fig. 1, DSEWPaC 2012). At almost 1 million km^2, this would make it the world's largest marine reserve. A number of attributes make it a favourable candidate for this option: 1) it is relatively lightly used and sufficiently remote to escape land-derived pollution (Halpern et al. 2008); 2) it lies entirely within Australia waters, avoiding the multi-jurisdictional problems of other large ocean areas; 3) the coral reefs and seamounts are oceanographically connected to the highly diverse Coral Triangle and GBR, and they serve a potentially critical function as stepping-stones to dispersal between adjacent regions; and 4) the high diversity of habitats and their connectivity would ensure the protection of widely dispersing and migratory species and their habitats.

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