Australian Government
Australian Fisheries Management Authority

Management of Coral Harvest in the Coral Sea Fishery, Aquarium Sector

Information to support a non-detrimental finding

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Introduction

Hard corals (hermatypic corals in the order Scleractinia) are a key component of coral reef ecosystems, contributing to the geomorphology, biodiversity, and structure of coral reef ecosystems. Hard corals are major contributors to the formation of reef structures, as framework builders, and also make a disproportionate contribution to carbonate production and reef accretion (Hopley et al. 2007). Hard corals also provide food and habitat for a wide range of reef-associated fishes (Coker et al. 2014) and motile invertebrates (Stella et al. 2011).

While some hard corals may be very long-lived (e.g. massive *Porites* that live for centuries), many corals (e.g., Acroporidae) experience high rates of population turnover and grow relatively quickly. Even in the absence of major disturbances (e.g., cyclones, bleaching), corals are consistently subject to significant levels of background mortality (Pisapia and Pratchett 2014). Coral populations are maintained by high rates of reproduction and recruitment, which provides resilience to major disturbances (e.g., Gilmour et al. 2013) and greatly reduces vulnerability to over-exploitation (Harriott 2003).

Inherent vulnerabilities of hard corals

The abundance of scleractinian corals has been *in decline* across many major coral reef regions (e.g., the Caribbean and the Great Barrier Reef) for the past 20-40 years. Sustained declines in coral cover are generally attributed to increased frequency and severity of major disturbances (e.g., cyclones, outbreaks of coral predators and coral disease, and mass coral bleaching), which are increasingly compounded by declines in the growth and productivity of coral populations, attributable to increasing environmental stresses (e.g., sedimentation, pollution, ocean warming, and ocean acidification). On Australia’s Great Barrier Reef (GBR), mean coral cover is reported to have declined by 50.7% from 28.0% in 1985 down to 13.8% in 2012 (De’ath et al. 2012), based on repeated manta-tow surveys around the circumference of 218 reefs. This decline is largely attributed to impacts of outbreaks of crown-of-thorns starfish and cyclones, though severe coral bleaching in 2016-17 has certainly contributed to further coral loss, especially in northern GBR (Hughes et al. 2017).

A total of 845 coral species (including scleractinian corals, octocorals and hydrocorals) have been assessed by the International Union for the Conservation of Nature (IUCN) Red List (Table 1). One-third of coral species are considered to be Vulnerable, Endangered or

Critically Endangered, mostly due to declines in abundance of species throughout their range (Carpenter et al. 2008). A disproportionate number of Acroporidae corals are listed as threatened, mainly because they are considered to be particularly vulnerable to climate-induced coral bleaching, cyclones and outbreaks of crown-of-thorns starfish (*Acanthaster* spp.). However, the long-term persistence of different species depends as much upon their capacity for recovery, rather than their inherent vulnerability to specific disturbances.

Table 1 Number and percentage (in brackets) of species in each Red List category for Acroporidae (271 species), Pocilloporidae (32 species) and 845 species of zooxanthellate corals (scleractinians, octocorals and hydrocorals) that have been assessed (Carpenter

	Acroporidae	Pocilloporidae	Total
Data deficient	81 (29.9%)	2 (6.3%)	141 (16.7%)
Least concern	54 (19.9%)	15 (46.9%)	297 (35.1%)
Near threatened	42 (15.5%)	6 (18.8%)	176 (20.8%)
Vulnerable	85 (31.4%)	4 (12.5%)	201 (23.8%)
Endangered	7 (2.6%)		25 (3.0%)
Critically endangered	2 (0.7%)	1 (3.1%)	5 (0.6%)
Total	271	32	845

Coral assemblages have the capacity to recover quite quickly in the aftermath of major disturbances (e.g., Gilmour et al. 2011; Linares et al. 2011), as long as there are at least some surviving corals to grow and reproduce, contributing to population replenishment. Rates of recovery also vary among different types of corals. In the central GBR, *Acropora* corals recovered rapidly in the aftermath of bleaching in 2001-2002, (Linares et al. 2011), owing to their high rates of recruitment and relatively rapid growth. Similarly, coral assemblages recovered within 12-years following major bleaching at Scott Reef, in Western Australia (Gilmour et al. 2013), largely due to disproportionate increases in the cover and abundance of Acroporidae.

Coral harvesting in Australia

Select species of hard corals are harvested throughout tropical Australia by coral fisheries operating in Queensland, Northern Territory and Western Australia. The Queensland Coral Fishery (QCF) is a small-scale, quota managed hand collection fishery, which targets a wide range of hard corals as well as soft corals, anemones and live rock. Previous assessments of the QCF (e.g., Harriott 2001) have reported that strict quota limits combined with the very large area over which harvesting is permitted contributes to the sustainability of coral harvesting on the GBR. Even within major fishery areas, the amount of coral removed each year is estimated to be less than the amount of new coral added by the growth of remaining corals combined with sustained high rates of population replenishment (Harriott 2001).

All species of hard corals (Scleractinia) are listed in CITES Appendix II, which necessitates official assessment of CITES Non-Detriment Findings (NDF), to ensure that ongoing harvesting does not jeopardize the survival of species in the wild. The CITES NDF is a significant addition to the assessment of environmental performance under the

Environment Protection and Biodiversity Conservation (EPBC) Act for export eligibility of corals. For the most part, NDF decisions are based on expert testament and intuition. The only empirical data to inform this process are catch and export data, though there are projects underway to explicitly assess the stock structure and vulnerability of commonly harvested corals throughout Australia.

This report is intended to inform CITES NDF considerations for the limited collection of corals from the families Acroporidae within the Coral Sea Commonwealth Marine Reserve. Acroporidae corals are relatively fast growing and often recruit in high densities (Pratchett et al. 2015). These corals also experience high rates of natural mortality (Pisapia and Pratchett 2014) and are accordingly, relatively short-lived. These life-history characteristics result in rapid population turnover, which would confer generally high resilience to moderate levels of exploitation.

Life History

Distribution and abundance

Acroporidae corals are very abundant throughout the Indo-Pacific. In the south-west Pacific (e.g., GBR, Coral Sea, and Vanuatu) *Acropora* corals tend to dominate (accounting for >40% of coral cover) coral assemblages across a very broad range of habitats.

Extensive surveys of coral assemblages were conducted in the Coral Sea in 2012-13 (Edgar et al. 2015), and 2016-17 (Harrison et al. 2017). Edgar et al. (2015) visited 160 sites across 17 reefs from Osprey Reef to Cato Reef. Coral cover averaged 18% across all sites and reefs, but was highest (>35%) at Osprey Reef and at southernmost reefs (e.g., Wreck and Cato). Coral cover was lower (7-30%) at reefs in the central and northern reefs, which was attributed to recent effects of major cyclones, though actual causes of coral loss are generally unknown. Despite moderate coral cover and recent effects of coral bleaching (Harrison et al. 2017), Acroporidae corals are among the dominant family of corals across the Coral Sea (Figure 1).

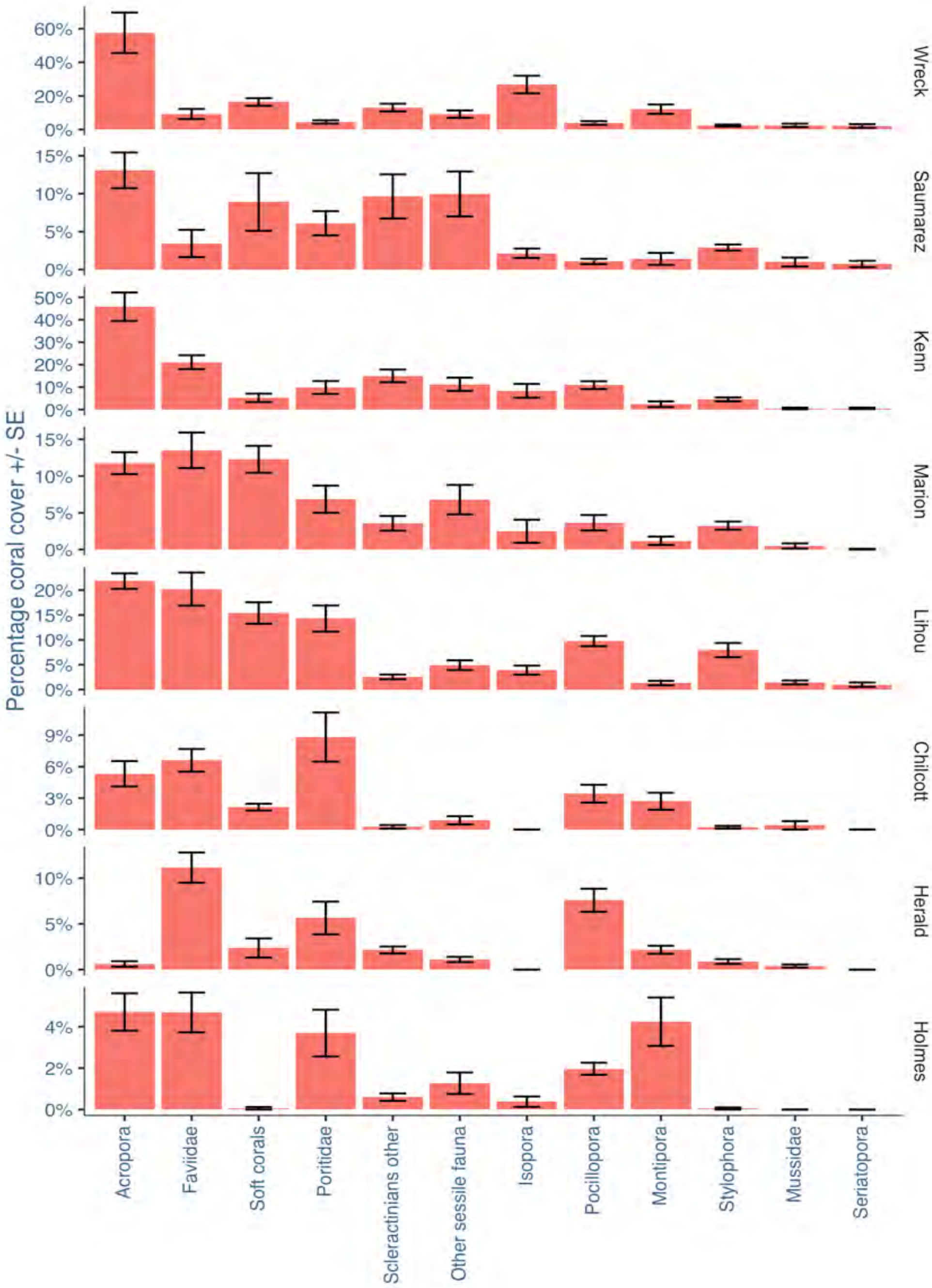

Figure 1. Coral composition at each of 8 Coral Sea reefs. Source: Harrison et al. (2017). These surveys were supported by the Director of National Parks and Parks Australia and permitted (CMR-16-000394 and CMR-16-000443) by Parks Australia under the Environment Protection and Biodiversity Conservation Act 1999.

Growth

Acroporidae corals are among the fastest growing hard corals (Pratchett et al. 2014). Average annual linear extension for Acroporidae (averaged across all published estimates for all species of *Acropora*, *Montipora*, *Isopora* and *Astreopora*) is >5 times higher than average annual linear extension recorded for most other families (Figure 2). Annual growth rates of *Acropora* corals range from 4.7 mm (for *A. hemprichii* in the Red Sea) up to 333 mm (for *A. valenciennesi* in Indonesia) depending on species and location (Pratchett et al. 2014). Branching and plating species often grow quickly into large, arborescent colonies that out-compete other corals (Baird and Hughes 2000) and monopolize space.

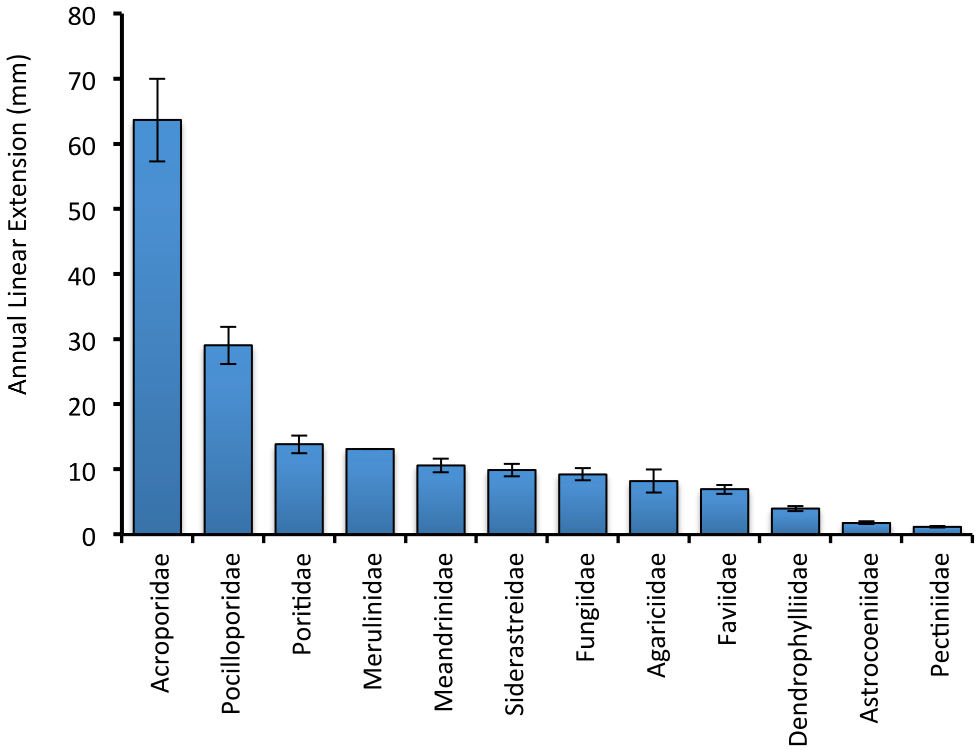

Figure 2 Variation in annual extension rates (mm) of corals by family. Data are based on an extensive meta-analysis of published growth rates for coral species from throughout the world. Source: Pratchett et al. 2014.

Reproduction and recruitment

Acroporidae corals are mostly hermaphroditic, broadcast spawners (Baird et al. 2009). Compared with other corals, *Acropora* have low polyp fecundity (Wallace 1985), though the fecundity of colonies is very high owing to their large colony size and small and tightly packed polyps. Larvae from broadcast spawning Acroporidae may be very long-lived (Graham et al. 2008), such that larvae may be dispersed considerable distances. Specific local rates of population replenishment will depend on the location of, and connectivity to, viable source populations.

Acroporidae tend to exhibit high rates of recruitment, though recruitment is often conditional upon high local abundance of adult coral colonies (Gilmour et al. 2013), especially at small and isolated reef locations. For example, severe bleaching at Scott Reef in 1998 killed all large *Acropora* corals and resulted in effective recruitment failure for the next 6 years (Gilmour et al. 2013).

Population and community status

Major threats

Low coral cover across much of the central Coral Sea is attributed to the relatively recent effects of major cyclones (Edgar et al. 2015). However, there is limited ongoing research and monitoring in this region, which constrains understanding of the factors that have structured contemporary biological communities. Shallow reef environments in the Coral Sea are exposed to considerable wave action, which may naturally suppress cover of hard corals in forereef habitats (Ceccarelli 2011), even in the absence of severe tropical storms.

Average sea surface temperatures in the Coral Sea have risen by ~ 0.5^{o}C in the last 5 years and are projected to increase a further 1-3 degrees by 2100 (Ceccarelli 2011). Increasing ocean temperatures are expected to cause increasing incidence and severity of coral bleaching, as well as potentially undermining the productivity and resilience of coral populations. In 2016, extreme sea surface temperatures occurred across the northern GBR and Coral Sea following a strong El Nino event in the Pacific. Accordingly, significant coral bleaching occurred in the north-west Coral Sea (Harrison et al. 2017). High sea surface temperatures also occurred in early 2017, again resulting in widespread coral bleaching. Recurrent bleaching episodes represent a significant threat to shallow reef coral assemblages, though the full extent of the recent bleaching episodes is yet to be realized and we are currently unclear about the capacity of these reef assemblages to recover in the aftermath of such disturbances. Ongoing monitoring will be critical to inform long-term predictions about the fate of coral assemblages in the Coral Sea, though this will be logistical challenging given the isolation and vast area of reef habitat.

Vulnerability and resilience

The resilience of marine species and communities in the Coral Sea is all but unknown. Persistent low cover of scleractinian corals in some areas of the Coral Sea CMR (e.g., Coringa-Herald reefs) suggests that there may be limited connectivity among reef systems (Ceccarelli 2011), which would constrain recovery and resilience. However, isolated reefs can recover (Gilmour et al. 2011) and may exhibit increased resilience owing to their isolation from chronic anthropogenic pressures (e.g., fishing, sedimentation and eutrophication).

Management Arrangements for the Coral Sea Fishery

Currently, the only areas subject to closures in the Coral Sea are the Coringa-Herald and Lihou Reef National Nature Reserves, which cover an area of approximately 17,000km^2. No commercial fishing is permitted in these areas.

Under the Draft Coral Sea Marine Park Management Plan 2017, the proposed Coral Sea Commonwealth Marine Reserve is a single, large (989,842km^2) and continuous marine reserve directly adjacent to the Great Barrier Reef Marine Park and extending north-east into the Coral Sea to the outer extent of Australia's Exclusive Economic Zone.

Under that proposal, the most accessible reefs in the south-western section of the Coral Sea (e.g., Flinders Reef and Holmes Reefs) are zoned Habitat Protection Zone (Reefs) (IUCN IV) that do allow for commercial fishery activities subject to approval of necessary permits. There will be limited areas which prohibit all commercial fisheries activities (National Park Zone (IUCNII)) located to the north (e.g., Osprey) east (e.g, Herald Cays) of Holmes Reefs, but these are >100km from the likely focal area (Holmes Reefs) for coral harvesting (Figure 3).

Catch limits

Despite reports of relatively low coral cover (Edgar et al. 2015), the expansive area of shallow reef habitat across the Coral Sea would allow for relatively high sustainable catch limits, especially given that the fishery is targeting only fast growing coral taxa (Acroporidae). The vast area of reef area within multiple management zones will also provide inherent resilience against any localized fisheries depletion.

If fisheries activity is spread over a sufficiently large area and across multiple species, catch limits could afford to be very high (Table 1). For example, there is an extensive area (16.20 km^2) of fore reef habitat at Holmes Reef (Leatherbarrow and Woodhams 2015), which is the habitat that supports maximum growth and abundance of *Acropora* corals (Longenecker et al. 2015). Depending on current estimates of coral cover, and assuming even distribution and abundance of *Acropora* across the fore reef, this would equate to a combined areal extent of 450-664 thousand square meters of *Acropora*. Assuming a very conservative mean size for colonies (2,000 cm^2) and using published area-weight relationships for corymbose *Acropora* colonies (Longnecker et al. 2015) this would equate to a standing stock of 6,310– 9,240 tons across all *Acropora* species at just this one reef complex. Moreover, very conservative estimates of annual production (accounting for growth rates of moderate sized coral colonies and not accounting for any recruitment) of *Acropora* from just this system (the reef crest at Holmes Reefs) would equate to 75-110 tons per annum, following Longenecker et al. (2015).

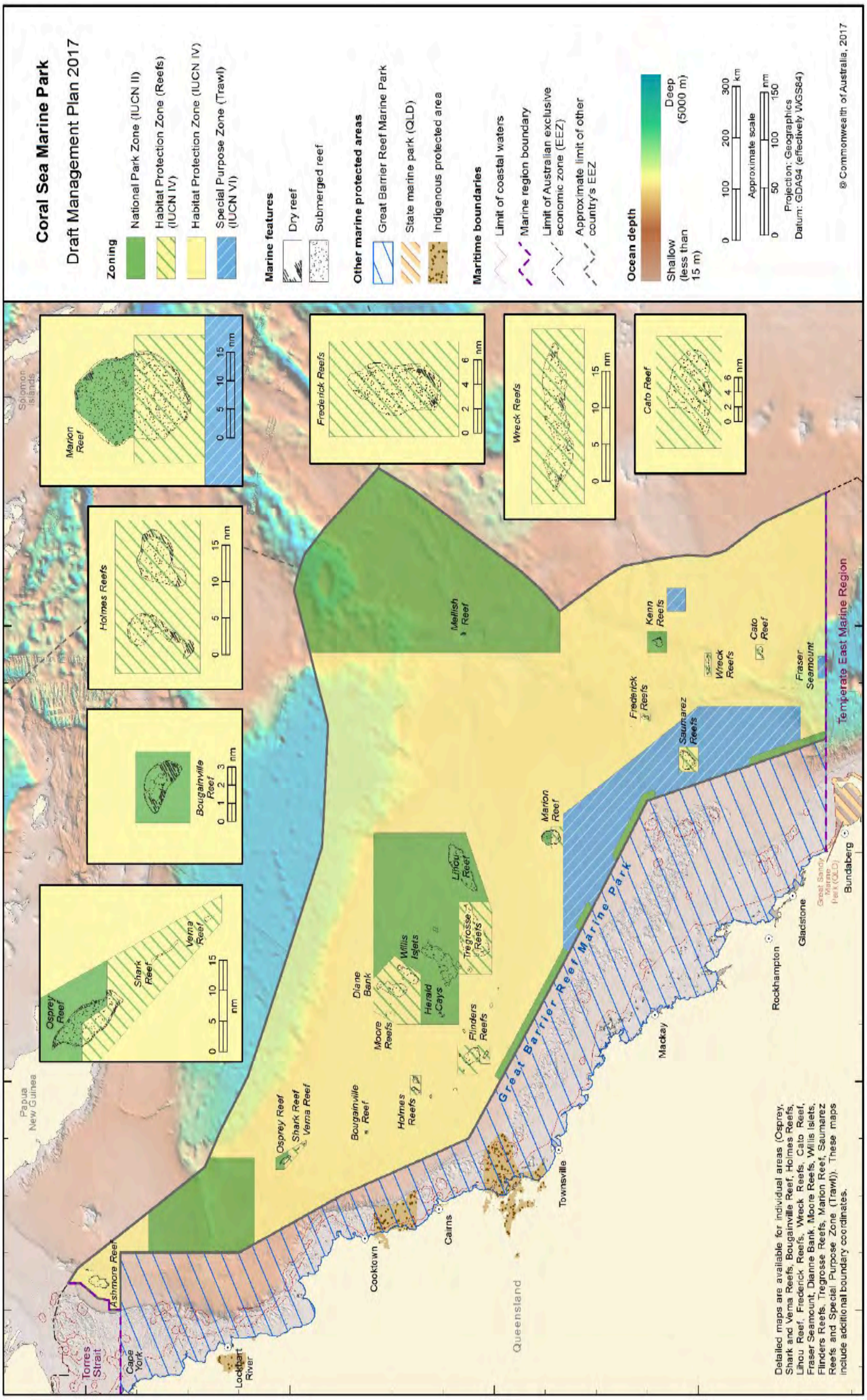
Coral Sea Marine Park
Draft Management Plan 2017
Zoning
National Park Zone (IUCN II)
Habitat Protection Zone (Reefs) (IUCN IV)
Habitat Protection Zone (IUCN IV)
Special Purpose Zone (Trawl) (IUCN VI)
Marine features
Dry reef
Submerged reef
Other marine protected areas
Great Barrier Reef Marine Park
State marine park (QLD)
Indigenous protected area
Maritime boundaries
Limit of coastal waters
Marine region boundary
Limit of Australian exclusive economic zone (EEZ)
Approximate limit of other country's EEZ
Ocean depth
Shallow (less than 15 m)
Deep (5000 m)
Approximate scale
Projection: Geographics
Datum: GDA94 (effectively WGS84)
© Commonwealth of Australia, 2017
Detailed maps are available for individual areas (Osprey, Shark and Verna Reefs, Bougainville Reef, Holmes Reefs, Lihou Reef, Frederick Reefs, Wreck Reefs, Cato Reef, Fraser Seamount, Dianne Bank, Moore Reefs, Willis Islets, Flinders Reefs, Tregrosse Reefs, Marion Reef, Saumarez Reefs and Special Purpose Zone (Trawl)). These maps include additional boundary coordinates.
Great Barrier Reef Marine Park
Temperate East Marine Region
Torres Strait
Cape York
Ashmore Reef
Lockhart River
Cooktown
Cairns
Townsville
Mackay
Rockhampton
Gladstone
Bundaberg
Queensland
Papua New Guinea
Solomon Islands
Osprey Reef
Shark Reef
Verna Reef
Bougainville Reef
Holmes Reefs
Moore Reefs
Diane Bank
Willis Islets
Herald Cays
Flinders Reefs
Tregrosse Reefs
Lihou Reef
Mellish Reef
Marion Reef
Frederick Reefs
Saumarez Reefs
Kenn Reefs
Wreck Reefs
Cato Reef
Fraser Seamount
144°E
148°E
152°E
156°E
160°E
10°S
14°S
18°S
22°S

Table 2 Annual catch limits for the extensive fore reef (16.20 km^2) at Holmes Reefs calculated based on very rudimentary fisheries management strategies and contemporary estimates of abundance across all *Acropora* species. These catch limits will need to be modified if i) exploitation will be specific to only select Acropora species, and ii) if there are ongoing (fishery independent) threats to the local abundance and productivity of Acropora corals. Development of more established harvest strategies (e.g., Maximum Sustainable Yield) is currently constrained by limited understanding of dynamic feedbacks for coral populations. There is also, yet to be any explicit research into the responses of coral populations or assemblages to direct exploitation.

Harvest strategy	Lowest estimated annual catch (tonnes)	Highest estimated annual catch (tonnes)
1% of standing biomass	63.1	92.4
5% of standing biomass	315.5	462.0
50% of annual production*	37.9	55.4
100% of annual production*	75.7	110.8

*Annual production is carbonate production (or total skeletal weight) that is added solely through projected annual growth of *Acropora* colonies, based on published growth estimates for exposed reef crest habitat in Indonesia (Longenecker et al. 2015) and does not account for any population replenishment.

AFMA proposes to limit the take of Corals from the families Acroporidae to 40 t annually between the two aquarium sector permits. This amount of corals will allow operators to supply national and international markets whilst maintaining a sustainable harvest.

Catch Triggers

Under the proposed harvest limit of 40 t between the two aquarium sector permits, AFMA will review the species catch composition and spatial extent of the harvest when 20 t of corals have been harvested to ensure that a disproportionate amount of coral species are not taken from a single reef.

Reporting and logbooks

Currently the logbooks used in the CSF do not accommodate reporting to species level, nor is there a space to report corals. Operators will be required to report species, weight and location of harvested corals in the comments section of their logbooks, as they are for live rock and Maori Wrasse.

Summary

Acroporidae corals are generally very abundant, and likely to be very resilient to fisheries exploitation owing to their intrinsic life history characteristics (e.g., rapid growth, high rates of recruitment and naturally high levels of population turnover). The impact of limited collecting of Acroporidae corals across broad areas of the Coral Sea is therefore, expected to be negligible. If fisheries activity is constrained to specific locations and/ or select coral species, then it may be prudent to undertake more detailed and specific stock assessments to establish likely impacts of the fishery and guide sustainable fishery limits.

Ongoing fishery activity by QCF operators within the Coral Sea could have some significant benefits for addressing major knowledge gaps and considerable logistic constraints on effective management of reef habitats and coral assemblages within the Coral Sea. Given the significant fishery-independent threats (e.g., mass coral bleaching) to coral assemblages, annual catch limits should be conditional upon the current status and trends in coral abundance and productivity, with onus placed upon fishery operators to provide timely advice on the incidence of mass coral bleaching and/ or apparent effects of other major disturbances (e.g., cyclones). The QCF is already very active, and engaging with scientists, to improve sustainability of coral harvesting across the Great Barrier Reef, and has adopted sampling protocols to provide rigorous and defensible estimates of coral health and abundance.

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