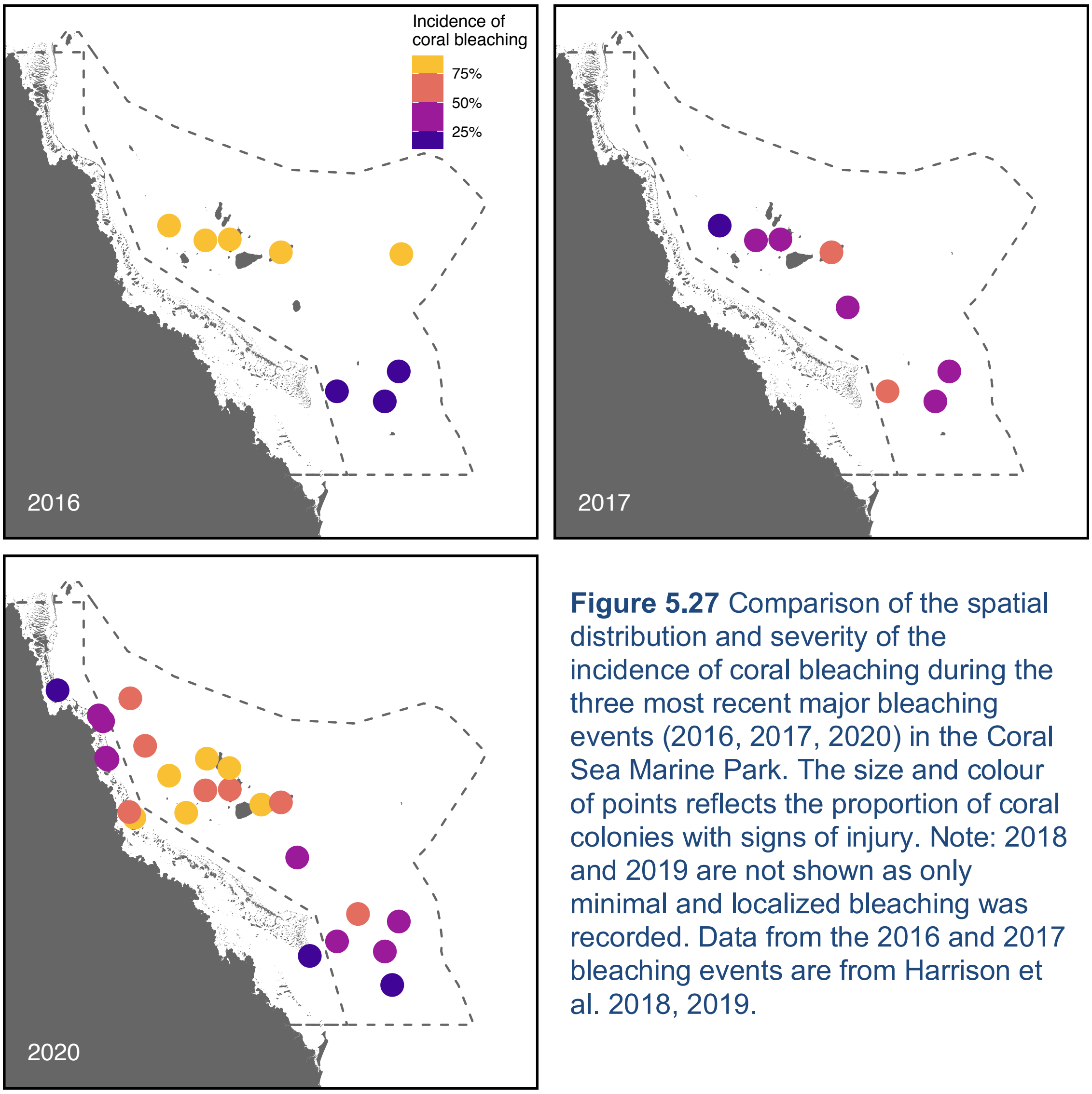


Figure 5.27 Comparison of the spatial distribution and severity of the incidence of coral bleaching during the three most recent major bleaching events (2016, 2017, 2020) in the Coral Sea Marine Park. The size and colour of points reflects the proportion of coral colonies with signs of injury. Note: 2018 and 2019 are not shown as only minimal and localized bleaching was recorded. Data from the 2016 and 2017 bleaching events are from Harrison et al. 2018, 2019.

5.8 Water current models

Data extracted and analysed from the initial deployment of water current meters in 2019 revealed variation in both the velocity and direction of water currents and water temperature between depths. Importantly, water current meters deployed at Bougainville and Osprey Reefs in December 2019 and retrieved in March 2020 recorded water flow and temperature data during the 2020 marine heatwave that lead to mass coral bleaching events in the CSMP (Section 5.7) and GBRMP (Hughes and Pratchett 2020). Data extracted from these current meters indicate that the wind field was weaker than predicted by climatology models (negative values in blue; Figure 5.28), while the major water currents, the North Vanuatu Jet

(NVJ), the East Australian Current (EAC) and the North Papua Gyre (NPG) were stronger than usual (positive anomaly shown in red; Figure 5.28) during the 3-month period December 2019 to March 2020. The weaker wind field may have played an important role contributing to the 2020 marine heatwave, while the stronger NVJ could have increased the frequency of upwellings around CSMP reefs, bringing cooler and nutrient-rich water to shallow regions and thereby reducing heat stress on corals in these areas.

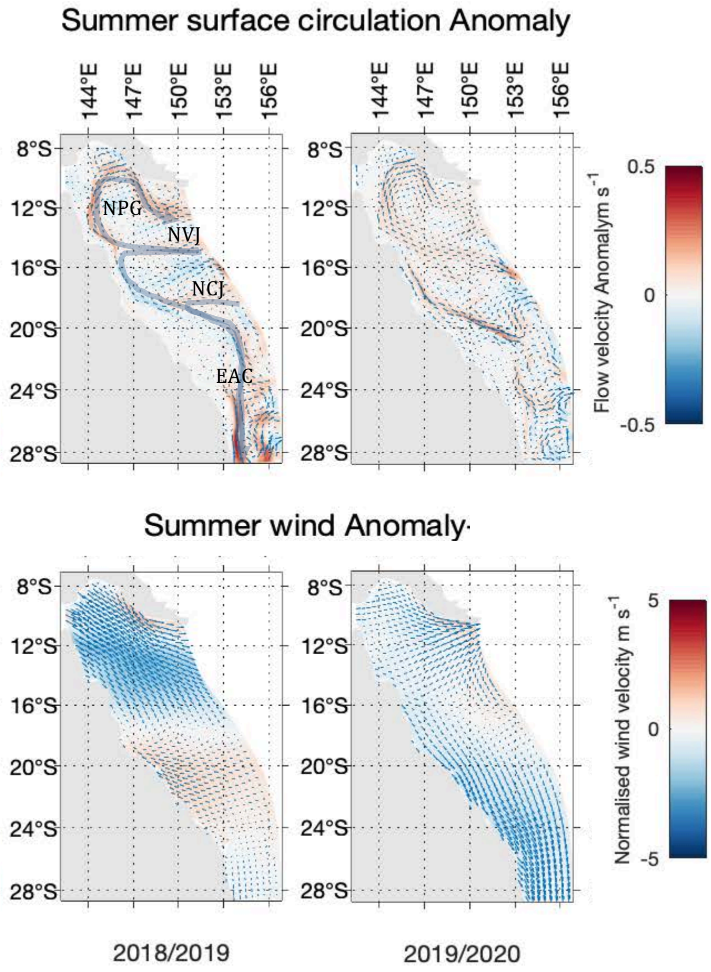


Figure 5.28 Maps showing modelled sea surface circulation and wind climatology for the Coral Sea. The wind and velocity summer climatology (November to March) was computed using the eReef GBR4 (https://research.csiro.au/ereefs/models/model-outputs/gbr4/) results for 10 years. The anomaly was derived from the climatology. NPG: North Papua Gyre; NVJ: North Vanuatu Jet; NCJ: North Caledonian Jet; EAC: East Australian Current

Bougainville Reef is located on the path of the NVJ (i.e., the northern arm of the South Equatorial Current; Figure 5.28). The NVJ bifurcates to form the Gulf of

Papua Current (GPC) to the north, and the northern start of the EAC, to the South. Water flow derived from the current meters around Bougainville Reef is consistent with the presence of the NVJ, with mean water flow oriented between north-northwest and north-northeast (Figure 5.29). There was, however, variability in the flow velocity, direction and temperature among sites and depths with water flow being stronger at the sites on the south-east aspect, and weaker at the site 1 on the north-west aspect. Further, the shallow (5-10m) current meter at the *SE Corner* site indicates a relatively weak flow, oriented to the south-west while the deeper (>10m) current meter indicates a flow 3 times stronger, oriented to the north-west (Figure 5.29).

As well as differences in the direction and velocity of water flows, significant temporal variation in water temperatures was evident within individual sites and depths around Bougainville Reef (Figure 5.29). Numerous episodes of intrusions of both cooler water and warmer water were detected around the Bougainville Reef (Figure 5.29). Intrusions of cooler water (up to 2.5ºC cooler) were evident at all sites, and were especially pronounced at the deeper current meter sites. These decreases in water temperature are likely driven by upwelling of cooler water from deeper areas, and although relatively short-lived would decrease any heat stress and potential mediate coral bleaching on corals in these areas. Conversely, intrusions of warmer water (up to 2.7ºC warmer) was visible from the shallow (4m) current meter at Site1 on Bougainville Reef, and are likely generated by shallow reef flat or lagoonal water overflowing the reef crest.

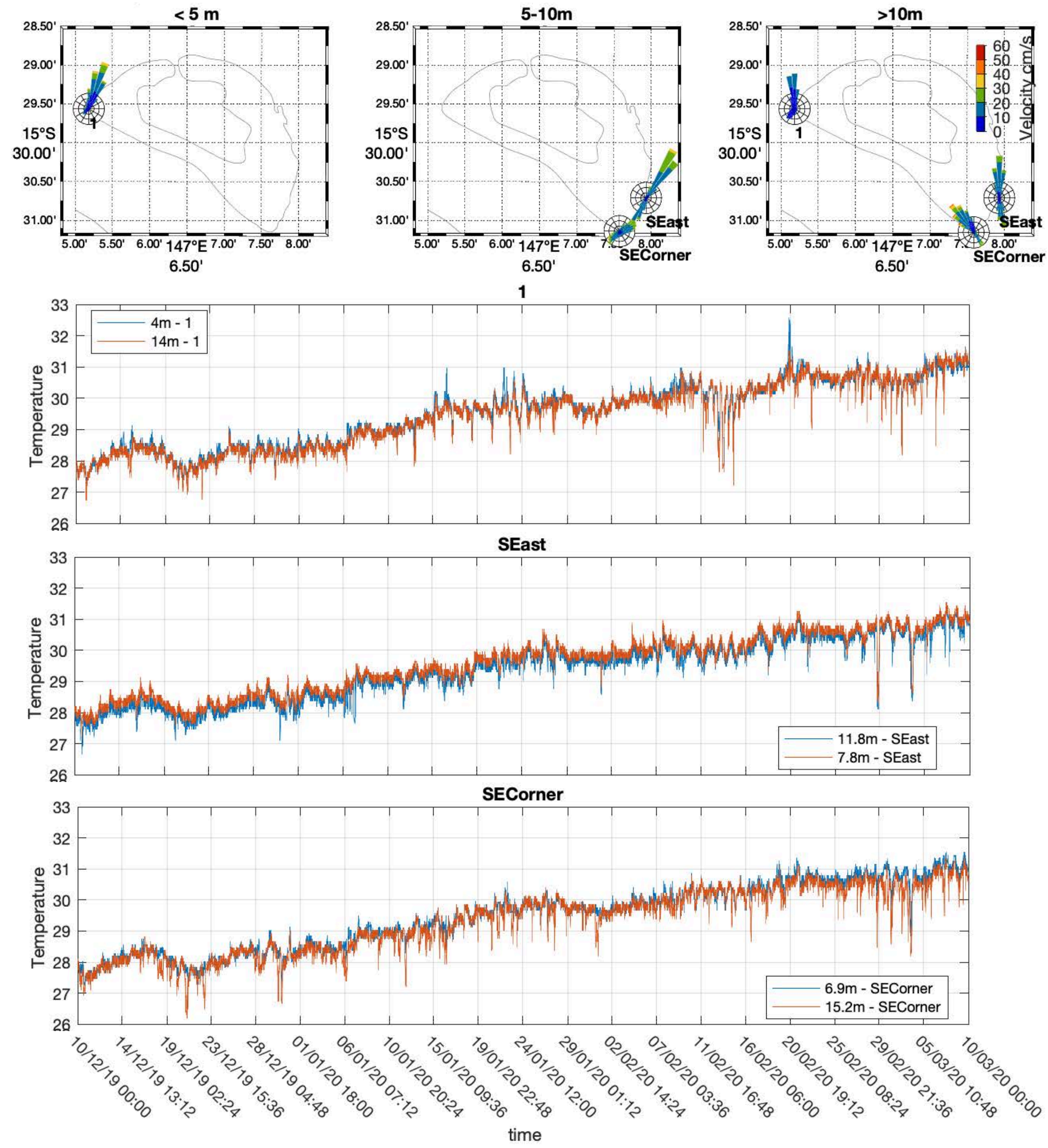


Figure 5.29 Observed water flow velocities and directions (top three panels) and water temperatures (lower panels) around Bougainville Reef, northern Coral Sea Marine Park between December 2019 to March 2020.

Similar variation in the velocity and direction of water flows, and local water temperatures were evident from nine current meters deployed around Osprey Reef between December 2019 and March 2020 (Figure 5.30). Cold water upwellings are also visible around Osprey Reef, however the timing of these events varied among sites and depths (Figure 5.30). This likely reflects the complex water circulation around Osprey Reef as it sits within the NPG, which forms mesoscale eddies. Further deployment of current meters would be necessary to understand the processes initiating these cold water upwellings.

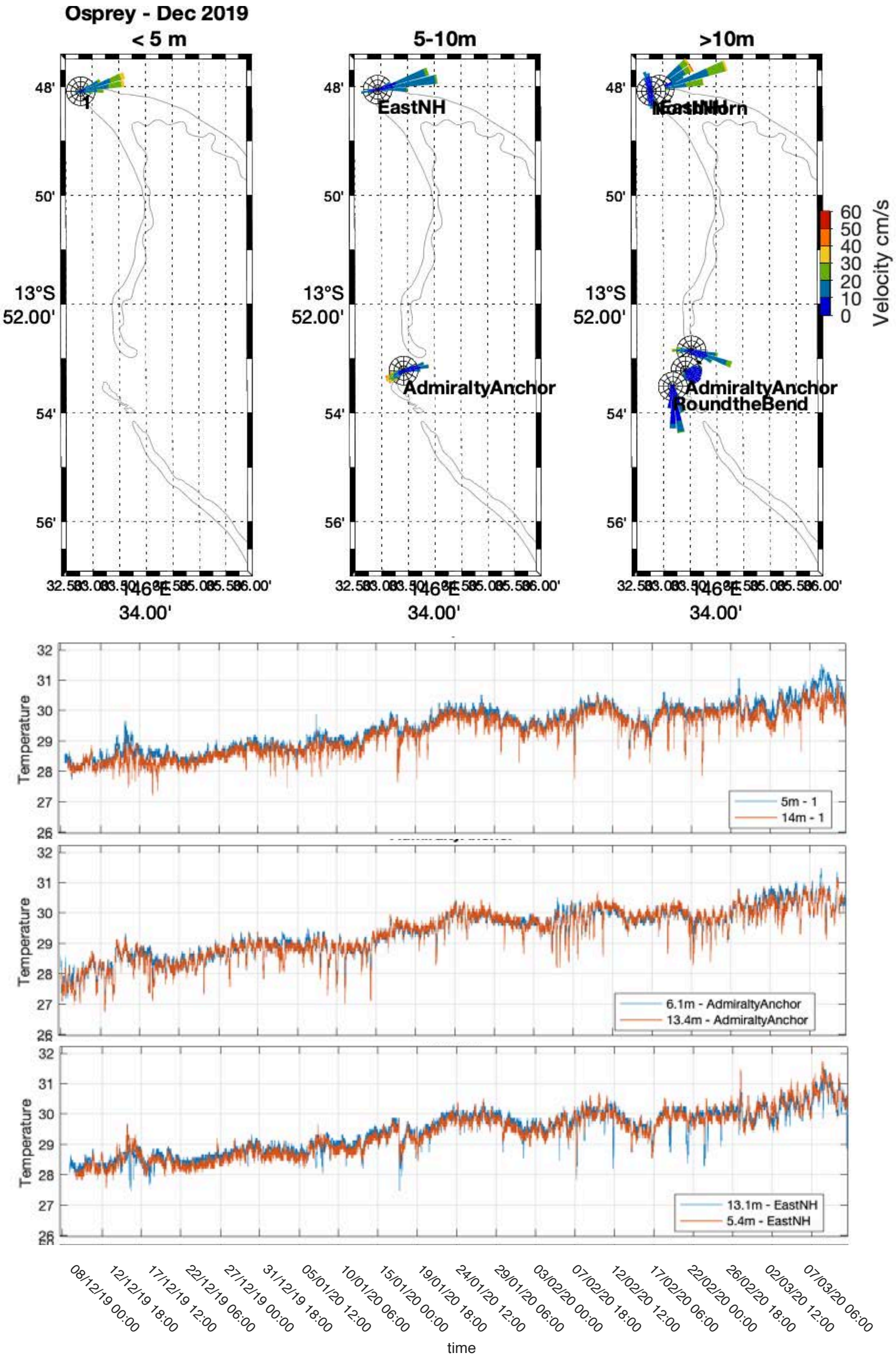


Figure 5.30 Observed water flow velocities and directions (top three panels) and water temperatures (lower panels) around Osprey Reef, northern Coral Sea Marine Park between December 2019 to March 2020.

The data from these current meters were used to compare observed temperature, velocity and direction against modelled data from Ereef GBR4 (https://research.csiro.au/ereefs/models/model-outputs/gbr4/). Comparison of the observed versus modelled time series for the *East North Horn* site on Osprey Reef show the GBR4 model captured the gradual warming of water over the 3-month period (Figure 5.31) heating up trend, which is to be expected as the model assimilates Satellite Sea Surface temperature data. However, temperature data derived from the model demonstrated a bias toward cooler temperature by 1 to 1.5ºC compared to the observations from the current meters, for all sites (Figure 5.32). Critically, the model doesn't resolve any of the cooler water nor the warmer waters intrusions that were regularly detected using current meters at these reefs. The model also over-estimates flow velocities and doesn't predict the flow direction well (Figure 5.31). In summary, the current coarse resolution of the Ereef GBR4 model doesn't resolve or capture physical processes that take place at the reef scale.

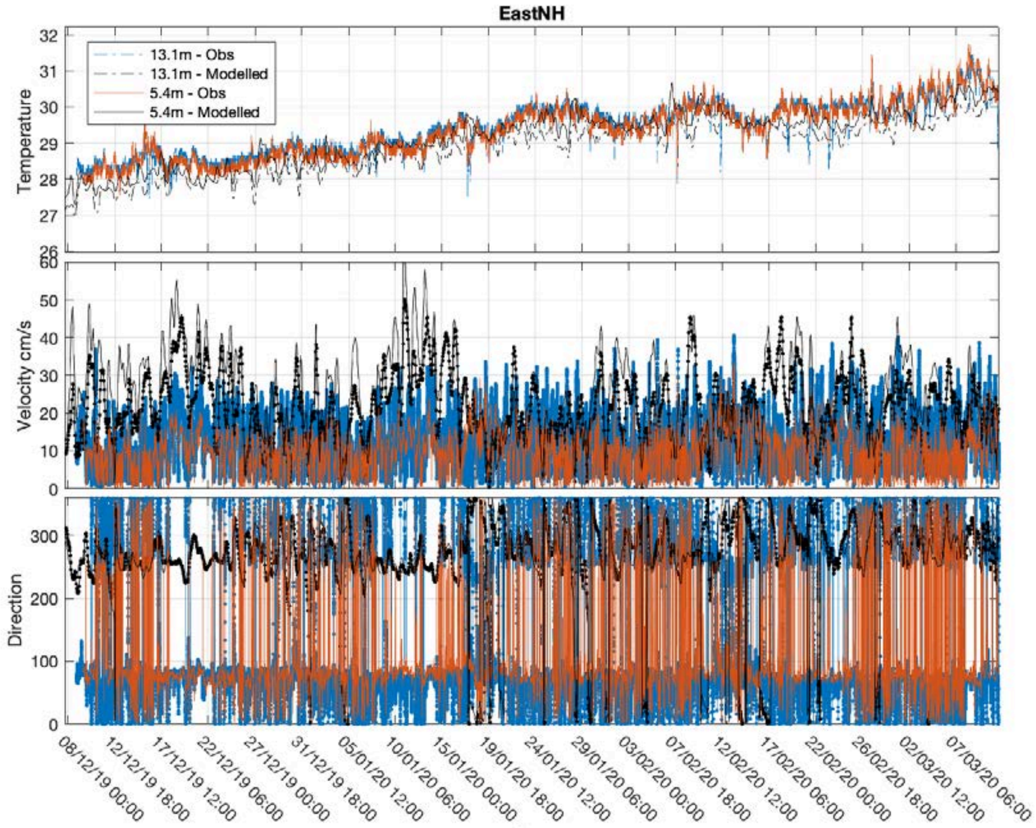


Figure 5.31 Comparison of water temperature, flow velocity and flow direction data between the Ereef GBR4 model and in-water current meter for two depths (13.1m and 5.4m) at the *East North Horn* site at Osprey Reef. Modelled data is represented in black.

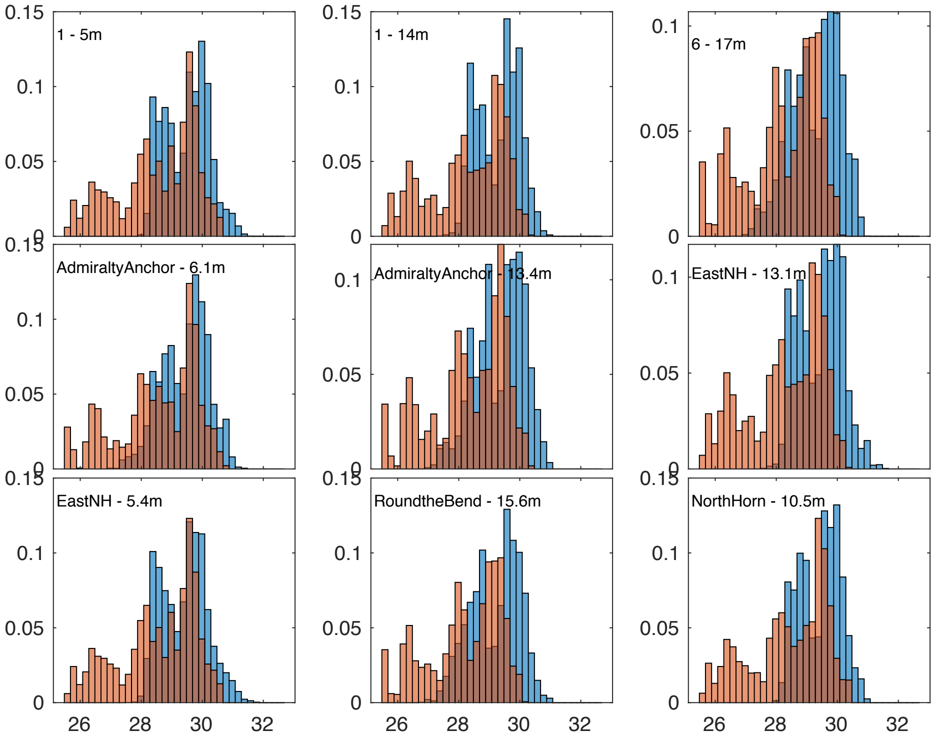


Figure 5.32 Histograms comparing the frequency of normalized temperature (binned into 0.1°C intervals) predicted by the Ereef GBR4 model (red) versus those observed by the in-water current meters (blue) for all sites at Osprey Reef, northern Coral Sea Marine Park.

5.9 Connectivity

Oceanographic connectivity – Model simulations parameterised for coral trout predicted weak connectivity patterns within and between the CSMP and GBRMP. Over the course of an 8-year period, reefs of the western CSMP (Osprey, Bougainville and Flinders Reefs) generated the most larval supply to the GBRMP (Figure 5.33 a). Of these reefs, Osprey Reef was the most important source of particles to the GBRMP, with most particles entrained by the GPC and settling north of Princess Charlotte Bay in the GBRMP. However, larval supply amongst other reefs within the CSMP was predominantly low or inconsistent throughout the modelled period.

Three main community clusters were identified within the source reefs, which correspond largely to the distinction in biogeographic patterns of corals and fishes in the CSMP (Figure 5.33 a). The central reefs of the CSMP represent a highly connected cluster, with each reef representing an important source of particles within the CSMP. In contrast, low connectivity in the southern CSMP suggests most reefs are isolated from each other. Particles released from Mellish Reef did not reach any destination reefs, however particles may have been 'lost' outside of the model boundaries and therefore could not reach other reefs in the CSMP.

The GBRMP and some western reefs in the central CSMP were the dominant destination for particles released from the CSMP (Figure 5.33 b). Once again, three dominant clusters were identified in the destination reefs, which correspond largely to the distinction in biogeographic patterns of corals and fishes in the CSMP. The dominant connectivity patterns followed a westward flow from the CSMP reefs to the GBRMP following the SEC. No particles released from the CSMP settled at Mellish Reef, though these may have been entrained beyond the model boundaries.

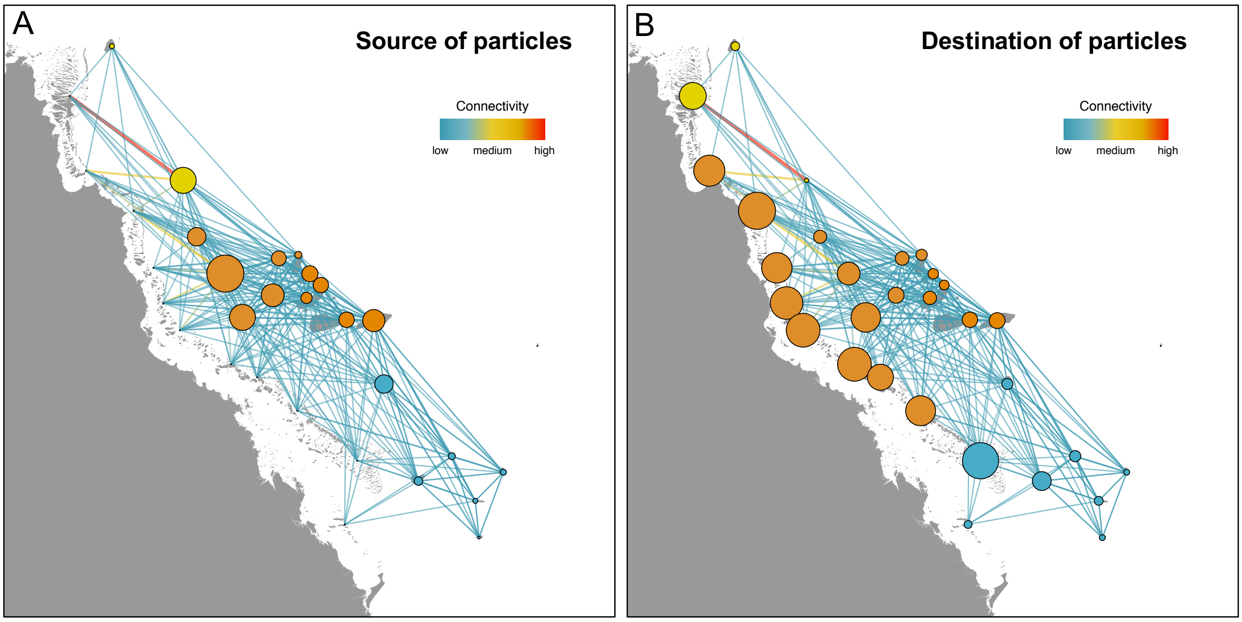


Figure 5.33 Predicted mean connectivity patterns from oceanographic larval dispersal modelling from 20 source reefs in the Coral Sea Marine Park between 2010 and 2017. The degree of connectivity between individual reefs ranges from low to high and represented by lines between reefs. Coloured nodes represent source reefs with colour represent highly connected communities. The size of nodes represents the importance of reefs as A. sources and B. destinations of simulated particles.

Genetic connectivity – Connectivity patterns inferred from the genetic structure between populations in the CSMP and GRBMP showed largely similar patterns between species. Both genetic connectivity networks suggest a strong influence of Mellish Reef on the genetic structure of *P. laevis* (Figure 5.34 a) and *C. bispinosa* (Figure 5.34 b) in the CSMP, which is indirectly supported by the westerly flow observed in model simulations. However, the connectivity networks are poorly resolved, which suggest a strong influence of unsampled 'ghost' populations. This may indicate a strong influence of either the GBRMP or other populations on the genetic structure of populations in the CSMP. Nevertheless, a weak community clustering distinguishes reefs in the central and northern CSMP from reefs in the southern CSMP. With the addition of high genetic similarity between a sample of *P. laevis* from the Townsville region and the southern CSMP, these results indicate that the GRBMP may be acting as a stepping stone for connectivity between the central and southern CSMP.

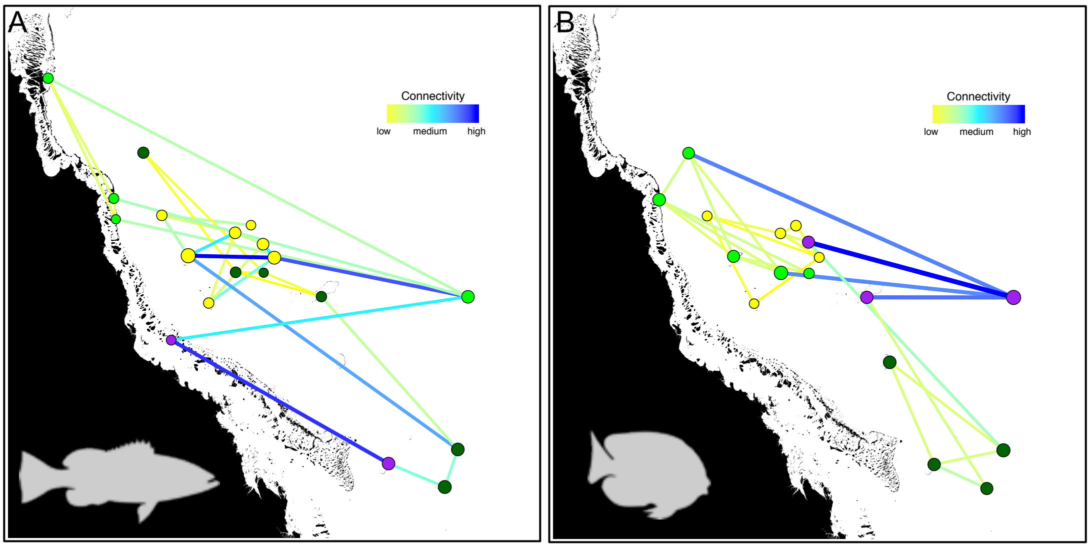


Figure 5.34 Measured connectivity patterns between reefs in the Coral Sea Marine Park and Great Barrier Reef Marine Park for (a) bluespotted coral trout (*Plectropomus laevis*) and (b) twospined angelfish (*Centropyge bispinosa*). The degree of connectivity between individual reefs ranges from low to high and represented by lines between reefs. Coloured nodes represent reefs in the CSMP and GBRMP, with colour representing highly connected communities within the network.

Together, results from the biophysical modelling of larval connectivity of *Plectropomus* spp. and genetic connectivity for two species of coral reef fish (*P. laevis* and *C. bispinosa*) indicate that connectivity within the CSMP is low, with many reefs demographically isolated from each other. The biophysical modelling indicates a high degree of connectivity between the northern CSMP (Osprey, Bougainville and Flinders Reefs) and the northern GBRMP. However, connectivity amongst other reefs within the CSMP was predominantly low and inconsistent. These results indicate that the replenishment of fish populations in the CSMP may depend largely on processes of self-recruitment rather than replenishment from distant populations. The lack of connectivity in fish populations among CSMP reefs will likely reflect that of other reef taxa (e.g., corals) given the limited swimming abilities of most marine larvae. Low connectivity between reefs and the limited number of possible source reefs increases the exposure of populations to fluctuations in larval supply (fish and likely other reef taxa), which can lead to large fluctuations in recruitment and population density. Because of this, smaller reefs (e.g. Moore Reef and Coringa-Herald Islets and Cays) that have smaller populations and limited habitat will be highly sensitive to exploitation and slower to recover following localised disturbances.

The lack of genetic differentiation in both *P. laevis* and *C. bispinosa* between the CSMP and GBRMP indicates there is likely some contemporary gene flow (i.e., connectivity) between the two systems. Based on the biophysical modelling, it is likely that gene flow is predominantly from the CSMP to GBRMP, however further modelling would be necessary to establish the relative importance of GBRMP reefs in the supply of larvae to reefs in the CSMP. There is a weak but prominent genetic cluster that includes reefs in the central and northern CSMP, separate from the southern CSMP. Mellish Reef stands out as an important node. As the most easterly reef in the CSMP, Mellish Reef may have a strong influence on the genetic diversity of populations of *P. laevis* and *C. bispinosa* in the CSMP. Its isolation combined with its position in the centre of the broader Coral Sea, would lead to strong genetic differentiation from other reefs in the CSMP. It is more likely that a unique genetic signature of populations of *P. laevis* and *C. bispinosa* is pervading through to other sampled populations, supporting a dominant westerly gene flow in the CSMP. However, the low sample size of *C. bispinosa* from Mellish Reef may be accentuating this pattern. Furthermore, limited sampling in the GBRMP, particularly in the southern GBRMP does not fully resolve the connectivity patterns between the central and southern CSMP, and the GBRMP.

The influence of the GBRMP on reefs in the CSMP remains unclear without further biophysical modelling. Meanwhile, the dominant westerly flow of connectivity suggests that biogeographic processes in the CSMP may be driven by other reef systems in the broader Coral Sea, particularly from eastern regions bordering the CSMP (Solomon, Vanuatu, New Caledonia). Understanding the importance of other fish populations in shaping the genetic structure in the CSMP would require extending both model boundaries and genetic sampling in the broader Coral Sea. The low and variable fish connectivity patterns within the CSMP indicate populations of reef fish, particularly those on remote reefs such as Mellish Reef, are demographically isolated, and therefore highly susceptible to disturbance and exploitation. It's important to note that the conclusion drawn here may not apply to other species in the CSMP.

5.10 Disturbance history

Tropical cyclone (TC) waves can severely damage coral reefs and predicting the damaged caused by wave exposure can help target management responses and explain spatial patterns in the condition of coral reef habitats. The damage from wave exposure varies with the intensity of waves as well as their duration, and result in minor damage to colony tips and branches to the dislogement and removal of entire colonies. Brief exposure to very powerful waves can have immediate effect on coral assemblages, while persistent exposure can lead to the removal of entire sections of the reef framework. Here, we reconstruct wind speeds generated from TCs in the CSMP to predict damaging wave heights above 4m as an indicator of very rough sea states that lead to coral damage. Periods of prolonged exposure to damaging wave height are an important indicator of disturbance regimes in coral reef ecosystems.

Wave exposure – The exposure to damaging waves (>4m) in the CSMP varied both spatially and temporally between 1985-2019, with relatively calm years interspersed with severe disturbance events. The early 1990's marked a period of high TC activity throughout the CSMP, with seven notable TCs or Severe TCs that traversed the CSMP between 1990 and 1997 (Figure 5.35, Table 5.1). Several of these moved slowly through the CSMP (e.g. TC *Fran*, TC *Rewa*, Severe TC *Oliver*, Severe TC *Justin*), and generated up to 127 hours of high intensity wave action within a single year (Diane Bank, 1991). Such events are likely to have caused widespread damage to shallow reef environments and declines in coral cover.

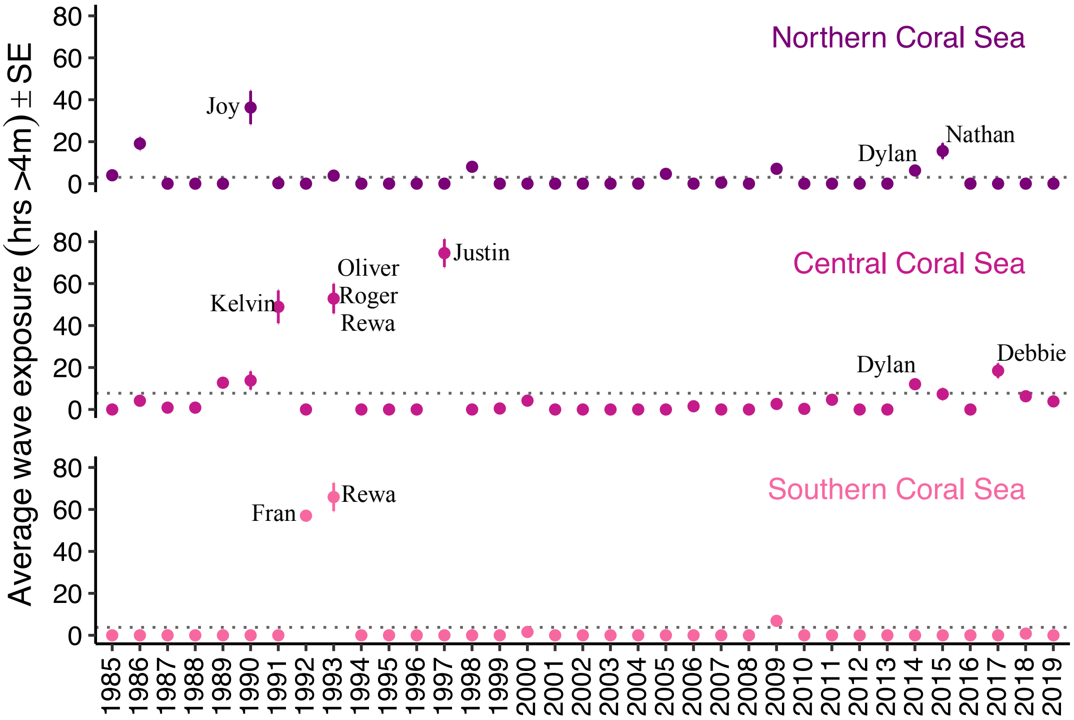


Figure 5.35 Average wave exposure activity (hours of wave activity > 4m) across reefs in southern, central and northern Coral Sea Marine Park. Notable and recent tropical cyclones that led to high wave activity are highlighted in each year. Dotted lines indicate average wave exposure.

Of notable absence in the wave exposure predictions is Severe TC *Yasi* (Figure 5.36 b) that intensified to a category 5 system and is the most powerful cyclone to have affected Queensland in recorded history. It passed Willis Islets as a category 4 system and while winds reached 285 km/h on land, *Yasi* was a fast-moving system (average forward speed of 30.2 km/hr) that transited the region within 39 hours. Despite *Yasi's* relatively large size (average radius to gales – 370 km), the relatively short time it spent within the region limited the duration of damaging waves it created to a maximum of 9 hours. In contrast, Severe TC *Justin* (Figure 5.36 a) was a large and long-lived cyclone that crossed the Queensland coast in March 1997. Brought about by the merging of two low pressure systems in an active monsoon trough, *Justin* remained almost stationary over the central Queensland plateau for nearly two weeks, and affected the CSMP for more than twice as long as *Yasi* (95 hours). It moved through the region at about one-third of the forward speed of Yasi (average speed – 7.9 km/hr), and did so while nearly 40% larger than *Yasi* (average radius to gales – 507 km).

The large size of *Justin*, very slow forward speed and slow progress through the region generated damaging waves predicted to have lasted up to 190 hours. Despite its relatively short duration of damaging seas, field surveys of reefs within the GBRMP showed widespread severe damage from *Yasi* (Beeden et al. 2015). Actual patterns of damage depend just as much on the local scale exposure and structural vulnerability of coral communities to wave damage as they do on patterns of cyclone energy. Thus, a linear increase in damage severity with increasing duration of exposure does not exist.

Several TCs moved slowly through the CSMP (e.g. TC *Fran*, TC *Rewa*, Severe TC *Oliver*, Severe TC *Justin*), and generated up to 127 hours of high intensity wave action within a single year (Diane Bank, 1991) (Figure 5.37).

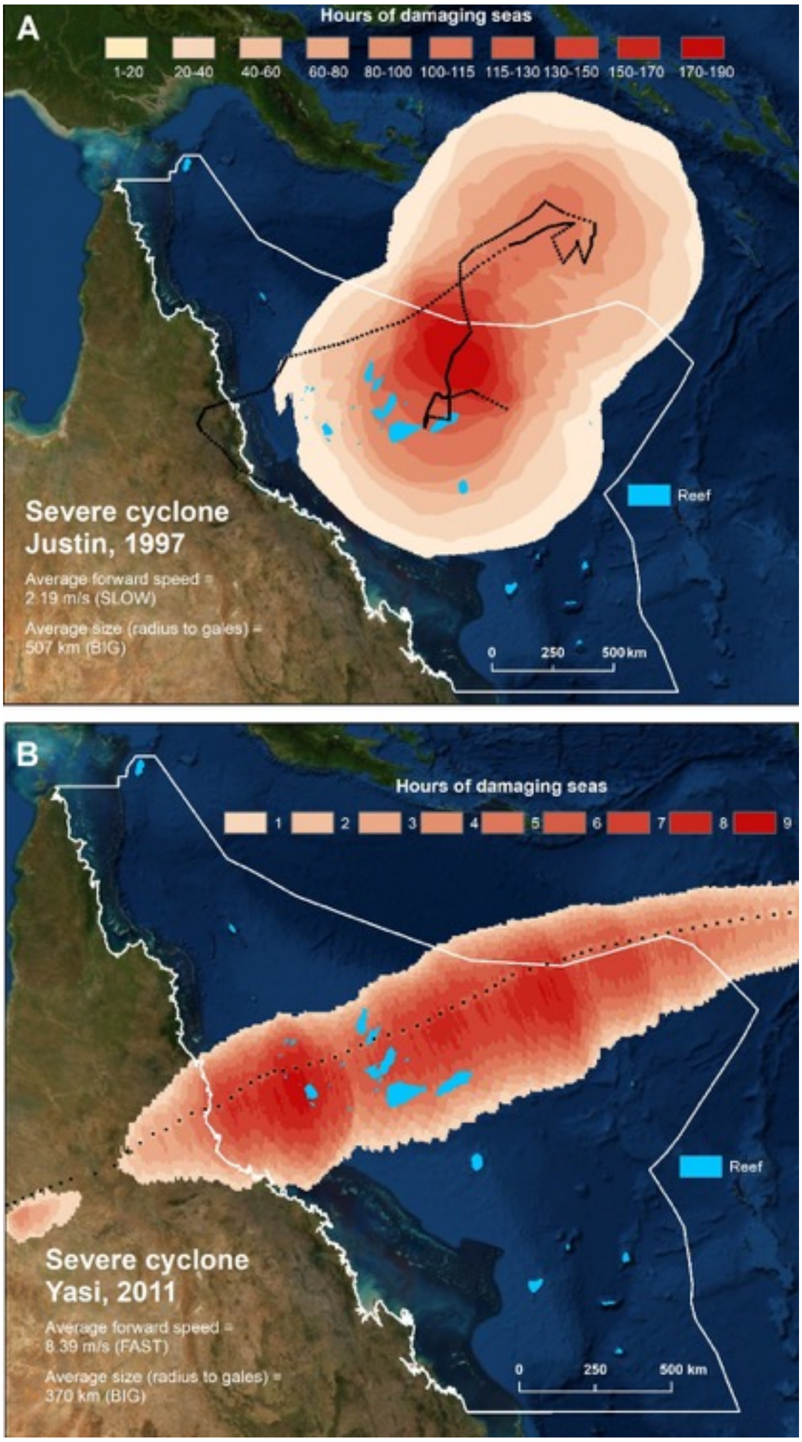


Figure 5.36 Predicted zone of damaging seas within the study area generated by (a) Severe Tropical Cyclone *Justin* (1997) versus (b) Severe Tropical Cyclone *Yasi* (2011). Yasi moved relatively quickly (average forward speed within the region was 8.39 m/s [30.2 km/hr]), and tracked through the region within 39 hours. In contrast, *Justin* took 95 hours to transit the region at an average speed of 2.19 m/s [7.9 km/hr]. Further, on average, *Justin* was nearly 40% larger than *Yasi* (average radius to gales = 506.77 km) when within the Coral Sea Marine Park.

Table 5.1 Notable tropical cyclones that traversed the CSMP exposing coral reefs to long-lasting damaging wave action (data source: Australian Bureau of Meteorology).

Cyclone name	Cyclone date	Category
Tropical Cyclone Joy	18 - 27 December 1990	1
Tropical Cyclone Kelvin	24 February - 5 March 1991	2
Tropical Cyclone Fran	5 - 16 March 1992	3
Tropical Cyclone Rewa	28 December 1993 - 21 January 1994	4
Severe Tropical Cyclone Oliver	5-13 February 1993	3
Tropical Cyclone Roger	12 - 21 March 1993	2
Severe Tropical Cyclone Justin	6 - 24 March 1997	3
Tropical Cyclone Dylan	30 - 31 January 2014	2
Severe Tropical Cyclone Nathan	10 - 24 March 2015	4
Tropical Cyclone Debbie	25 March - 29 March 2017	4

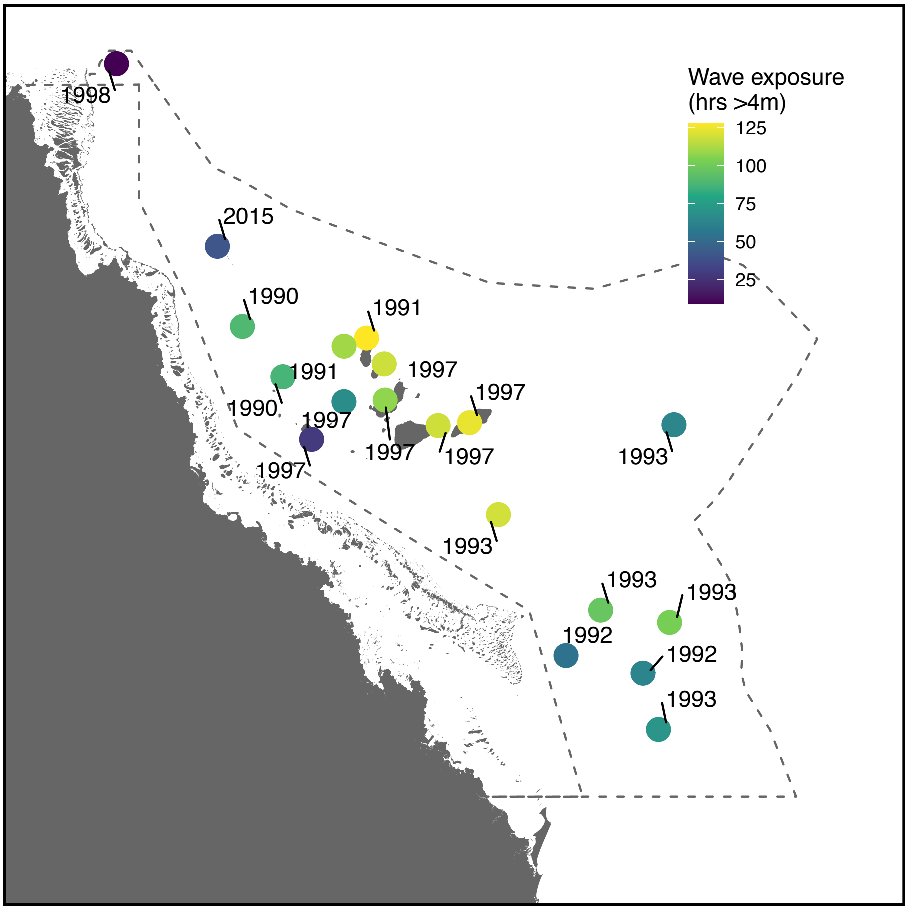


Figure 5.37 Peak wave activity for selected reefs in the Coral Sea Marine Park and Great Barrier Reef Marine Park. Coloured dots represent the maximum number of hours for which reefs were exposed to damaging wave activity (Hs >= 4m waves) in a single year.

Disturbance regimes – Wave exposure since 1985 has been concentrated in the central CSMP, with the greatest impacts on the most easterly reefs of the CSMP (Figure 5.38). Lihou Reef, Diamond and Willis Islets, and Diane Bank are the most frequently exposed to the longest lasting damaging waves as they are in the region most often exposed to tropical cyclone activity. On average, reefs in the central CSMP are exposed to 7.7 hours of damaging waves per year, almost twice as much as other regions of the CSMP (Figure 5.38 a). Cumulatively, reefs in the CSMP have been exposed to between 13.8 hours (Osprey Reef) and 367 hours (Lihou Reef) between 1985 and 2019 (Figure 5.38 b) with the highest intensity occurring the central CSMP. Both the northern and southern CSMP appear to be have low exposure to damaging waves. The intensity of the cyclone damage in the central CSMP is highlighted by the maximum annual wave exposure, which demarks areas where long periods of damaging wave action have occurred (Figure 5.38 c) and which are associated with severe, large, long-lasting and slow-moving tropical cyclones forming in the broader Coral Sea. The return time between TC events with at least one hour of significant wave height over 4m over the past 35 years is between 4 and 9 years (Figure 5.38 d).

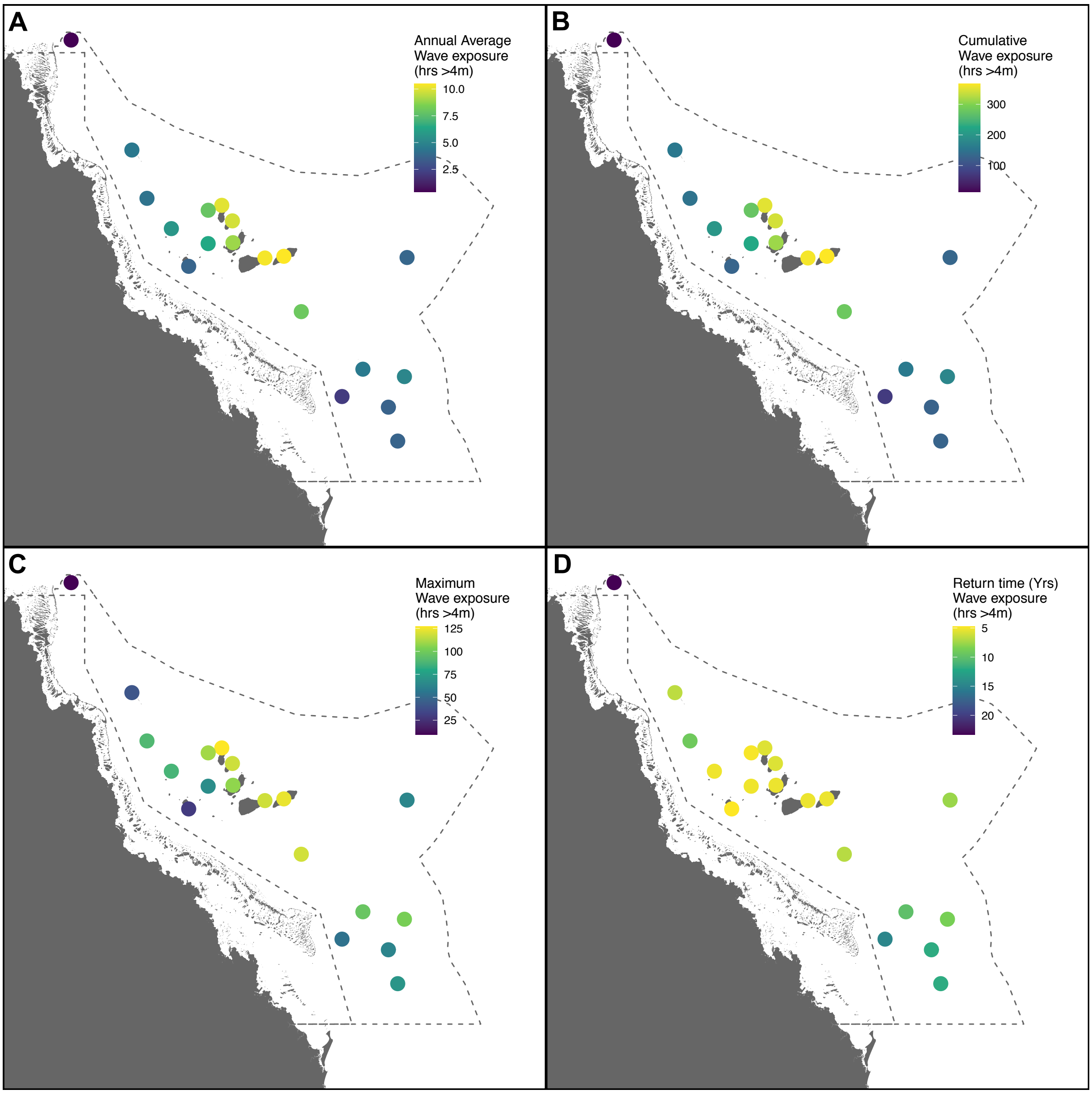


Figure 5.38 Damaging wave regimes (over 4m) in the Coral Sea Marine Park between 1985 and 2019. (a) Annual average exposure to damaging waves (over 4m) between 1985 and 2019; (b) The cumulative wave exposure from 1985 to 2019; (c) The maximum exposure to damaging waves (over 4m), and; (d) The return time in years between damaging wave activity. Damaging wave activity caused by tropical cyclones can erode shallow-water benthic communities on coral reefs. The impact of such events depends on intensity, duration and return time of damaging wave activity.

Spatial and temporal patterns in wave exposure in the CSMP indicate the importance of TCs when considering historical patterns of coral cover and diversity on coral reefs. From 1985 to 2019, regular exposure to damaging waves in the central CSMP would have led to localised coral loss, particularly for structural vulnerable coral communities. Assessing the impact of past TC activity on coral cover and coral assemblages is made difficult by the absence of historical data in CSMP. However, past TC activity is likely to have contributed to the decline of coral cover on exposed sites, as well as the low coral cover on many central CSMP reefs.

5.11 Taxonomic assessments

Corals - We recorded a total of 259 species of coral: 229 occurred in the southern CSMP, 108 in the central CSMP; and 162 in the northern CSMP (Appendix 5), with regional differences likely reflecting differences in sampling intensity among regions. These include approximately 11 species that are likely to be new to science (e.g. *Acropora* aff *hyacinthus*; *A.* aff *nasuta*, *A.* aff *paniculata*; *Leptastrea gibbosa*, *Montipora* aff *spongodes*; Figure 5.39). While this provisional species list is likely to be far from complete due to low sampling effort in the central and northern CSMP, overall richness is likely to be lower than on the GBRMP or reefs to the east, due to less areas of reef and fewer habitats, such as reef habitats surrounding high islands that are absent throughout the CSMP. Seventy-three species were found in all three regions suggesting there is considerable overlap among the regions. Nonetheless, ~15% (22 species) of the species recorded in the northern CSMP were found only in this region and ~30% (68 species) of the species in the southern CSMP were found only in this region. This suggests that there is some provincialism within the CSMP, as you would expect over this latitude and given the prominent role of temperature in affecting coral distributions (Dana 1843, Veron 1995, Mizerek et al. 2016). Preliminary phylogenomic work suggests that the southern CSMP has much stronger affinities with reefs in the Tasman Sea and the southern GBRMP than with the central and northern CSMP. These preliminary biogeographical hypotheses require testing with quantitative surveys at species level, as opposed to the genus level surveys used in the current monitoring, across multiple sites and habitats within each reef.

ACROPORIDAE

Acropora cf *abrotanoides*

Acropora chesterfieldensis

Acropora aff *hyacinthus*

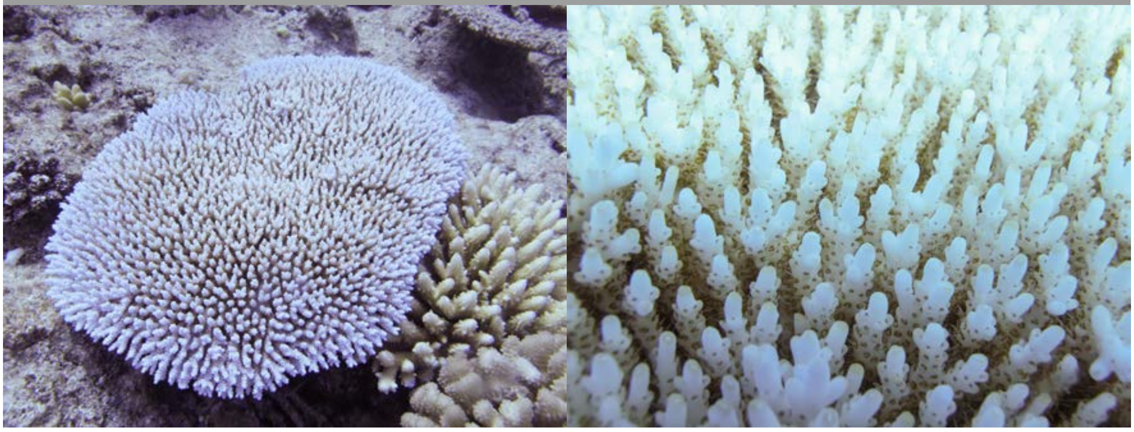


Figure 5.39 Plates showing habitat and close-up photographs of three species of *Acropora* recorded within the Coral Sea Marine Park (photographs: Andrew Baird)

Fish - We recorded a total of 621 reef-associated fish species across the CSMP, which included 461 species of conspicuous (i.e., non-cryptic) reef fishes recorded through visual surveys and observations and an additional 160 species of cryptobenthic fishes recorded through dedicated sampling (Appendix 6). Our estimates represent a substantial increase in the numbers of fish species reported in earlier studies (342 species in Oxley et al., 2003; 326 in Ceccarelli et al., 2008; 507 species in Edgar et al. 2015), and are likely to increase further if additional habitats, such as those on the exposed aspects of reefs or in deeper areas are sampled. For the non-cryptic fishes, the total number of species recorded was greatest in the central CSMP (375 spp.), and declined marginally to the northern (343 spp.), and southern CSMP (317 spp.) regions (Appendix 6). These values are likely influenced by the disproportionate effort in each region, with 8-9 reefs in the central CSMP sampled in each of the three years, versus 2-4 reefs in the northern CSMP and 2-5 reefs in the southern CSMP. The most species rich family of fishes in all CSMP regions was Labridae (wrasses and parrotfishes), followed by Pomacentridae (damselfishes), Acanthuridae (surgeonfishes and unicornfishes) and Chaetodontidae (butterflyfishes), and is similar to patterns of fish species richness in the GBRMP and other Indo-Pacific locations (Bellwood and Wainwright 2002).

The targeted sampling of cryptobenthic fishes yielded 213 species, including 160 species that were not identified through visual surveys or observations (Figure 5.40). Preliminary analyses of the fishes collected suggest that six of these species may be new to science (5 *Eviota* dwarfgoby and 1 *Doryrhamphus* pipefish species), seven species are likely new records for Australia (7 *Eviota* species), and >30 species will likely represent range extensions.

Figure 5.40 Cryptobenthic fishes collected in the southern Coral Sea Marine Park in February 2020. Species are from top to bottom, left column: *Scorpaenodes* sp. *Enneapterygius tutuilae*, *Cetoscarus ocellaris*, *Eviota cf. herrei*, *Crossosalarias macrospilus*, *Neosynchiropus morrisoni*, *Doryrhamphus* sp.; Right column: *Limnichthys fasciatus*, *Eviota* sp. 1, *Paragobiodon xanthosoma*, *Eviota fallax* (likely new record for Australian waters), *Pterois volitans*, *Lepadichthys frenatus*, *Cypho purpurascens.* Most fishes shown are 10-20mm in length.

5.12 Demographic rates of corals and reef fish

Coral Recruitment - The density of juvenile corals (<5cm diameter) recorded on CSMP reefs was generally <2 per m^2 (Figure 5.41). The only exceptions to this pattern were Saumarez, Holmes and Osprey Reefs, which had nearly twice the density of juvenile corals compared to other CSMP reefs. These densities of juvenile corals are similar to those recorded on the subtropical Elizabeth and Middleton Reefs (0.5-1.5 juveniles per m^2; Hoey et al. 2018), but are much lower than densities of juvenile corals previously recorded on mid-shelf reefs of the GBRMP (6.1-8.2 juveniles per m^2; Trapon et al. 2013). It should be noted, however, that our surveys conducted on outer-shelf reefs of the GBRMP revealed much lower densities of juvenile corals (1-6 juveniles per m^2), potentially reflecting widespread suppression of coral recruitment in the aftermath of the recent mass bleaching (Hughes et al. 2019). Nontheless, densities of juvenile corals were higher on outermost reefs of the GBRMP compared to reefs in the CSMP, especially when comparing among southern reefs (Figure 5.41).

Local densities of juvenile corals are reflective of both recent rates of reproduction and recruitment, but may also be moderated by localised disturbances that cause elevated mortality of small corals (Harrison et al. 2018, Hughes et al. 2018). Rates of recruitment are expected to be lower on isolated, offshore reefs, reflecting lower levels of connectivity and the limited extent of reef habitat (see Hoey et al. 2011). Accordingly, the lowest densities of juvenile corals recorded in the CSMP was at Mellish Reef (Figure 5.39), which is one of the most isolated reefs in the CSMP and the broader Coral Sea. Low rates of recruitment will constrain recovery on isolated reefs, making them much more vulnerable to disturbances (Gilmour et al. 2013). However, there is no baseline data on densities of juvenile corals in the CSMP and so it is unclear whether our estimates are reflective of normal low levels of replenishment, or are suppressed due to recent disturbances and low abundance of adult corals. Continued monitoring of juvenile coral assemblages with the CSMP will be critical to establish relationships with adult coral cover and detect the effect of disturbances on both densities and assemblage composition.

Based on recent research on the GBRMP, widespread mass-bleaching is likely to have had direct impacts on the reproductive potential of corals (Hughes et al 2019), particularly for genera that are most susceptible to coral bleaching (e.g., *Acropora*). Comparing the composition of juvenile corals among regions of the CSMP and GBRMP reveals a lack of juvenile *Acropora* in the central and southern CSMP (Figure 5.42), which may suggest that seemingly low levels of replenishment are reflective of the contemporary declines in abundance of corals that are highly susceptible to large-scale disturbances. The paucity of juvenile *Acropora* also suggests that there are likely to be extensive delays in the recovery or re-assembly of coral communities at these locations.

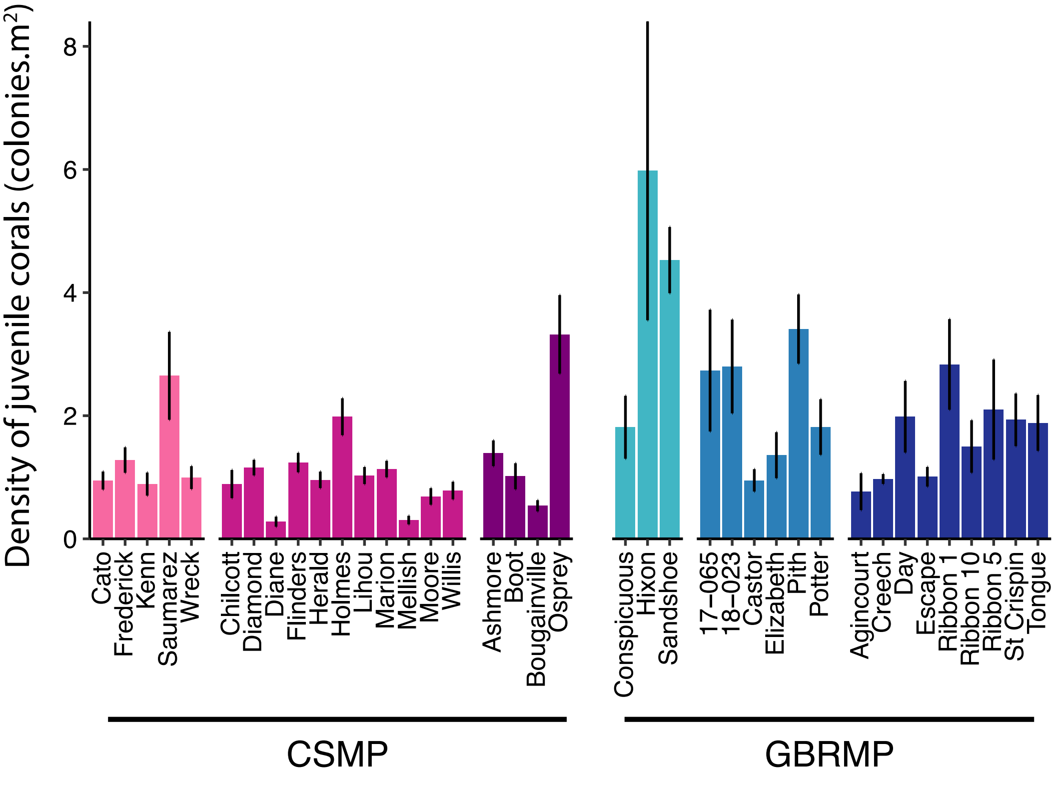


Figure 5.41 Mean (± SE) density of juvenile corals (<5cm diameter) at each of 20 reefs in the Coral Sea Marine Park and 18 outer-shelf reefs in the Great Barrier Reef Marine Park between 2018 and 2020.

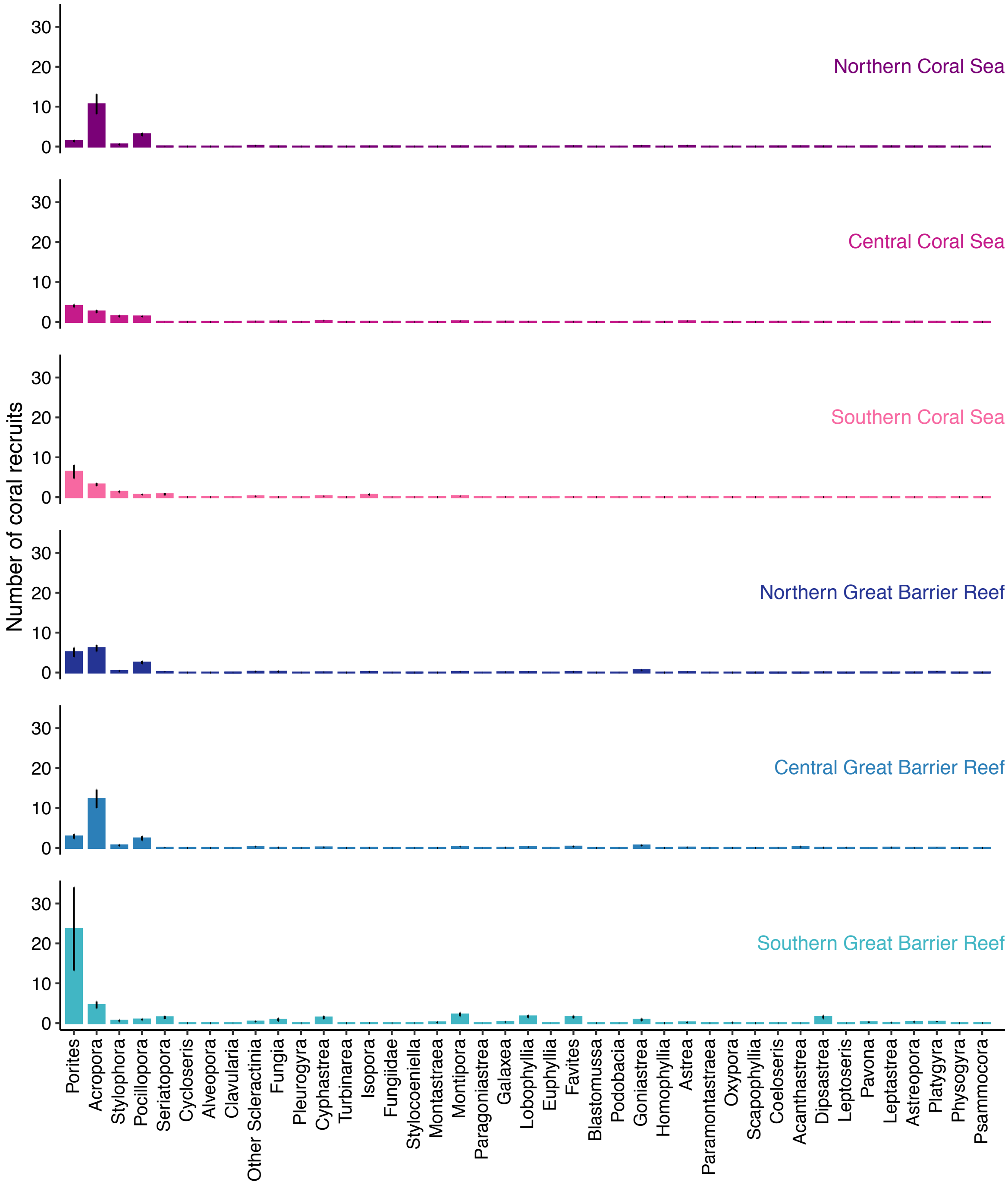


Figure 5.42 Regional patterns in the taxonomic composition of juvenile coral colonies in the Coral Sea Marine Park and Great Barrier Reef Marine Park between 2018 and 2020. Coral taxa are in order of overall abundance.

Coral Growth – Temporal linear models of calcification rate, extension rate and density from 1832-2018 show regional differences in growth parameters. The rate of calcification of coral colonies ranged from 1.07 g.cm^{-3}.year^{-1} to 2.47 g.cm^{-3}.year^{-1} throughout the CSMP and varied widely between individual colonies (Figure 5.43

a). The rate of annual extension of coral colonies (linear growth) ranged from 0.66 cm.ya^{-1} to 1.77 cm.ya^{-1} (Figure 5.43 b), while density ranged from 1.30 g.cm^{-3} to 1.78 g.cm^{-3} (Figure 5.43 c). Growth parameters in *Porites* depend largely on environmental condition with a strong linear relationship between average linear extension and calcification rates and average sea surface temperature (SST), though depth and irradiance are also important (Lough and Barnes 2000). There is a weaker, inverse relationship between average skeletal density and average SST (Lough and Barnes 2000). The lower density of coral cores collected in the northern CSMP, represented by 5 coral cores from Bougainville Reef, is thus a reflection of the higher SST at lower latitude. However, the average density of coral cores in the central and northern CSMP are higher than would be expected for reefs at similar latitude and mean annual SST (Lough 2008; Lough and Cantin 2004).

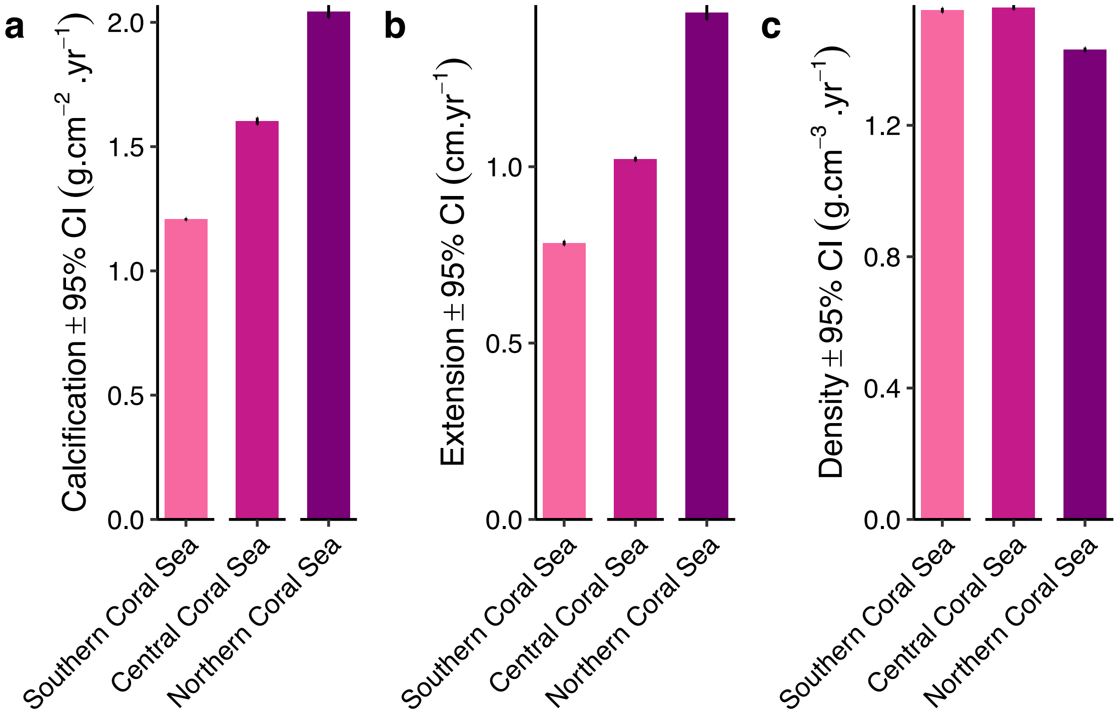


Figure 5.43 Temporal linear models of calcification rate, extension rate and density from 36 coral cores of massive Porites corals 1832-2018 show regional differences in growth parameters in the Coral Sea Marine Park

The strong linear relationship between *Porites* calcification and extension rates and average annual SST can be used to identify whether growth parameters in the

CSMP are comparable to other Indo-Pacific regions. Growth parameters obtained from coral cores in the CSMP were compared to growth records in the Indo-Pacific regions (Lough 2008) and plotted against average annual SST (Reynolds et al. 2002, Rayner et al. 2003). We observed a 35% lower increase in calcification rates with SST in CSMP cores compared to the other Indo-Pacific regions (Figure 5.44 a). The relationship between extension rates, or density, and SST differed for cores in the CSMP compared to previously established baselines (Lough 2008). In low latitude reefs, where temperatures are higher, extension rates were slower and the density higher than would be expected based on SST alone (Figure 5.44 b, c). Such disparities might be due to differences in the time-series covered by the Indo-Pacific coral cores, which pre-date cores from the CSMP and the tropical oceans have been significantly warming as the global climate system warms (e.g., Lough et al. 2018). However, we would expect an increase in extension rates with the rise of SST in the CSMP. SST was a strong predictor of extension rates in the CSMP, however density could not be predicted by SST alone. This suggest local environmental (e.g., depth) and oceanographic conditions in the CSMP are likely affecting growth parameters in massive *Porites* corals and, by extension, other sceleractinian corals in the CSMP.

Large individual *Porites* colonies like ‘Big Mel’ (height: 8m; diameter: 19m; surface area: ~680m^2) at Mellish Reef, and other bommies that stand > 3m tall, represent centuries of coral response and oceanic history retained within the skeletal records. These living recorders can be used to explore historical change and the current state of remote locations like the CSMP to guide how the conditions of the broader Coral Sea, individual reefs and/or individual coral colonies respond to a changing climate. Current collections from the CSMP have been collected with light weight pneumatic equipment with a maximum core depth of ~1.5m. Future targeted trips could be planned with hydraulic coring equipment capable of extracting complete long cores through the entire length of these large individual colonies. ‘Big Mel’ has an average annual growth rate of 1-1.5 cm/year, which provides the potential for 500-800 years of historical calcification and environmental history retained within the skeleton of this unique and rare massive individual coral.

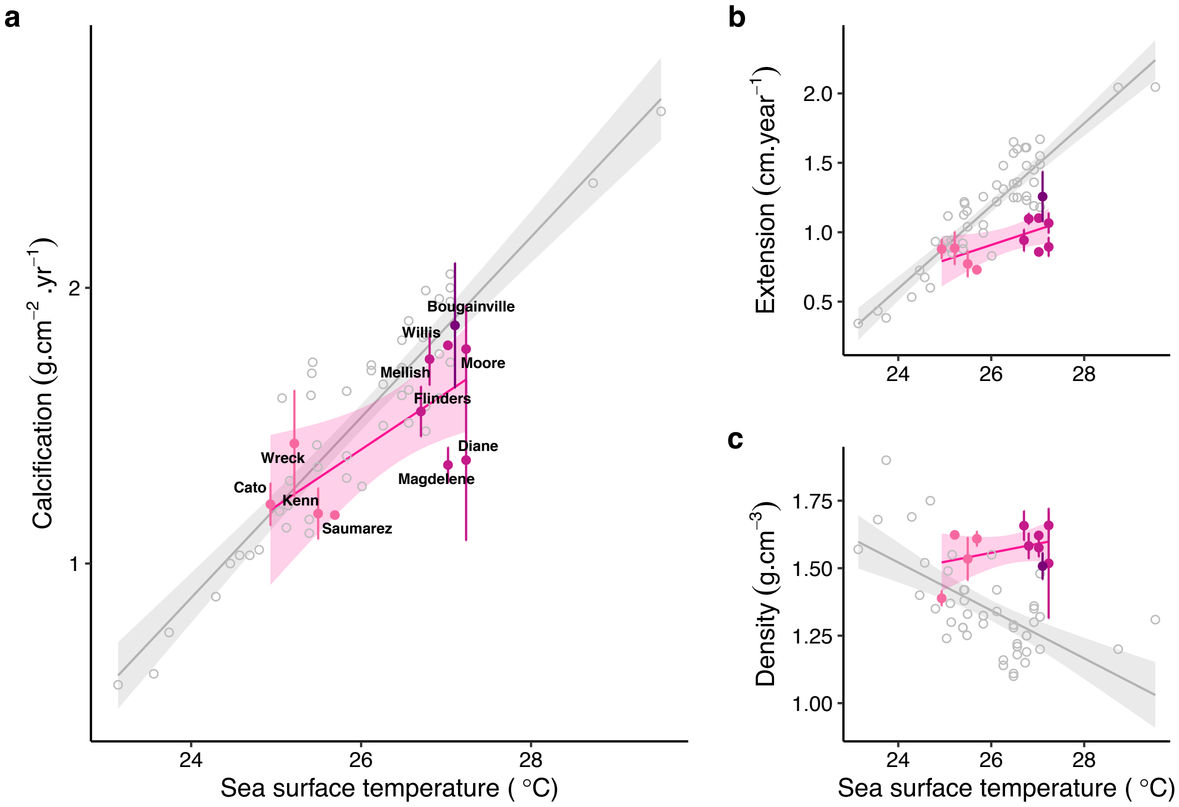


Figure 5.44 Annual average *Porites* growth parameters *vs.* annual average sea surface temperature for 11 reefs in the Coral Sea Marine Park (colour key) and 49 Indo-Pacific sites (grey circles; from Lough 2008). Lines are linear regression fits for growth rate ~ SST*region, for a) Calcification (Indo-Pacific: slope = 0.37; Coral Sea: slope = 0.24; interaction for region p = 0.1); b) Extension (Indo-Pacific: slope = 0.33; Coral Sea: slope = 0.13; interaction for region p = 0.005) and c) Density (Indo-Pacific: slope = -0.1; Coral Sea: slope = 0.04; interaction for region p = 0.02).

Stress bands - The oldest stress band in our coral core record corresponds to 1940 at Bougainville Reef with widespread occurrence of stress bands from 1980 onwards (DeCarlo et al. 2019). Multiple stress bands were present in 2002, 2010, 2015 and 2016, which coincides with major temperature anomalies in the broader Coral Sea and observations of coral bleaching in the GBRMP and CSMP (Hughes et al. 2017). Despite increasing exposure to heat stress in the 21st century, the proportion of coral cores with stress-bands declined following successive bleaching so that no stress-bands were present in 2017. The presence of only a few stress bands in 2016 and complete absence in 2017 is the first identified decoupling between coral bleaching and the occurrence of stress bands in *Porites* skeletal cores (DeCarlo et al. 2019). The absence of stress bands suggests that the survival of *Porites* corals may have been less reliant on nourishment from symbiotic algae, instead relying on stored energy reserves or heterotrophic feeding. These results also suggest that prior exposure to bleaching events can increase the thermal tolerance of *Porites* corals (DeCarlo et al. 2019). However, the study by DeCarlo et al. (2019) suggests that the thermal tolerance of corals from the CSMP was already higher than corals from the GBRMP and New Caledonia, and hence the scope for acclimatisation to further heat stress may be negligible. Alternatively, it is possible that other environmental factors, such as localized currents or cloud cover, dampened heat stress for these corals in 2017. Local environmental conditions can influence stress, the presence of stress bands and the susceptibility of corals to bleaching, thus monitoring of a greater suite of environmental conditions is necessary to improve our understanding of bleaching thresholds and corals' adaptive capacity.

***Growth anomalies* –** Coral calcification is an important determinant of the health of reef ecosystems and provides a record of changes in local environmental conditions. While average calcification rates increase linearly with increasing average SST at regional-scales (Lough and Barnes 2000), annual temperature anomalies at a local-scale can lead to non-linear responses in growth. High and low temperatures beyond the thermal optimum of corals, and acute heat stress (e.g. bleaching events) can lead to prolonged periods of lower calcification rates (Suzuki *et al.* 2003, Carilli *et al*. 2009). We measured changes in growth parameters over time relative to a baseline that likely pre-dates major bleaching events in the CSMP (1971-1981). We observed regional differences in calcifications rates through time (Figure 5.45). In the southern and central CSMP, calcification rates have decline progressively since the 1980's, though increases in the extension rates in the last decade have reversed this trend in the southern CSMP. In contrast, calcification rates in the northern CSMP appear to increase in the early 1990's. However, the limited number of coral cores from the northern CSMP (n = 5), as indicated by the high variability density and extension rates, suggests our baseline estimates may not be robust to assess changing conditions in the northern CSMP.

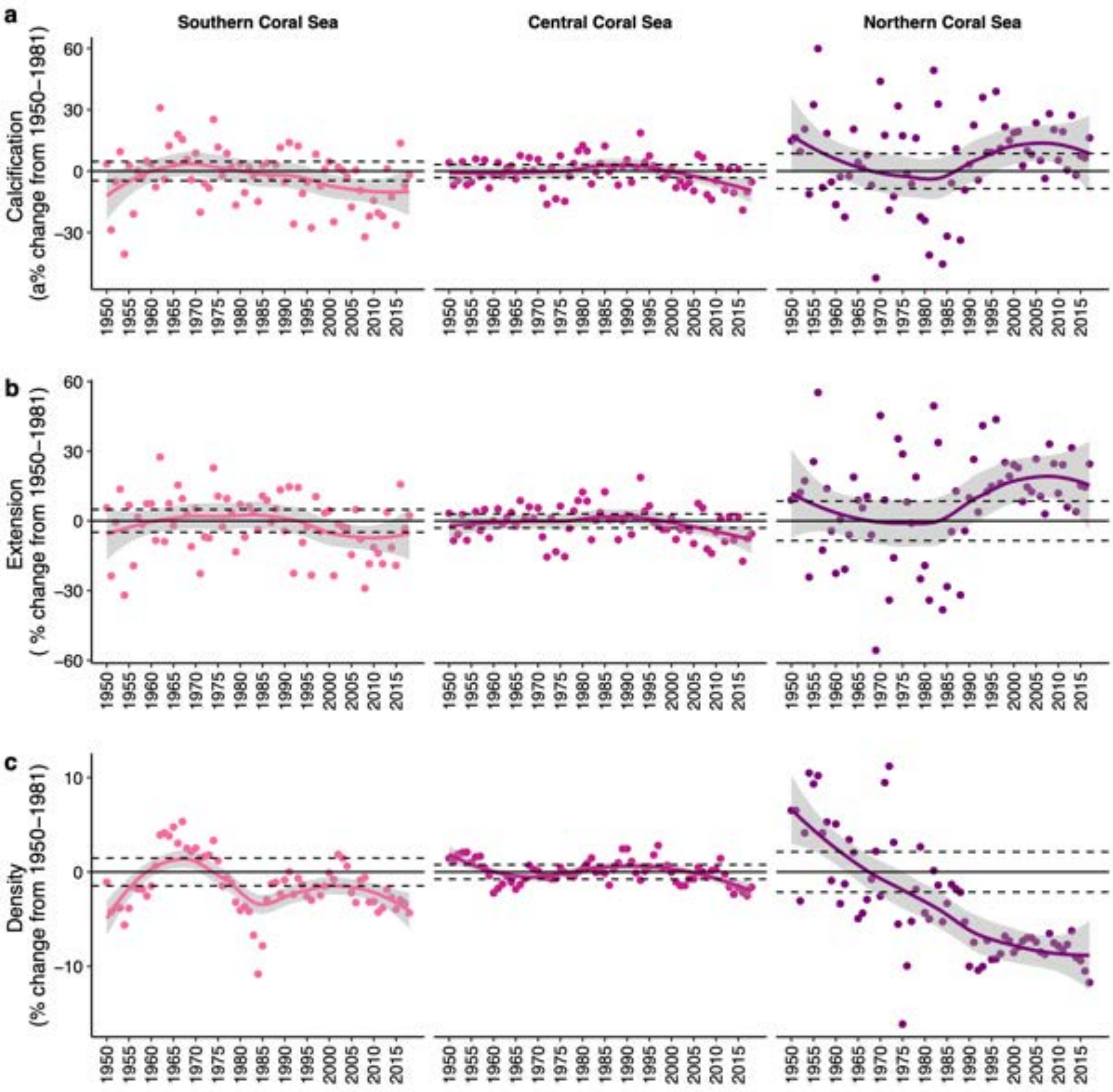


Figure 5.45 Average annual standardized Porites growth anomaly time series from the Coral Sea Marine Park (1950–2018), as a percent difference from mean baseline growth rates (1950-1981) prior to the 1998 mass bleaching event (± SE). Smoother is a loess fit, with shaded 95% CI.

Fish growth and mortality

***CSMP vs GBRMP* -** Fish size-at-age data showed little difference in lifetime growth patterns of *Plectropomus leopardus, Plectropomus laevis, Centropyge bispinosa* and *Ctenochaetus striatus* between the CSMP and GBRMP (Figures 5.46 a, 5.47 a). Similarly, mortality rates did not differ between CSMP and GBRMP populations for the three of the four species examined (Figure 5.46 b). The only exception to this was *P. laevis* for which GBRMP populations had significantly higher rates of mortality than populations in the CSMP (Figure 5.46 b). Interestingly, the mean maximum sizes of *P. leopardus* and *C. bisponosa* were smaller within the CSMP than the GBRMP, whereas the reverse was true for *P. laevis* (Figure 5.46 c), even when considering populations sampled within GBRMP no-take zones. Similarities in the growth profiles of the four reef fish species between regions suggest that the environmental differences between the oceanic reefs of the CSMP and the continental shelf reefs of the GBRMP may not have significant impacts on lifetime growth. Rather, our results suggest that fishing may have influenced the demography of coral trout on GBRMP reefs at scales that transcend zone boundaries, particularly for the slower growing and longer lived species, *P. laevis*.

Among CSMP regions – comparisons of populations of *C. bispinosa* (f. Pomacanthidae) and *C. striatus* (f. Acanthuridae) revealed that growth, asymptotic lengths, and mortality did not differ among northern, central and southern CSMP regions (Figure 5.47 a,b). There were, however, differences in longevity and mean maximum size among regions, with *C. bispinosa* being longer-lived and *C. striatus* tending to have a larger maximum body length in the southern CSMP compared to the central and northern CSMP (Figure 5.47 c). The lack of variation in growth rates of fishes on reefs spanning ~1,800km of latitude and representing a 2ºC difference in mean annual SST within the CSMP is surprising, and suggests that local environmental conditions (e.g., habitat) and/or biotic interactions may have a greater effect than SST on the demographic rates of these two species. A previous study that compared growth and longevity of *C. striatus* across broad geographic scales found that individuals were longer-lived at higher latitudes, but found no relationship between SST and growth rates (Trip et al. 2008). Several other studies have reported that the life history traits of some reef fish species respond more strongly to local environmental conditions than temperature regimes (Yamahira and Conover, 2002; Floeter et al., 2005; Robertson et al., 2005; Trip et al., 2014). Future research should consider how both local (within reef; e.g., habitat, productivity, competition, predation) and regional (among reefs; e.g., temperature) factors affect demographic rates across a broader range of reef fish species.

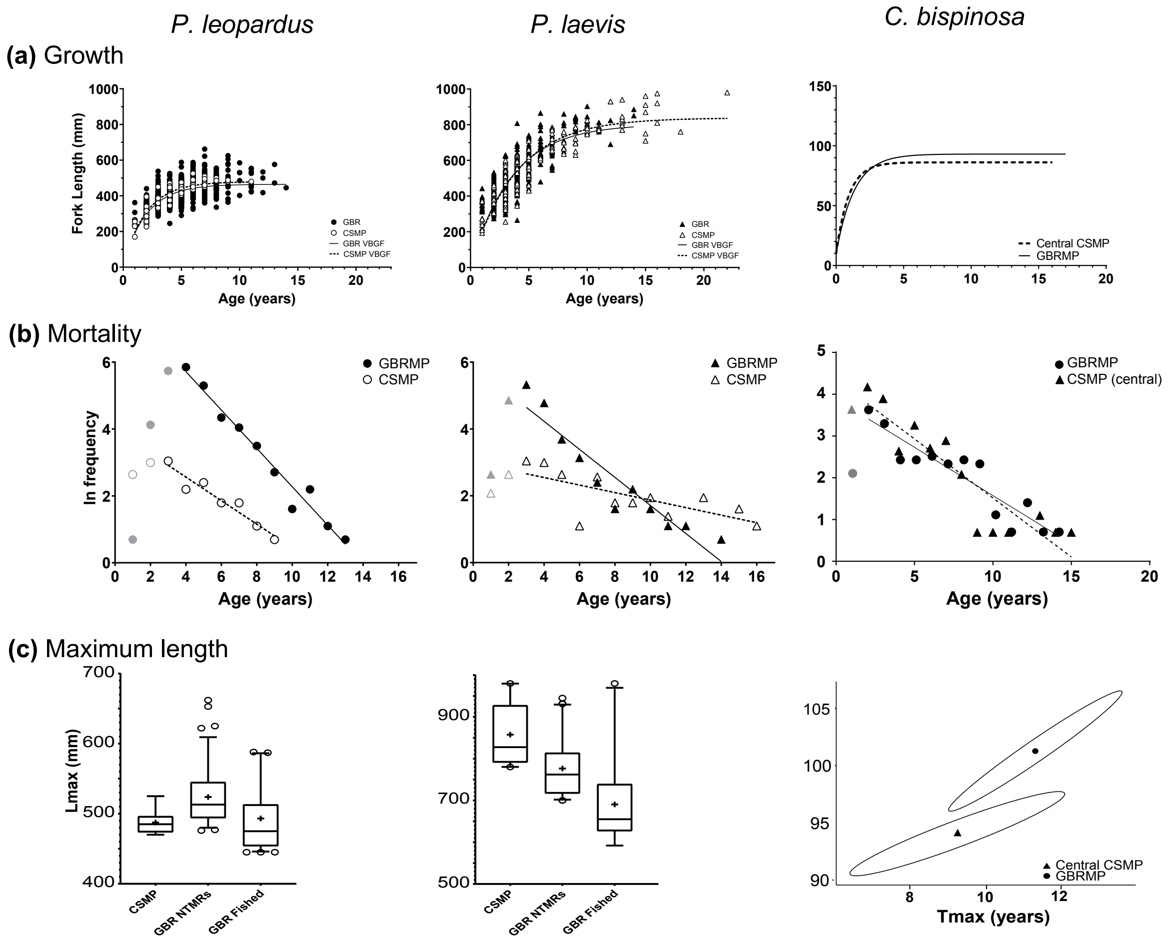
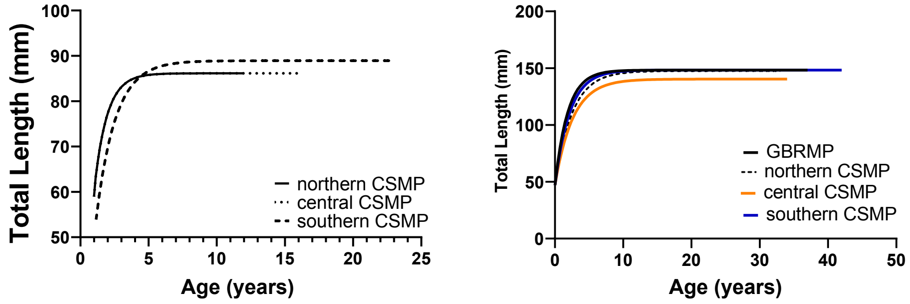


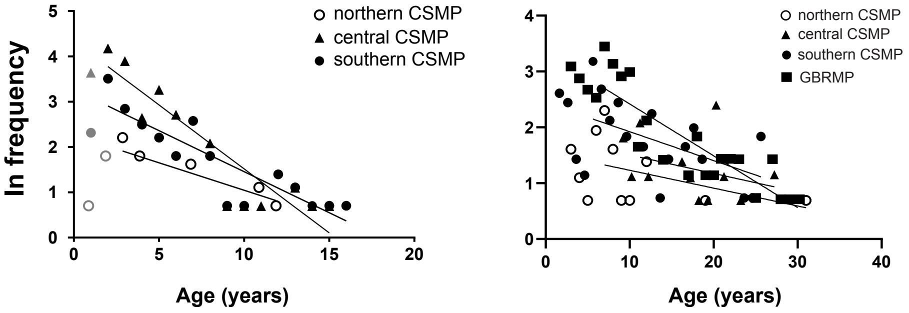
Figure 5.46 Comparison of demographic traits for three species of reef fish (*Plectropomus leopardus*, *Plectropomus laevis*, and *Centropyge bispinosa*) between the Coral Sea Marine Park and the Great Barrier Reef Marine Park. (a) Size-at age data fitted with comparative von Bertalanffy Growth Functions; (b) Age-based catch curves estimating rates of instantaneous mortality, and (c) Mean maximum lengths (L_{max}) of the largest 15% of each population.

C. bispinosa *C. striatus*

(a) Growth



(b) Mortality



(c) Maximum length

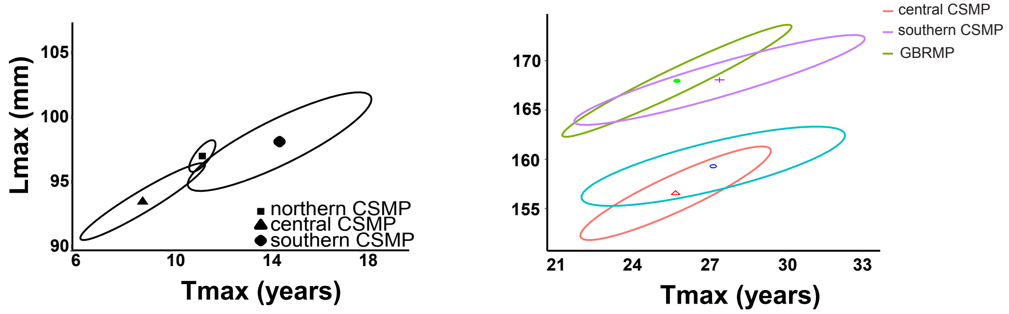


Figure 5.47 Comparison of demographic traits for two species of reef fish (*Centropyge bispinosa* and *Ctenochaetus striatus*) between the northern, central, and southern Coral Sea Marine Park. (a) Size-at age data fitted with comparative von Bertalanffy Growth Functions; (b) Age-based catch curves estimating rates of instantaneous mortality, and (c) Mean maximum lengths (L_{max}) of the largest 15% of each population.

6 Conclusions

The coral reefs of the CSMP are some of the most isolated coral reef environments in Australian waters. While this isolation and inaccessibility reduces the exposure of the CSMP reefs to direct human pressures (e.g., fishing, run-off) relative to more accessible coastal or inshore reefs, it has also limited the amount of research and monitoring conducted in these reef environments. The surveys conducted in this 3-year project represent the most extensive assessment of coral reef health and marine biodiversity ever undertaken in the CSMP, greatly improving our understanding of these unique reef systems and providing an important baseline for further studies in the region. We recorded 621 species of reef-associated fishes and 259 species of coral (including 6 fish species and 11 coral species that are likely new to science), representing substantial increases on the numbers of species recorded in previous surveys (e.g., Oxley et al. 2003, 2004, Ceccarelli et al. 2008, 2009; Edgar et al. 2015). That said, there are some reefs and habitats (especially habitats on the weather exposed aspects of reefs, and in deeper areas below 12-15m) that are yet to be effectively surveyed. Surveys of these habitats will require modified survey methods due to difficulties in anchoring tenders in exposed areas and/or diving restrictions for deeper habitats, but will likely add considerably to the number of fish and coral species recorded within the CSMP, and facilitate a greater understanding of the functioning of these unique reefs.

The surveys conducted in the three-year project (2018-2020) show that coral reefs in the CSMP support unique coral and reef fish communities that are distinct from those of the adjacent GBRMP. Both coral and fish communities on CSMP reefs include species that have closer affinities with reefs in the Tasman Sea to the south (i.e., Elizabeth and Middleton Reefs, and Lord Howe Island), and nations on the eastern boarder of the CSMP (New Caledonia, Vanuatu and the Solomon Islands), than to reefs in the GBRMP. Many fish and coral species that are abundant on CSMP reefs, are rare or absent on GBRMP reefs. For example, the highfin parrotfish *Scarus longipinnis* is one of the most common parrotfish species across shallow reef habitats of the CSMP, yet is extremely rare within the GBRMP where it is occasionally seen in deeper (>30m) habitats. There was also clear structuring of biological communities within the CSMP, with northern (Boot, Ashmore, Osprey and Bougainville Reefs), central (Diane Bank, Willis and Diamond Islets, Coringa-Herald Islets and Cays, Holmes, Moore, Flinders, Lihou, Mellish and Marion Reefs) and southern (Frederick, Saumarez, Kenn, Wreck and Cato Reefs) CSMP reefs supporting distinct fish and, to a lesser extent, coral assemblages. Moreover, the species richness of both corals and reef fishes was greatest in the northern CSMP and lowest in the southern CSMP, consistent with latitudinal gradients in biodiversity (e.g., Bellwood and Hughes 2001; Hillebrand 2004).

The general condition of coral reef environments in the CSMP (and similarly the GBRMP) varied considerably among regions, with differences in coral cover and coral species composition likely reflecting the impacts of recent major disturbances. Coral cover was particularly low in the central CSMP, likely due to the impacts of recent and /or sustained disturbances (e.g., bleaching events, Harrison et al. 2018; cyclones, Section 5.10). The scarcity of coral taxa that typically dominate shallow reef habitats, particularly those that are most sensitive to both severe storms and thermal stress, (e.g. *Acropora*, *Seriatopora*; Madin and Connolly 2006; Hughes et al. 2018), and the predominance of relatively small coral colonies (<20cm diameter) across many of the CSMP reefs provide further evidence that these locations have been subject to recent and/or sustained disturbances.

Despite the lower than expected coral cover on central CSMP reefs, there is some evidence that coral cover on these reefs has been increasing, albeit gradually, over the past 15-20 years. On the few select reefs that have been repeatedly surveyed as far back as 1984 (i.e., Herald Cays, Chilcott Islet and Lihou Reef) coral cover initially declined from ~10% in 1984 to 1-5% in 2003 (following the 1998 coral bleaching event; Oxley et al. 2003), and has been gradually increasing since, to ~6% in 2007 (Ceccarelli et al. 2008), and 20-30% in 2018-2020 (present surveys Figure 6.1). However, differences in methods and sampling intensity (i.e., 1984 estimates were based on limited observations; and surveys between 2003 and 2017 were based on a limited number of sites) preclude robust comparisons. Such protracted increases in coral cover are characteristic of isolated reef systems due to the lack of connectivity and hence the reliance of self-recruitment, and reductions in local adult coral broodstock (Gilmour et al. 2013). The current coral cover on these three reefs in the central CSMP is 2- to 2.5-fold greater than that recorded prior to the 1998 bleaching event (but see Byron et al. 2001 who estimated coral cover to be ~20% on Coringa-Herald Islets and Cays in 1997), however this is likely to decline as mortality associated with the 2020 bleaching event are realised (discussed below).

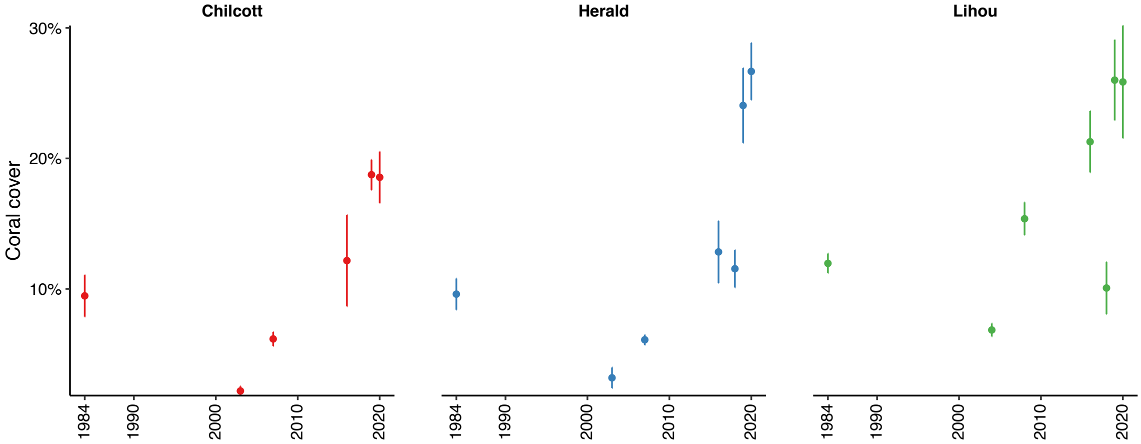


Figure 6.1 Temporal changes in coral cover on three reefs in the central Coral Sea Marine Park from 1984 – 2020. Data were extracted and compiled from Ayling and Ayling 1985; Oxley et al. 2003, Ceccarelli et al. 2007, 2009; Harrison et al. 2019; present surveys (2018-2020). NB: differences in survey methods, sites surveyed and observers may have contributed to observed differences

It was also apparent that reefs in the CSMP, and the central CSMP in particular, had a higher cover of macroalgae compared to outer-shelf GBRMP reefs. Excessive cover of macroalgae is often viewed as a sign of reef degradation (e.g., Bellwood et al. 2004), however this is highly dependent on the macroalgal taxa. The predominant macroalgae recorded in the CSMP was *Halimeda* spp., a green calcifying algae, which is typically abundant on oceanic reefs, including those in the CSMP (Edgar et al. 2015). *Halimeda* is an important contributor to the production of reef sediments (Drew 1983), and is not symptomatic of reef degradation (cf. canopy-forming brown algae that predominate on coastal and inshore reefs of the GBRMP and elsewhere: Wismer et al. 2009; Hoey and Bellwood 2010; Rasher et al. 2013).

The biomass of reef fishes (a key indicator of reef health, together with coral cover) on CSMP reefs was generally comparable to or greater than that on reefs in the GBRMP. The biomass of reef fishes recorded across all reefs in the CSMP was 500 – 4,000 kg per hectare, which is high relative to coral reef environments globally (Cinner et al. 2016) and likely reflects their isolation and limited fishing pressure. Notably, two CSMP reefs, Mellish and Moore Reefs, had exceptionally high biomass (3,500 – 4,000 kg per hectare) that was 2 to 8-fold greater than other CSMP reefs. These estimates of reef fish biomass are exceptional given the relatively low levels of coral cover, and seemingly altered composition of coral assemblages on many reefs in the CSMP. While there was a positive relationship between the abundance of reef fish and coral cover across CSMP reefs, there was no relationship between reef fish biomass and coral cover or topographic complexity of reef habitats. The absence of any relationship between fish biomass and benthic habitat characteristics suggest that other factors such as reef size, isolation, disturbance history, and/or alternate habitat variables may be influencing reef fish biomass (e.g. Ceccarelli et al. 2016, Lam et al. 2018, Zinke et al. 2018), or that there may be lags in the response of fish biomass to changes in benthic habitat (e.g., Graham et al. 2007).

There were marked differences in functional composition of fish assemblages between the CSMP and GBRMP with those in the CSMP being characterised by high biomass of piscivores (e.g., groupers and snappers), whereas those in the GBRMP had comparatively higher biomass of herbivorous fishes (e.g., parrotfishes and surgeonfishes). The high biomass of piscivores is likely a reflection of the limited fishing pressure on CSMP reefs, and is often used as evidence for isolated reefs, such as those in the CSMP, as supporting ‘near pristine’ fish biomass (e.g., Graham and McClanahan 2013). These broad-scale differences in the functional composition of fish assemblages between the GBRMP and CSMP will likely influence the transfer of energy among trophic groups, and hence the productivity of reef fish assemblages (e.g., Hempson et al. 2018) and may have important implications for the functioning and resilience of these reef ecosystems.

Together with the regional differences in fish and coral communities, there was considerable variation among reefs within each region. Of particular note are those reefs that had higher biodiversity, coral cover and fish biomass than expected for each region. These ‘bright spots’ (*sensu* Cinner et al. 2016) were Ashmore and Boot Reefs in the northern CSMP, and Mellish and Moore Reefs in the central CSMP. Mellish Reef, in particular, was a standout in terms of both coral and fish communities, and was identified as a potentially important source of larvae for other reefs in the central and northern CSMP (Section 5.9). Unfortunately, we were only able to survey three of these four reefs (Ashmore, Boot, and Mellish Reefs) once (in 2018) during the three-year project due to their remoteness in the far north and far east of the CSMP. The features of these ‘bright spot’ reefs that have contributed to their higher than expected biodiversity and abundance of corals of fish are unknown, and warrant future investigation.

Ashmore and Boot Reefs are unique among CSMP reefs, not only because of the diverse and abundant coral and fish communities they support, but also their proximity to the reefs within the GBRMP, Torres Strait, and Papua New Guinea, and their close connection with the Meriam people. During our surveys of Ashmore and Boot Reefs in October 2018 we met with, discussed and presented our research to the traditional owners of these reefs (the Meriam people), and invited two traditional owners to join us for our surveys of these two reefs. This was extremely valuable, increased our understanding of traditional knowledge and cultural values of this sea country, and identified issues that were of concern to the Meriam people. For example, concern was expressed about the current status of giant clam and sea cucumber populations on Boot and Ashmore Reefs, as well as the status of select fish species such as the humphead maori wrasse, *Cheilinus undulatus.* Future research within the CSMP should prioritise Ashmore and Boot Reefs and include collaborations with the Meriam people to improve our understanding of their connections with sea country and to build their capacity to participate and take an active role in the management of the CSMP.

The marked delineation in the geographic distribution of sea snakes was striking, with sea snakes abundant on Marion Reef and all reefs in the southern CSMP but absent from all other reefs in the central and northern CSMP. This defined latitudinal variation is consistent with the only other quantitative surveys of sea snake densities within the CSMP (Edgar et al. 2015), but it is unclear if this is a natural pattern (e.g., due to regional changes in temperature, prey availability, or predation) or is reflective of more recent changes in sea snake abundances. Earlier qualitative studies have reported sea snakes to be abundant within the CSMP (e.g., Heatwole et al. 1978), but did not allude to such a marked latitudinal change in their distribution. There have been marked declines and/or local extinctions of sea snakes in other regions in Australian waters (e.g., GBRMP: Lukoschek et al. 2007; Ashmore Reef, north-western Australia: Lukoschek et al. 2013), and the global population of the olive sea snake, the most abundant species in the CSMP, is described as decreasing (Lukoschek et al. 2010). Further research and ongoing monitoring of sea snake populations will be necessary to identify potential drivers of their geographic distribution.

The abundances of non-coral invertebrates (i.e., giant clams, trochus, sea cucumbers, and sea urchins) generally displayed higher variation among reefs than among the three regions within the CSMP, suggesting that local, as opposed to regional, processes may be important determinants of their populations. Moreover, the habitats surveyed were selected specifically to identify changes in coral communities, and as such did not include all of the all typical habitats for sea cucumbers (i.e., sandy and lagoonal habitats), or the giant clam *Tridacna gigas* (i.e., lagoonal and shallow reef flat habitats). Dedicated monitoring of their typical habitats are required to provide robust assessments of the population structure of sea cucumbers and giant clams.

There were, however, important patterns in the distribution of trochus and sea urchins within the CSMP. It is unclear if the low abundance of trochus on reefs in the northern CSMP, and complete absence on Ashmore and Boot Reefs are related to historical patterns or more recent declines due to fishing. This is particularly relevant for Ashmore and Boot Reefs given their proximity to the operations of the small commercial and subsistence fishery for trochus that operates throughout much of the Torres Strait (D'Silva 2001). Similarly, the drivers of the exceptionally high densities of sea urchins, *Diadema* spp., at Kenn Reef in the southern CSMP is unclear (>80 urchins per 100m^2). Echinoids, such as *Diadema* spp., are known for their large spatial and temporal variations in population densities (Uthicke et al. 2009). While the high densities at Kenn Reef may simply reflect a chance recruitment event in a boom and bust population cycle, if these densities are sustained over long temporal scales they could lead to significant internal erosion and weakening of the reef framework (Glynn et al. 1979; Eakin 1996).

The current state and health of coral reef communities in the CSMP is likely to be driven by a combination of reef geomorphology, reef size, habitat type, habitat complexity at different scales, connectivity to larval sources and disturbance history (Ceccarelli et al. 2013). However, climate change and associated disturbances are increasingly shaping the composition and state of coral reefs globally (e.g., Hughes et al. 2017, 2018; Pratchett et al. 2020), and it is becoming increasingly important to understand the patterns of disturbance, resilience and recovery of individual reefs. Unlike the large, interconnected network of reefs and inter-reefal habitats of the GBRMP, the CSMP reefs need to be viewed more as isolated and independent reef systems, reliant to a large extent on self-recruitment for replenishment and resilience.

6.1 Major threats to coral reef health in the CSMP

Climate-induced coral bleaching is now the foremost threat to coral reefs globally (Hughes et al. 2017), with the likelihood of global mass-coral bleaching occurring in any given year now being three-fold higher than pre-2000 (Hughes et al. 2018). Indeed, extensive and severe coral bleaching was recorded across all surveyed CSMP reefs in 2020, coinciding with an extended period of very high ocean temperatures. This is the third mass coral bleaching event to affect shallow reef habitats in the CSMP in the past five years, with widespread coral bleaching being reported in the CSMP in 2016 and 2017 (Harrison et al. 2018). These bleaching events led to a marked shift in the composition of coral assemblages over this period, and declines in total coral cover at some sites of up to 50%. However, the changes in total coral cover following the 2016 and 2017 bleaching events were highly variable among sites, both within and between reefs. The cover of thermally sensitive tabular and branching *Acropora* decreased markedly on central, and to a lesser extent southern, CSMP reefs following the 2016-17 bleaching events.

Similarly, the GBRMP has also experienced three mass coral bleaching events and similar shifts in coral species composition in the past five years (2016, 2017, and 2020) due to extended periods of elevated ocean temperatures (Hughes et al. 2018; Hughes and Pratchett 2020). While only very low levels of localized bleaching were recorded on CSMP reefs in 2018 and 2019, and the outcomes of the 2020 bleaching event on coral populations are yet to be ascertained, the return time between successive bleaching events (i.e., 3 years) is not sufficient for coral populations and communities to recover. Even within well-connected reef systems where the supply and settlement of coral larvae is not limiting, it has been estimated that reefs will require a minimum of 10-15 years free of any major disturbance to recover from a major bleaching event (Hughes et al. 2018). The recovery times for isolated reefs such as those in the CSMP are likely to be considerably longer (Gilmour et al. 2013), especially when the effects of these bleaching events are compounded by the high frequency of damaging waves (Section 5.10). Given sustained and ongoing increases in global ocean temperatures it is very likely that there will be severe and widespread mass-bleaching in CSMP within coming years and decades, which is likely to further suppress coral cover and delay recovery.

The 2020 bleaching event in the CSMP was severe and widespread with 63% of all corals surveyed across 16 reefs showing signs of heat stress from high ocean temperatures. The extent of bleaching varied among regions (from 40% in the southern CSMP to 70-72% in the central and northern CSMP) and among reefs (from 23% at Cato Reef to 89% at Willis Islets). Although differences in the taxonomic composition of coral assemblages among years make direct comparisons of bleaching events difficult, the 2020 coral bleaching event in the CSMP appeared to be more severe and widespread than either the 2016 or 2017 events. Together with the high incidence of bleaching, it is important to consider that the 2020 bleaching occurred against a shifted baseline of coral communities, with the abundance of bleaching sensitive coral taxa being reduced because of the 2016 and 2017 bleaching events. Further, a high proportion of the colonies surveyed were completely (100%) bleached or recently dead, including many genera (e.g., *Porites* and *Montipora*) that are generally considered to be less sensitive to increased temperatures (Baird and Marshall 2002; McClanahan et al.

2004; Hughes et al. 2018). It is important to note that some bleached corals can recover if water temperatures decrease sufficiently, while other corals may take months to die follow bleaching (Baird and Marshall 2002). Future surveys at the identical sites in the next 12 months (prior to April 2021) will be critical to assess the full extent of the 2020 bleaching event on reefs within the CSMP.

6.2 Recommendations

Regular and ongoing comprehensive monitoring of coral reef environments in the CSMP is essential to understand its health and ecological significance. Notably, there are considerable constraints in understanding the timing and causes of historical coral loss in the central CSMP due to the lack of rigorous baseline data and/or recurrent monitoring to detect temporal dynamics in key metrics of coral reef health. To redress this, we compiled available data on disturbance history, and reconstructed spatial and temporal variation in sea surface temperature as well as tropical cyclone history since the 1980s. These data have provided some insight into the role of disturbances in shaping the current state of shallow reef habitats in the CSMP with areas of low coral cover coinciding with the frequency and intensity of damaging waves, and will allow any future changes in the frequency and/or severity of disturbances affecting the CSMP to be examined. Looking forward, this study provides a comprehensive baseline of the health and condition of CSMP reefs to enable meaningful temporal comparisons and to assess the vulnerability or resilience to future disturbances. As well as monitoring the current state or health of reefs (i.e., coral cover and population sizes of fishes and non-coral invertebrates), it is critical to quantify demographic processes of key reef taxa (e.g., recruitment, growth and mortality of corals and fishes) among reefs and regions within the CSMP to better understand the vulnerability and recovery potential of coral reef environments in the face of rapidly changing environmental and habitat conditions. Continued monitoring of juvenile corals, in particular, will be critical to establish the potential replenishment of coral populations following major disturbances, and local stock-recruitment relationships for shallow water corals within the CSMP.

In the absence of any major environmental disturbances (e.g., marine heatwaves or severe tropical cyclones), the time between recurrent surveys of individual reefs could afford to be 2-5 years. However, given the increasing incidence of major disturbances (e.g., three mass bleaching events within the CSMP in the past 5 years) and the logistical constraints of working in the CSMP, related to the isolation and exposure of these reefs, we recommend more regular (i.e., annual or even biannual) monitoring of coral, fish, sea snakes and other communities using the same methods as the 2018-20 surveys. Given the similarities of coral and fish assemblages on reefs within each region not every reef would need to be surveyed each year, allowing for more detailed annual surveys of a few representative reefs. These representative reefs should include 9-12 reefs (with a minimum of 3 reefs, 4 reefs and 2 reefs in the southern, central and northern CSMP, respectively to allow rigorous statistical analyses), with consideration given to the availability of suitable anchorages, and hence access, under all weather conditions. As a minimum we recommend that Saumarez, Wreck and Kenn Reefs in the southern CSMP, Flinders and Lihou Reefs, Herald Cays, and Chilcott Islet in the central CSMP, and Bougainville and Osprey Reefs in the northern CSMP are surveyed annually, and that all 20 CSMP reefs are surveyed once every 3-5 years.

Critically, to determine the fate of corals that bleached in 2020 sites surveyed in 2020 should be re-surveyed within the next 6-9 months (i.e., prior to April 2021), before further disturbances potentially augment patterns of coral abundance. As discussed above some corals can recover from extensive bleaching if water temperatures decrease sufficiently, while other corals may take months to die follow bleaching. Quantifying the proportion of corals that die vs recover will be critical in assessing the full impact of the 2020 bleaching event on benthic communities and likely future impacts on fish and invertebrate communities throughout the CSMP, and importantly in understanding the potential resilience and thermal tolerance of corals within the CSMP. Ideally this would involve re-surveying all sites on all reefs visited in 2020 using the same methods as the 2018-20 surveys, although a reduced set of representative reefs could be targeted if resources are limiting (see above).

Greater flexibility needs to be incorporated into future voyage schedules, so that sampling can be adapted to answer specific questions and make the most of particular conditions. For example, if a major disturbance is occurring at the time of the voyage/s then re-surveying existing sites at a restricted number of representative reefs would be a priority. However, in the absence of any disturbance the survey of ‘new’ (i.e., previously un-surveyed) sites should be prioritised to gain a greater understanding of the overall biodiversity and structure of reef communities within each reef. Most surveys conducted in 2018, 2019, and 2020 were in relatively sheltered back reef and lagoonal habitats, with very few surveys on the exposed aspects of the reefs. This was primarily due to severe weather at the time of the surveys (2018 and 2019), and a lack of safe anchorages for the tenders due to the depth and oceanic swells in relatively calm weather (2020). There is a definitive need to survey more exposed fore-reef habitat to better characterise the reef assemblages that occur in shallow reef environments in the CSMP, which will require an adaptation of the current survey methods. To avoid having to anchor or lay and retrieve transect tapes in these exposed habitats we recommend the use of a series of 5-min timed swims whereby divers swim at a constant speed along a depth profile while recorded the taxa of interest. Fishes, sea snakes and non-coral invertebrates would be recorded within the same belt widths as used in the present surveys (see Appendix 3) and the benthic community quantified at 100 haphazard points during each 5-min swim. Previous research has estimated a 5-min timed swim to cover a linear distance of 50-60m (e.g., Hoey and Bellwood 2009; Wismer et al. 2009), and the distance covered could be estimated from GPS coordinates of start and end points of each survey, or using a towed GPS if conditions allow.

Moreover, our current understanding of other habitat types (e.g., deeper reef environments and soft-bottom habitats) is limited and should be incorporated into future monitoring. Spending a greater amount of time (i.e., 3-4 days compared to only 1 day in the present surveys) at the representative reefs identified above would allow for surveys of these additional habitats, as well as additional reef crest and reef slope sites. We recommend the use of timed-swims with a towed GPS (e.g., Lynch et al. 2015), or manta tow (e.g., Friedman et al. 2011) to survey non-coral invertebrates (namely sea cucumbers) and fishes over soft-bottom habitats.

Given the logistics, safety concerns, and regulations around SCUBA diving to depths below ~20m, we strongly recommend the use of remotely operated vehicles (ROV's) to capture video transects of benthic communities, and a combination of baited remote underwater videos (BRUV) and unbaited remote underwater videos to capture video of fish assemblages in depth from 30-100m. The collection of such information will not only require specialised equipment but also considerable time investment to process videos.

The present surveys identified several stand out reefs, namely Boot and Ashmore Reefs in the northern CSMP, and Moore and Mellish Reefs in the central CSMP that supported exceptional biodiversity, coral cover, and/or reef fish biomass. With the exception of Moore Reefs, these reefs were only visited once during the 3 years of this project due to their locations in the far north and far east of the CSMP and hence the logistical challenges of accessing them. Understanding what makes these reefs unique will require comprehensive monitoring of coral and fish assemblages at multiple sites, together with dedicated and extensive research on key demographic (i.e., recruitment, growth and mortality of corals and fishes) and ecological (e.g., primary and secondary productivity, nutrient inputs, local hydrodynamics) processes. Monitoring and research on these 'stand out' or 'bright spot' reefs should be a future priority.

Ashmore and Boot Reefs in the far northern CSMP were not only 'bright spots' in terms of the biological communities they supported, but also offered a unique opportunity to engage with, and work alongside the Meriam people, the traditional owners of this sea country. Two members of the Mariam people joined us during our only surveys of Boot and Ashmore Reefs for this project in October 2018. This time was extremely valuable in gaining a greater understanding of traditional knowledge, their connections with their sea country, and their concerns regarding the current status of Ashmore and Boot Reefs (namely declines in giant clam, sea cucumber and some fish populations). Further, our surveys revealed a complete absence of trochus at Ashmore and Boot Reef, that may be related to their harvest outside the boundaries of the Torres Strait trochus fishery. Comprehensive and targeted monitoring of trochus, giant clam, sea cucumber and fish assemblages at Boot and Ashmore Reefs should be prioritised every 2-3 years, and conducted over an extended period (6-8 days) to allow multiple habitats (including hard and soft substrata) and sites to be surveyed. Importantly, members of the Meriam people should be invited and encouraged to participate in research voyages to Ashmore and Boot Reefs to i) increase understanding of traditional knowledge and cultural values, ii) establish new, and/or build on existing collaborations between traditional owners, researchers and Parks Australia, and iii) build the capacity of the Meriam people to participate and take an active role in the management of the CSMP.

Exceptionally high densities of sea urchins (*Diadema* spp.) and high densities of giant clams (*Tridacna* spp.) were observed at Kenn Reef during our surveys. While the factors contributing to the high densities of these invertebrates are currently unknown, the comparable patterns for sea urchins and giant clams suggest it may reflect a chance recruitment event and/or high levels of self-recruitment. Continued monitoring of sea urchin and giant clam populations at Kenn Reef should be prioritised every 1-2 years. This is particularly important for sea urchin populations because if these high densities are sustained over long temporal scales they could lead to significant internal erosion and weakening of the reef framework.

Biophysical modelling and genetic analyses of fish populations revealed low connectivity among CSMP reefs, suggesting they are largely reliant on self-recruitment for replenishment and resilience. Understanding the importance of connectivity with other fish populations (i.e., outside the CSMP) and their influence on biogeographic patterns in the CSMP would require expanding connectivity modelling and sampling within all regions bordering the CSMP, with particular focus towards eastern regions (New Caledonia, Vanuatu, Solomon Islands). Moreover, the low levels of connectivity among CSMP reefs suggest that populations of reef taxa may be extremely sensitive to local declines in abundance. A dedicated case study of the degree of isolation and reliance on self-replenishment for populations on remote reef such as Mellish Reef is needed to establish their susceptibility to disturbance and exploitation.

Scheduling the timing of surveys for late summer-early autumn (i.e., Feb-Apr) is ideal to capture the incidence of bleaching when it does occur (as evidenced by the extensive bleaching recorded in 2020), however it limits the capacity to explore other important biological and ecological processes, such as coral reproduction and fish spawning aggregations which typically peak in mid- to late-spring (i.e., Oct – Nov). More frequent (e.g., biannual surveys) would allow for much more detailed understanding of seasonal process, as well as allowing for the more effective deployment of in-water sampling devices for which the longevity of their data sampling is limited (e.g., tilt current meters only record for ~3 months) to quantify seasonal changes in environmental conditions.

The major constraint to undertaking research and monitoring in the CSMP relates to accessibility and the limited number of vessels that operate in this area. For this reason, it is important to make full and effective use of all opportunities that do exist, especially when visiting the most isolated reefs (e.g., Mellish, Ashmore and Boot Reefs). There are certainly opportunities to make better use of vessels (e.g., dive tourism and fishing charter vessels) that repeatedly visit the innermost reefs in the CSMP, including Osprey, Flinders and Saumarez Reefs, to increase the frequency at which in-water sampling devices are deployed and retrieved (see above). These sites are also the prime locations for studying more direct anthropogenic pressures (e.g., line- and spear-fishing) on CSMP reefs. Therefore, increased communication and collaboration among government and non-government agencies should be prioritised to facilitate more extensive sampling and re-visitation across the CSMP. A first and potential useful step would be to hold workshops with relevant stakeholders (i.e., dive tourism and fishing charter operators, researchers, and Parks Australia staff) in Gladstone and Port Douglas to initiate discussions, identify potential synergies and plan collaborations.

Given the broad geographical focus of the surveys, our capacity to test for differences in the health and condition of coral reef assemblages between zones was not possible because any such comparisons (at the scale of the entire CSMP) would be highly confounded by differences in the disturbance history, geomorphology, isolation, aspect and exposure among reef sites. If testing for “marine park zone effects” are of interest then we suggest that a dedicated sampling program should be established that is designed in accordance with detailed spatial and temporal information on catches of major fisheries target species, and focusing mainly on innermost reefs that have split zoning.

Finally, regional differences in the composition of fish and coral assemblages were evident both between the GBRMP and CSMP, and within the CSMP (i.e., northern, central and southern CSMP). While these regional differences point toward the importance and uniqueness of the CSMP, comparable monitoring and research in all regions within and bordering the CSMP, including the GBRMP, Australia’s Temperate East Marine Parks Network, New Caledonia, Solomon Islands and Papua New Guinea, is required to establish the biogeographical significance of the CSMP. Cross-jurisdictional meetings, workshops, and ultimately scientific expeditions will be invaluable to better understand biological and ecological connections among these regions. Given the increasing use of online meeting platforms (e.g., Zoom, Microsoft Teams) during the COVID-19 pandemic, now may the ideal time to initiate such cross-jurisdictional meetings without the expense of travel.

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7 APPENDIX 1.

Several additional projects were leveraged from this collaboration between James Cook University and Parks Australia and capitalised on available space during the voyages. These leveraged projects involved 23 researchers from 7 institutions and represent an in-kind contribution of over 310 person days.

Project description	Key Personnel	Institution
Quantifying regional patterns in biodiversity and community composition of cryptobenthic fishes	Dr Christopher Goatley Mr Tane Sinclair-Taylor Ms Amanda Hay Mr Renato Morais Mr Sterling Tebbet	University of New England Australian Institute of Marine Science Australian Museum James Cook University James Cook University
Taxonomic diversity of cryptic coral reef invertebrates	Dr Penny Berents	Australian Museum
Taxonomic diversity of shallow water sponges	Dr Merricks Ekins Dr Tom Bridge	Queensland Museum Queensland Museum
3D modelling of reef slope habitats to explore relationships with the biodiversity and assemblage structure of reef fishes	A/Prof Will Figuiera Mr Neil Doszpot Ms Sian Liddy	University of Sydney University of Sydney University of Sydney
3D photogrammetry of coral colonies to investigate variation in structural complexity and the provision of shelter for reef fishes	Mr Eoghan Aston Prof Andrew Hoey	James Cook University James Cook University
Mapping of key shallow water reef habitats within the CSMP	Dr Emma Kennedy Dr Chris Roelfsema Dr Alexandra Ordonez Mr Paul Tudman Ms Madeline Davey Ms Amber Moran Ms Gretel Waugh	University of Queensland University of Queensland University of Queensland University of Queensland University of Queensland University of Queensland University of Queensland
Measuring the tolerance of corals to acute thermal stress within the CSMP	Dr Hugo Harrison Ms Magena Marzonie	James Cook University Australian Institute of Marine Science
Investigating the reliability of aerial photos for detecting coral bleaching across the CSMP	Dr Hugo Harrison Prof Andrew Hoey Prof Terry Hughes	James Cook University James Cook University James Cook University
Opportunistic surveys for fish spawning aggregations	Mr Martin Russell	Science and Conservation of Fish Aggregations

8 APPENDIX 2.

List of sites surveyed in the Coral Sea Marine Park (CSMP) and Great Barrier Reef Marine Park (GBRMP) between April 2018 and March 2020. Voyage dates were 16 Feb 16 – 12 March 2020, 14 Feb – 26 March 2019, 3 -19 Dec 2018, 17-26 Oct 2018, 11-25 Apr 2018.

Region	Sector	Site	Exposure	Aspect	Lat	Long
CSMP	Southern	Cato 1	Sheltered	NW	-23.24763	155.53525
CSMP	Southern	Cato 2	Sheltered	NW	-23.24515	155.54097
CSMP	Southern	Cato 3	Sheltered	NW	-23.24406	155.54829
CSMP	Southern	Frederick 1	Sheltered	NE	-21.01111	154.351
CSMP	Southern	Frederick 2	Semi-sheltered	W	-21.01043	154.34743
CSMP	Southern	Frederick 3	Sheltered	NW	-20.97567	154.39644
CSMP	Southern	Frederick 4	Sheltered	W	-20.93838	154.39737
CSMP	Southern	Kenn 1	Sheltered	NE	-21.2476	155.76616
CSMP	Southern	Kenn 2	Sheltered	NE	-21.25323	155.76216
CSMP	Southern	Kenn 3	Sheltered	W	-21.19062	155.76448
CSMP	Southern	Kenn 4	Sheltered	W	-21.20459	155.77238
CSMP	Southern	Saumarez 1	Sheltered	N	-21.88607	153.64764
CSMP	Southern	Saumarez 2	Sheltered	N	-21.87617	153.65356
CSMP	Southern	Saumarez 3	Sheltered	NW	-21.9178	153.58452
CSMP	Southern	Saumarez 4	Sheltered	W	-21.91898	153.57565
CSMP	Southern	Saumarez 5	Sheltered	W	-21.75002	153.76973
CSMP	Southern	Saumarez 6	Semi-exposed	SW	-21.76307	153.76363
CSMP	Southern	Saumarez 7	Sheltered	NW	-21.91194	153.59119
CSMP	Southern	Wreck 1	Sheltered	NW	-22.19267	155.33405
CSMP	Southern	Wreck 2	Sheltered	W	-22.17814	155.17674
CSMP	Southern	Wreck 3	Sheltered	NW	-22.18667	155.17049
CSMP	Southern	Wreck 4	Sheltered	NE	-22.16968	155.47392
CSMP	Central	Chilcott 1	Sheltered	NW	-16.9315	149.98988
CSMP	Central	Chilcott 2	Sheltered	NW	-16.9315	149.98988
CSMP	Central	Chilcott 3	Sheltered	NW	-16.9315	149.98988
CSMP	Central	Chilcott 4	Sheltered	NE	-16.93601	149.99835
CSMP	Central	Diamond 1	Semi-sheltered	NE	-17.44199	151.06255
CSMP	Central	Diamond 2	Sheltered	N	-17.43684	151.06972
CSMP	Central	Diamond 3	Sheltered	NW	-17.42587	151.0721
CSMP	Central	Diamond 4	Sheltered	W	-17.44721	151.06163
CSMP	Central	Diamond 5	Sheltered	N	-17.41302	151.07486
CSMP	Central	Diamond 6	Sheltered	W	-17.41871	151.07123
CSMP	Central	Diane 1	Sheltered	N	-15.71759	149.61794
CSMP	Central	Diane 2	Sheltered	NW	-15.71977	149.61554
CSMP	Central	Diane 3	Sheltered	NW	-15.72303	149.61757
CSMP	Central	Diane 4	Sheltered	N	-15.71625	149.62041
CSMP	Central	Flinders 1	Sheltered	NW	-17.71357	148.43713
CSMP	Central	Flinders 2	Sheltered	N	-17.70218	148.46655
CSMP	Central	Flinders 3	Exposed	NE	-17.70321	148.50844
CSMP	Central	Flinders 4	Sheltered	W	-17.78798	148.41219
CSMP	Central	Flinders 5	Sheltered	W	-17.86163	148.46652
CSMP	Central	Flinders 6	Sheltered	S	-17.83089	148.51353
CSMP	Central	Flinders 7	Exposed	NE	-17.53675	148.55112
CSMP	Central	Flinders 8	Exposed	E	-17.53949	148.56053
CSMP	Central	Flinders 9	Exposed	NW	-17.63107	148.58995
CSMP	Central	Flinders 10	Exposed	NW	-17.69391	148.52115
CSMP	Central	Herald 1	Semi-exposed	N	-16.94348	149.18565
CSMP	Central	Herald 2	Semi-exposed	W	-16.92173	149.20015
CSMP	Central	Herald 3	Sheltered	N	-16.9787	149.12634

CSMP	Central	Herald 4	Sheltered	SW	-16.97254	149.12865
CSMP	Central	Herald 5	Sheltered	W	-17.01441	149.13739
CSMP	Central	Herald 6	Sheltered	W	-16.99189	149.13075
CSMP	Central	Herald 7	Sheltered	W	-16.92931	149.20221
CSMP	Central	Holmes 1	Sheltered	NW	-16.52613	147.80701
CSMP	Central	Holmes 2	Semi-sheltered	W	-16.51181	147.84
CSMP	Central	Holmes 3	Sheltered	W	-16.50105	147.84419
CSMP	Central	Holmes 4	Sheltered	NW	-16.5045	147.99681
CSMP	Central	Holmes 5	Semi-sheltered	NW	-16.50534	147.96745
CSMP	Central	Holmes 6	Semi-sheltered	NW	-16.41898	147.98981
CSMP	Central	Holmes 7	Semi-sheltered	NW	-16.42693	147.98442
CSMP	Central	Holmes 8	Sheltered	W	-16.4309	147.85088
CSMP	Central	Holmes 9	Exposed	E	-16.52522	147.84312
CSMP	Central	Holmes 10	Semi-exposed	NW	-16.52143	147.83772
CSMP	Central	Holmes 11	Exposed	SE	-16.52687	147.97322
CSMP	Central	Holmes 12	Semi-sheltered	N	-16.41015	148.01141
CSMP	Central	Holmes 13	Semi-sheltered	N	-16.40672	148.0222
CSMP	Central	Lihou 1	Sheltered	NW	-17.59707	151.48956
CSMP	Central	Lihou 2	Sheltered	N	-17.59065	151.50027
CSMP	Central	Lihou 3	Sheltered	N	-17.47482	151.74574
CSMP	Central	Lihou 4	Semi-sheltered	N	-17.12527	151.82535
CSMP	Central	Lihou 5	Semi-sheltered	N	-17.12113	151.82939
CSMP	Central	Lihou 6	Sheltered	N	-17.58145	151.55675
CSMP	Central	Lihou 7	Exposed	SE	-17.41725	151.86607
CSMP	Central	Lihou 8	Sheltered	N	-17.41009	151.88113
CSMP	Central	Lihou 9	Lagoon	SE	-17.13022	151.83931
CSMP	Central	Lihou 10	Lagoon	SE	-17.12369	151.84775
CSMP	Central	Marion 5	Exposed	SW	-18.98541	152.34488
CSMP	Central	Marion 6	Exposed	SE	-19.12125	152.39993
CSMP	Central	Marion 7	Sheltered	N	-19.29511	152.23782
CSMP	Central	Marion 8	Exposed	S	-19.29981	152.23572
CSMP	Central	Marion 9	Lagoon	NE	-19.23144	152.17848
CSMP	Central	Marion 10	Semi-sheltered	NW	-19.00823	152.37038
CSMP	Central	Mellish 1	Sheltered	NE	-17.41608	155.8531
CSMP	Central	Mellish 2	Sheltered	N	-17.41767	155.85738
CSMP	Central	Mellish 5	Exposed	S	-17.43996	155.85533
CSMP	Central	Mellish 6	Sheltered	SW	-17.39041	155.8616
CSMP	Central	Mellish 7	Sheltered	SW	-17.37424	155.84311
CSMP	Central	Mellish 8	Exposed	S	-17.43929	155.86292
CSMP	Central	Mellish 9	Sheltered	W	-17.42651	155.85326
CSMP	Central	Moore 1	Exposed	SW	-15.89218	149.15359
CSMP	Central	Moore 2	Semi-exposed	N	-15.87038	149.17203
CSMP	Central	Moore 3	Semi-exposed	N	-15.87737	149.15955
CSMP	Central	Moore 4	Sheltered	W	-15.96481	149.19427
CSMP	Central	Moore 5	Exposed	E	-15.97315	149.35715
CSMP	Central	Willis 1	Lagoon	N	-16.29661	149.96089
CSMP	Central	Willis 2	Sheltered	W	-16.28728	149.9593
CSMP	Central	Willis 3	Sheltered	N	-16.30325	149.96307
CSMP	Central	Willis 4	Semi-exposed	NE	-16.28256	149.9657
CSMP	Central	Willis 5	Exposed	E	-16.29127	149.97182
CSMP	Central	Willis 6	Semi-exposed	NE	-16.20926	149.9959
CSMP	Central	Willis 7	Semi-sheltered	NW	-16.11697	149.97095
CSMP	Central	Willis 8	Sheltered	W	-16.13834	150.02405
CSMP	Central	Willis 9	Semi-sheltered	N	-16.11289	149.97757
CSMP	Northern	Ashmore 1	Sheltered	W	-10.13803	144.44118
CSMP	Northern	Ashmore 2	Exposed	NE	-10.2194	144.60172
CSMP	Northern	Ashmore 3	Lagoon	W	-10.21945	144.59666
CSMP	Northern	Ashmore 4	Exposed	E	-10.36421	144.54573
CSMP	Northern	Ashmore 5	Lagoon	W	-10.366	144.54124
CSMP	Northern	Boot 1	Semi-sheltered	NE	-9.98347	144.68056
CSMP	Northern	Boot 2	Semi-sheltered	W	-9.97814	144.68752

CSMP	Northern	Boot 3	Semi-sheltered	NW	-9.96217	144.71513
CSMP	Northern	Bougainville 1	Sheltered	N	-15.49273	147.08638
CSMP	Northern	Bougainville 2	Sheltered	N	-15.48617	147.09161
CSMP	Northern	Bougainville 3	Sheltered	NE	-15.48066	147.10858
CSMP	Northern	Bougainville 4	Semi-exposed	SW	-15.50667	147.11234
CSMP	Northern	Bougainville 5	Semi-exposed	SW	-15.50083	147.09891
CSMP	Northern	Bougainville 6	Sheltered	N	-15.48139	147.10422
CSMP	Northern	Osprey 1	Exposed	N	-13.80132	146.5461
CSMP	Northern	Osprey 2	Sheltered	W	-13.90095	146.56187
CSMP	Northern	Osprey 3	Lagoon	N	-13.85862	146.56769
CSMP	Northern	Osprey 4	Semi-exposed	SW	-14.01625	146.67931
CSMP	Northern	Osprey 5	Semi-sheltered	SW	-14.00955	146.67274
CSMP	Northern	Osprey 6	Sheltered	S	-13.88078	146.55881
CSMP	Northern	Osprey 7	Lagoon	E	-13.88845	146.5594
GBRMP	Southern	Conspicuous 1	Sheltered	N	-22.33057	152.6694
GBRMP	Southern	Conspicuous 2	Sheltered	W	-22.33499	152.66357
GBRMP	Southern	Hixon 1	Semi-exposed	W	-22.33111	152.71092
GBRMP	Southern	Hixon 2	sheltered	N	-22.3317	152.73036
GBRMP	Southern	Hixon 3	exposed	NE	-22.31141	152.73413
GBRMP	Southern	Sandshoe 1	Sheltered	N	-22.20391	152.75301
GBRMP	Southern	Sandshoe 2	Sheltered	NW	-22.21185	152.74361
GBRMP	Southern	Sandshoe 3	Sheltered	W	-22.2161	152.73814
GBRMP	Central	17-065 1	NA	NA	-17.85747	146.73357
GBRMP	Central	17-065 2	NA	NA	-17.86272	146.73322
GBRMP	Central	18-023 1	Sheltered	W	-18.13544	146.96771
GBRMP	Central	18-023 2	Sheltered	NW	-18.126	146.97148
GBRMP	Central	Castor 1	Sheltered	SW	-19.01787	148.31615
GBRMP	Central	Castor 2	Sheltered	W	-19.02111	148.31538
GBRMP	Central	Castor 3	Sheltered	NW	-19.01398	148.3241
GBRMP	Central	Elizabeth 1	Sheltered	SW	-19.34364	149.04122
GBRMP	Central	Elizabeth 2	Sheltered	W	-19.33153	149.0512
GBRMP	Central	Pith 1	Exposed	NE	-18.20752	147.02625
GBRMP	Central	Pith 2	Exposed	E	-18.21786	147.02727
GBRMP	Central	Potter 1	NA	NA	-17.66617	146.55737
GBRMP	Central	Potter 2	NA	NA	-17.68037	146.55626
GBRMP	Northern	Agincourt 1	NA	NA	-15.9395	145.81456
GBRMP	Northern	Creech 1	Exposed	E	-13.63011	144.11528
GBRMP	Northern	Creech 2	Exposed	NW	-13.64465	144.10272
GBRMP	Northern	Creech 3	Exposed	S	-13.64737	144.10687
GBRMP	Northern	Day 1	NA	NA	-14.48258	145.51596
GBRMP	Northern	Day 2	NA	NA	-14.47672	145.51762
GBRMP	Northern	Escape 1	NA	NA	-15.88507	145.7648
GBRMP	Northern	Escape 2	NA	NA	-15.88303	145.76949
GBRMP	Northern	Ribbon 1 1	Exposed	S	-15.61943	145.8055
GBRMP	Northern	Ribbon 1 2	Sheltered	NW	-15.51602	145.79715
GBRMP	Northern	Ribbon 10 1	NA	NA	-14.66914	145.65965
GBRMP	Northern	Ribbon 10 2	NA	NA	-14.67608	145.66327
GBRMP	Northern	Ribbon 5 1	Exposed	E	-15.38946	145.76942
GBRMP	Northern	Ribbon 5 2	Sheltered	SW	-15.39165	145.77513
GBRMP	Northern	St Crispin 1	Sheltered	NE	-16.07259	145.84637
GBRMP	Northern	St Crispin 2	Sheltered	NW	-16.07504	145.85056
GBRMP	Northern	Tongue 1	Exposed	E	-16.34238	145.92
GBRMP	Northern	Tongue 2	Sheltered	N	-16.31833	145.91248

9 APPENDIX 3.

List of fish species recorded from the southern, central and northern reefs in the CSMP and GBRMP and the area in which fish are counted in each transect.

Species	Transect area	Species2	Transect area2
Abudefduf sexfasciatus	50 x 2	*Acanthurus olivaceus*	50 x 5
Abudefduf vaigiensis	50 x 2	*Acanthurus pyroferus*	50 x 5
Abudefduf whitleyi	50 x 2	*Acanthurus thompsoni*	50 x 5
Acanthochromis polyacanthus	50 x 2	*Acanthurus triostegus*	50 x 5
Amblyglyphidodon aureus	50 x 2	*Acanthurus xanthopterus*	50 x 5
Amblyglyphidodon curacao	50 x 2	*Anyperodon leucogrammicus*	50 x 5
Amblyglyphidodon leucogaster	50 x 2	*Aphareus furca*	50 x 5
Amphiprion akindynos	50 x 2	*Aprion virescens*	50 x 5
Amphiprion chrysopterus	50 x 2	*Balistapus undulatus*	50 x 5
Amphiprion clarkii	50 x 2	*Balistoides conspicillum*	50 x 5
Amphiprion melanopus	50 x 2	*Balistoides viridescens*	50 x 5
Amphiprion perideraion	50 x 2	*Bolbometopon muricatum*	50 x 5
Chromis agilis	50 x 2	*Caesio cuning*	50 x 5
Chromis alpha	50 x 2	*Caesio lunaris*	50 x 5
Chromis amboinensis	50 x 2	*Calotomus carolinus*	50 x 5
Chromis atripectoralis	50 x 2	*Carangoides bajad*	50 x 5
Chromis atripes	50 x 2	*Carangoides ferdau*	50 x 5
Chromis chrysura	50 x 2	*Carangoides fulvoguttatus*	50 x 5
Chromis flavomaculata	50 x 2	*Carangoides orthogrammus*	50 x 5
Chromis iomelas	50 x 2	*Caranx ignobilis*	50 x 5
Chromis lepidolepis	50 x 2	*Caranx lugubris*	50 x 5
Chromis margaritifer	50 x 2	*Caranx melampygus*	50 x 5
Chromis retrofasciata	50 x 2	*Caranx sexfasciatus*	50 x 5
Chromis ternatensis	50 x 2	*Caranx sp.*	50 x 5
Chromis vanderbilti	50 x 2	*Carcharhinus albimarginatus*	50 x 5
Chromis viridis	50 x 2	*Carcharhinus amblyrhynchos*	50 x 5
Chromis weberi	50 x 2	*Cephalopholis argus*	50 x 5
Chromis xanthochira	50 x 2	*Cephalopholis cyanostigma*	50 x 5
Chromis xanthura	50 x 2	*Cephalopholis leopardus*	50 x 5
Chrysiptera biocellata	50 x 2	*Cephalopholis miniata*	50 x 5
Chrysiptera brownriggii	50 x 2	*Cephalopholis spiloparea*	50 x 5
Chrysiptera flavipinnis	50 x 2	*Cephalopholis urodeta*	50 x 5
Chrysiptera glauca	50 x 2	*Cetoscarus ocellatus*	50 x 5
Chrysiptera rex	50 x 2	*Cheilinus chlorourus*	50 x 5
Chrysiptera rollandi	50 x 2	*Cheilinus fasciatus*	50 x 5
Chrysiptera talboti	50 x 2	*Cheilinus oxycephalus*	50 x 5
Chrysiptera taupou	50 x 2	*Cheilinus trilobatus*	50 x 5
Dascyllus aruanus	50 x 2	*Cheilinus undulatus*	50 x 5
Dascyllus reticulatus	50 x 2	*Chlorurus bleekeri*	50 x 5
Dascyllus trimaculatus	50 x 2	*Chlorurus frontalis*	50 x 5
Dischistodus melanotus	50 x 2	*Chlorurus japanensis*	50 x 5
Dischistodus pseudochrysopoecilus	50 x 2	*Chlorurus microrhinos*	50 x 5
Hemiglyphidodon plagiometopon	50 x 2	*Chlorurus spilurus*	50 x 5
Lepidozygus tapeinosoma	50 x 2	*Choerodon cyanodus*	50 x 5
Neoglyphidodon melas	50 x 2	*Choerodon fasciatus*	50 x 5
Neoglyphidodon nigroris	50 x 2	*Choerodon graphicus*	50 x 5
Neopomacentrus asyzron	50 x 2	*Cromileptes altivelis*	50 x 5
Neopomacentrus cf cyanomos	50 x 2	*Ctenochaetus binotatus*	50 x 5
Plectroglyphidodon dickii	50 x 2	*Ctenochaetus cyanocheilus*	50 x 5
Plectroglyphidodon imparipennis	50 x 2	*Ctenochaetus striatus*	50 x 5
Plectroglyphidodon johnstonianus	50 x 2	*Diploprion bifasciatum*	50 x 5

Plectroglyphidodon lacrymatus	50 x 2
Plectroglyphidodon leucozonus	50 x 2
Plectroglyphidodon phoenixensis	50 x 2
Pomacentrus adelus	50 x 2
Pomacentrus amboinensis	50 x 2
Pomacentrus bankanensis	50 x 2
Pomacentrus brachialis	50 x 2
Pomacentrus chrysurus	50 x 2
Pomacentrus coelestis	50 x 2
Pomacentrus grammorhynchus	50 x 2
Pomacentrus imitator	50 x 2
Pomacentrus lepidogenys	50 x 2
Pomacentrus moluccensis	50 x 2
Pomacentrus nagasakiensis	50 x 2
Pomacentrus pavo	50 x 2
Pomacentrus philippinus	50 x 2
Pomacentrus vaiuli	50 x 2
Pomacentrus wardi	50 x 2
Pomachromis richardsoni	50 x 2
Stegastes apicalis	50 x 2
Stegastes fasciolatus	50 x 2
Stegastes gascoynei	50 x 2
Stegastes nigricans	50 x 2
Anampses caeruleopunctatus	50 x 4
Anampses femininus	50 x 4
Anampses meleagrides	50 x 4
Anampses neoguinaicus	50 x 4
Anampses twistii	50 x 4
Apolemichthys trimaculatus	50 x 4
Bodianus axillaris	50 x 4
Bodianus diana	50 x 4
Bodianus dictynna	50 x 4
Bodianus loxozonus	50 x 4
Bodianus mesothorax	50 x 4
Bodianus perditio	50 x 4
Centropyge bicolor	50 x 4
Centropyge bispinosus	50 x 4
Centropyge flavissimus	50 x 4
Centropyge heraldi	50 x 4
Centropyge loricula	50 x 4
Centropyge smokey	50 x 4
Centropyge tibicen	50 x 4
Centropyge vrolikii	50 x 4
Chaetodon auriga	50 x 4
Chaetodon baronessa	50 x 4
Chaetodon bennetti	50 x 4
Chaetodon citrinellus	50 x 4
Chaetodon ephippium	50 x 4
Chaetodon flavirostris	50 x 4
Chaetodon kleinii	50 x 4
Chaetodon lineolatus	50 x 4
Chaetodon lunula	50 x 4
Chaetodon lunulatus	50 x 4
Chaetodon melannotus	50 x 4
Chaetodon mertensii	50 x 4
Chaetodon meyeri	50 x 4
Chaetodon ocellicaudus	50 x 4
Chaetodon ornatissimus	50 x 4
Chaetodon oxycephalus	50 x 4
Chaetodon pelewensis	50 x 4
Elagatis bipinnulatus	50 x 5
Epibulus insidiator	50 x 5
Epinephelus coeruleopunctatus	50 x 5
Epinephelus coioides	50 x 5
Epinephelus fasciatus	50 x 5
Epinephelus fuscoguttatus	50 x 5
Epinephelus hexagonatus	50 x 5
Epinephelus howlandensis	50 x 5
Epinephelus lanceolatus	50 x 5
Epinephelus merra	50 x 5
Epinephelus polyphekadion	50 x 5
Epinephelus quoyanus	50 x 5
Epinephelus tukula	50 x 5
Gnathodentex aureolineatus	50 x 5
Gracilla albomarginata	50 x 5
Gymnocranius euanus	50 x 5
Gymnocranius microdon	50 x 5
Hemigymnus fasciatus	50 x 5
Hemigymnus melapterus	50 x 5
Hipposcarus longiceps	50 x 5
Hologymnosus annulatus	50 x 5
Hologymnosus doliatus	50 x 5
Kyphosus cinerascens	50 x 5
Kyphosus vaigiensis	50 x 5
Lethrinus atkinsoni	50 x 5
Lethrinus erythracanthus	50 x 5
Lethrinus miniatus	50 x 5
Lethrinus nebulosus	50 x 5
Lethrinus obsoletus	50 x 5
Lethrinus olivaceus	50 x 5
Lethrinus sp. 1	50 x 5
Lethrinus xanthocheilus	50 x 5
Lutjanus argentimaculatus	50 x 5
Lutjanus bohar	50 x 5
Lutjanus carponotatus	50 x 5
Lutjanus fulviflamma	50 x 5
Lutjanus fulvus	50 x 5
Lutjanus gibbus	50 x 5
Lutjanus kasmira	50 x 5
Lutjanus monostigma	50 x 5
Lutjanus rivulatus	50 x 5
Lutjanus semicinctus	50 x 5
Luzonichthys sp	50 x 5
Macolor macularis	50 x 5
Macolor niger	50 x 5
Melichthys vidua	50 x 5
Monotaxis grandoculis	50 x 5
Monotaxis heterodon	50 x 5
Mulloidichthys flavolineatus	50 x 5
Mulloidichthys vanicolensis	50 x 5
Naso annulatus	50 x 5
Naso brachycentron	50 x 5
Naso brevirostris	50 x 5
Naso caesius	50 x 5
Naso hexacanthus	50 x 5
Naso lituratus	50 x 5
Naso tonganus	50 x 5
Naso unicornis	50 x 5
Naso vlamingii	50 x 5
Odonus niger	50 x 5

Chaetodon plebeius	50 x 4	*Oxycheilinus digramma*	50 x 5
Chaetodon punctatofasciatus	50 x 4	*Oxycheilinus orientalis*	50 x 5
Chaetodon rafflesi	50 x 4	*Oxycheilinus oxycephalus*	50 x 5
Chaetodon rainfordi	50 x 4	*Oxycheilinus unifasciatus*	50 x 5
Chaetodon reticulatus	50 x 4	*Paracanthurus hepatus*	50 x 5
Chaetodon semeion	50 x 4	*Parupeneus barberinoides*	50 x 5
Chaetodon speculum	50 x 4	*Parupeneus barberinus*	50 x 5
Chaetodon trifascialis	50 x 4	*Parupeneus ciliatus*	50 x 5
Chaetodon ulietensis	50 x 4	*Parupeneus crassilabris*	50 x 5
Chaetodon unimaculatus	50 x 4	*Parupeneus cyclostomus*	50 x 5
Chaetodon vagabundus	50 x 4	*Parupeneus multifasciatus*	50 x 5
Chaetodontoplus meredithi	50 x 4	*Parupeneus pleurostigma*	50 x 5
Chelmon rostratus	50 x 4	*Platax pinnatus*	50 x 5
Cirrhilabrus exquisitus	50 x 4	*Plectorhinchus albovittatus*	50 x 5
Cirrhilabrus laboutei	50 x 4	*Plectorhinchus chaetodontoides*	50 x 5
Cirrhilabrus lineatus	50 x 4	*Plectorhinchus lessoni*	50 x 5
Cirrhilabrus punctatus	50 x 4	*Plectorhinchus lineatus*	50 x 5
Cirrhilabrus scottorum	50 x 4	*Plectorhinchus picus*	50 x 5
Coris aygula	50 x 4	*Plectropomus areolatus*	50 x 5
Coris batuensis	50 x 4	*Plectropomus laevis*	50 x 5
Coris dorsomacula	50 x 4	*Plectropomus leopardus*	50 x 5
Coris gaimard	50 x 4	*Pomacanthus imperator*	50 x 5
Diproctacanthus xanthurus	50 x 4	*Pomacanthus semicirculatus*	50 x 5
Forcipiger flavissimus	50 x 4	*Pomacanthus sexstriatus*	50 x 5
Forcipiger longirostris	50 x 4	*Pomacanthus xanthometopon*	50 x 5
Gomphosus varius	50 x 4	*Prionurus maculatus*	50 x 5
Halichoeres biocellatus	50 x 4	*Pseudanthias cooperi*	50 x 5
Halichoeres hortulanus	50 x 4	*Pseudanthias pascalus*	50 x 5
Halichoeres margaritaceus	50 x 4	*Pseudanthias pleurotaenia*	50 x 5
Halichoeres marginatus	50 x 4	*Pseudanthias squamipinnis*	50 x 5
Halichoeres melanurus	50 x 4	*Pseudanthias tuka*	50 x 5
Halichoeres ornatissimus	50 x 4	*Pseudobalistes flavimarginatus*	50 x 5
Halichoeres prosopeion	50 x 4	*Pseudobalistes fuscus*	50 x 5
Halichoeres trimaculatus	50 x 4	*Pterocaesio digramma*	50 x 5
Hemitaurichthys polylepis	50 x 4	*Pterocaesio tile*	50 x 5
Heniochus acuminatus	50 x 4	*Pterocaesio trilineata*	50 x 5
Heniochus chrysostomus	50 x 4	*Rhinecanthus rectangulus*	50 x 5
Heniochus monoceros	50 x 4	*Scarus altipinnis*	50 x 5
Heniochus varius	50 x 4	*Scarus chameleon*	50 x 5
Labrichthys unilineatus	50 x 4	*Scarus dimidiatus*	50 x 5
Labroides bicolor	50 x 4	*Scarus flavipectoralis*	50 x 5
Labroides dimidiatus	50 x 4	*Scarus forsteni*	50 x 5
Labroides pectoralis	50 x 4	*Scarus frenatus*	50 x 5
Labropsis australis	50 x 4	*Scarus ghobban*	50 x 5
Labropsis xanthonota	50 x 4	*Scarus globiceps*	50 x 5
Macropharyngodon choati	50 x 4	*Scarus longipinnis*	50 x 5
Macropharyngodon kuiteri	50 x 4	*Scarus niger*	50 x 5
Macropharyngodon meleagris	50 x 4	*Scarus oviceps*	50 x 5
Macropharyngodon negrosensis	50 x 4	*Scarus psittacus*	50 x 5
Paracentropyge multifasciata	50 x 4	*Scarus rivulatus*	50 x 5
Pseudocheilinus evanidus	50 x 4	*Scarus rubroviolaceus*	50 x 5
Pseudocheilinus hexataenia	50 x 4	*Scarus schlegeli*	50 x 5
Pseudocoris yamashiroi	50 x 4	*Scarus spinus*	50 x 5
Pseudodax moluccanus	50 x 4	*Scarus viridifucatus*	50 x 5
Pteragogus sp.	50 x 4	*Scarus xanthopleura*	50 x 5
Pygoplites diacanthus	50 x 4	*Scolopsis bilineatus*	50 x 5
Stethojulis bandanensis	50 x 4	*Scomberoides lysan*	50 x 5
Stethojulis interrupta	50 x 4	*Scomberoides sp*	50 x 5
Stethojulis strigiventer	50 x 4	*Serranocirrhites latus*	50 x 5

Thalassoma amblycephalum	50 x 4	*Siganus argenteus*	50 x 5
Thalassoma hardwicke	50 x 4	*Siganus corallinus*	50 x 5
Thalassoma lunare	50 x 4	*Siganus doliatus*	50 x 5
Thalassoma lutescens	50 x 4	*Siganus puellus*	50 x 5
Thalassoma nigrofasciatum	50 x 4	*Siganus punctatissimus*	50 x 5
Thalassoma purpureum	50 x 4	*Siganus punctatus*	50 x 5
Thalassoma quinquevittatum	50 x 4	*Siganus stellatus*	50 x 5
Acanthurus albipectoralis	50 x 5	*Siganus vulpinus*	50 x 5
Acanthurus blochii	50 x 5	*Siganus woodlandi*	50 x 5
Acanthurus dussumieri	50 x 5	*Stegostoma fasciatum*	50 x 5
Acanthurus grammoptilus	50 x 5	*Sufflamen bursa*	50 x 5
Acanthurus guttatus	50 x 5	*Sufflamen chrysopterus*	50 x 5
Acanthurus lineatus	50 x 5	*Trachinotus blochii*	50 x 5
Acanthurus mata	50 x 5	*Triaenodon obesus*	50 x 5
Acanthurus nigricans	50 x 5	*Variola louti*	50 x 5
Acanthurus nigricauda	50 x 5	*Zanclus cornutus*	50 x 5
Acanthurus nigrofuscus	50 x 5	*Zebrasoma scopas*	50 x 5
Acanthurus nigroris	50 x 5	*Zebrasoma veliferum*	50 x 5

10 APPENDIX 4.

Species lists of Scleractinia (hard) corals compiled from previous monitoring trip to the CSMP and from specimens held in the Museum of Tropical Queensland (MTQ). Species names have been updated to comply with the currently accepted taxonomy as listed at the World Register of Marine Species.

Count	**Species**	**Oxley et al 2003**	**Oxley et al 2004**	**Ceccarelli et al 2008**	**Ceccarelli et al 2009**	**MTQ**
1	*Acanthastrea brevis*			1		
2	*Acanthastrea echinata*	1	1	1	1	
3	*Acanthastrea hemprichii*			1		
4	*Acropora abrolhosensis*					1
5	*Acropora abrotanoides*			1		1
6	*Acropora aculeus*			1		1
7	*Acropora acuminata*		1	1	1	1
8	*Acropora anthocercis*	1	1			1
9	*Acropora austera*	1	1	1	1	1
10	*Acropora carduus*					1
11	*Acropora cerealis*	1	1	1	1	1
12	*Acropora chesterfieldensis*					1
13	*Acropora clathrata*	1	1		1	1
14	*Acropora cytherea*	1	1	1	1	1
15	*Acropora dendrum*					1
16	*Acropora digitifera*	1	1	1	1	1
17	*Acropora divaricata*	1	1	1	1	
18	*Acropora donei*	1	1			1
19	*Acropora echinata*					1
20	*Acropora elseyi*		1			1
21	*Acropora florida*	1	1	1	1	1
22	*Acropora gemmifera*	1	1	1	1	1
23	*Acropora globiceps*					1
24	*Acropora grandis*					1
25	*Acropora granulosa*					1
26	*Acropora horrida*					1
27	*Acropora humilis*	1	1	1	1	1
28	*Acropora hyacinthus*	1	1	1	1	1
29	*Acropora intermedia*			1	1	
30	*Acropora kimbeensis*					1
31	*Acropora latistella*		1	1	1	1
32	*Acropora listeri*	1			1	1
33	*Acropora longicyathus*	1	1		1	1
34	*Acropora loripes*		1	1		1
35	*Acropora lutkeni*			1		1
36	*Acropora microclados*					1
37	*Acropora millepora*		1	1		1
38	*Acropora monticulosa*	1	1	1	1	1
39	*Acropora muricata*				1	1
40	*Acropora nana*	1			1	1
41	*Acropora nasuta*	1	1	1	1	1
42	*Acropora palmerae*			1		
43	*Acropora paniculata*	1	1		1	1
44	*Acropora polystoma*	1	1	1	1	1

45	*Acropora robusta*	1	1	1	1	1
46	*Acropora samoensis*			1		1
47	*Acropora sarmentosa*		1		1	1
48	*Acropora secale*		1	1	1	1
49	*Acropora selago*		1	1	1	
50	*Acropora solitaryensis*					1
51	*Acropora spathulata*					1
52	*Acropora speciosa*					1
53	*Acropora subglabra*					1
54	*Acropora subulata*	1		1	1	1
55	*Acropora tenuis*	1	1	1	1	1
56	*Acropora valenciennesi*				1	
57	*Acropora valida*	1	1		1	1
58	*Acropora vaughani*	1	1	1		1
59	*Acropora verweyi*	1	1	1	1	1
60	*Alveopora catalai*					1
61	*Alveopora fenestrata*					1
62	*Alveopora marionensis*					1
63	*Alveopora spongiosa*					1
64	*Alveopora verrilliana*					1
65	*Astrea curta*	1	1	1	1	
66	*Astreopora cucullata*					1
67	*Astreopora gracilis*		1	1	1	1
68	*Astreopora listeri*			1		1
69	*Astreopora macrostoma*			1		
70	*Astreopora moretonensis*					1
71	*Astreopora myriophthalma*	1	1	1	1	1
72	*Caulastrea furcata*			1	1	
73	*Coelastrea palauensis*			1		
74	*Coeloseris mayeri*	1	1	1	1	
75	*Coscinaraea columna*	1	1	1	1	
76	*Coscinaraea exesa*		1	1	1	
77	*Cycloseris wellsi*	1				
78	*Cyphastrea chalcidium*			1		
79	*Cyphastrea japonica*	1	1		1	
80	*Cyphastrea microphthalma*			1		
81	*Cyphastrea serailia*	1	1	1	1	
82	*Danafungia horrida*	1	1		1	
83	*Diploastrea heliopora*			1		
84	*Dipsastraea danae*		1			
85	*Dipsastraea favus*	1	1		1	
86	*Dipsastraea laddi*			1		
87	*Dipsastraea laxa*	1	1	1		
88	*Dipsastraea lizardensis*				1	
89	*Dipsastraea matthaii*		1	1	1	
90	*Dipsastraea maxima*				1	
91	*Dipsastraea pallida*			1		
92	*Dipsastraea rotumana*			1		
93	*Dipsastraea speciosa*	1		1	1	
94	*Dipsastraea truncata*		1			
95	*Dipsastraea veroni*			1		
96	*Duncanopsammia peltata*		1	1	1	
97	*Echinophyllia aspera*	1	1	1	1	
98	*Echinopora gemmacea*			1		
99	*Echinopora horrida*			1	1	
100	*Echinopora lamellosa*	1	1	1	1	
101	*Echinopora mammiformis*			1		
102	*Euphyllia cristata*		1		1	
103	*Euphyllia glabrescens*			1		
104	*Favites abdita*	1	1	1	1	
105	*Favites chinensis*	1		1		

106	*Favites complanata*	1		1		
107	*Favites flexuosa*		1	1		
108	*Favites halicora*	1	1	1	1	
109	*Favites magnistellata*			1		
110	*Favites rotundata*			1		
111	*Favites valenciennesi*	1	1	1	1	
112	*Galaxea fascicularis*	1	1	1	1	
113	*Galaxea horrescens*		1		1	
114	*Gardineroseris planulata*	1	1	1	1	
115	*Goniastrea edwardsi*			1		
116	*Goniastrea favulus*			1		
117	*Goniastrea pectinata*	1	1	1	1	
118	*Goniastrea retiformis*	1	1	1		
119	*Goniastrea stelligera*	1	1	1	1	
120	*Goniopora djiboutiensis*		1		1	1
121	*Goniopora lobata*			1		
122	*Goniopora minor*		1		1	1
123	*Goniopora norfolkensis*					1
124	*Goniopora somaliensis*	1				1
125	*Goniopora tenuidens*	1		1		1
126	*Halomitra pileus*			1		
127	*Herpolitha limax*	1		1	1	
128	*Hydnophora exesa*	1	1	1	1	
129	*Hydnophora microconos*	1		1		
130	*Hydnophora pilosa*		1			
131	*Isopora brueggemanni*					1
132	*Isopora crateriformis*			1		
133	*Isopora cuneata*		1			
134	*Isopora palifera*	1	1	1	1	
135	*Leptastrea inaequalis*	1	1	1	1	
136	*Leptastrea purpurea*	1	1	1	1	
137	*Leptoria phrygia*	1	1	1	1	
138	*Leptoseris explanata*			1		
139	*Leptoseris mycetoceroides*	1	1			
140	*Lithophyllon concinna*	1				
141	*Lithophyllon repanda*			1		
142	*Lobactis scutaria*	1	1		1	
143	*Lobophyllia corymbosa*			1		
144	*Lobophyllia hemprichii*	1	1	1	1	
145	*Lobophyllia recta*	1	1	1	1	
146	*Lobophyllia robusta*			1		
147	*Lobophyllia valenciennesii*			1		
148	*Merulina ampliata*				1	
149	*Micromussa lordhowensis*	1	1			
150	*Micromussa regularis*			1		
151	*Montipora aequituberculata*					1
152	*Montipora angulata*					1
153	*Montipora australiensis*					1
154	*Montipora caliculata*		1			1
155	*Montipora crassituberculata*			1		1
156	*Montipora efflorescens*					1
157	*Montipora floweri*					1
158	*Montipora foliosa*	1		1		1
159	*Montipora foveolata*	1	1	1	1	1
160	*Montipora grisea*	1		1	1	1
161	*Montipora hispida*					1
162	*Montipora hoffmeisteri*					1
163	*Montipora incrassata*		1	1	1	1
164	*Montipora informis*	1				1
165	*Montipora mollis*					1
166	*Montipora nodosa*					1

167	*Montipora peltiformis*					1
168	*Montipora tuberculosa*	1		1		1
169	*Montipora turgescens*			1		1
170	*Montipora venosa*		1			
171	*Montipora verrucosa*	1		1	1	1
172	*Moseleya latistellata*			1		
173	*Mycedium elephantotus*				1	
174	*Oulophyllia bennettae*	1		1	1	
175	*Oulophyllia crispa*	1		1		
176	*Pachyseris speciosa*				1	
177	*Paragoniastrea australensis*			1		
178	*Paramontastraea salebrosa*			1		
179	*Pavona duerdeni*	1		1	1	
180	*Pavona explanulata*	1		1	1	
181	*Pavona maldivensis*	1		1	1	
182	*Pavona varians*	1	1	1	1	
183	*Pavona venosa*	1		1		
184	*Physogyra lichtensteini*				1	
185	*Platygyra daedalea*	1	1		1	
186	*Platygyra lamellina*	1	1	1	1	
187	*Platygyra pini*	1	1	1	1	
188	*Platygyra ryukyuensis*			1		
189	*Platygyra sinensis*	1	1	1	1	
190	*Plerogyra sinuosa*			1		
191	*Pleuractis paumotensis*			1		
192	*Pocillopora damicornis*		1	1	1	1
193	*Pocillopora eydouxi*	1	1	1	1	
194	*Pocillopora indiania*			1		
195	*Pocillopora ligulata*			1		
196	*Pocillopora meandrina*			1		
197	*Pocillopora verrucosa*	1	1	1	1	
198	*Polyphyllia talpina*				1	
199	*Porites australiensis*			1		1
200	*Porites cylindrica*	1	1	1	1	1
201	*Porites densa*		1			1
202	*Porites horizontalata*			1		
203	*Porites lichen*	1	1	1	1	1
204	*Porites lobata*		1	1	1	1
205	*Porites lutea*		1	1	1	1
206	*Porites murrayensis*	1				
207	*Porites nigrescens*	1		1		1
208	*Porites solida*					1
209	*Porites vaughani*	1				1
210	*Psammocora contigua*	1				
211	*Psammocora digitata*			1		
212	*Psammocora nierstraszi*			1		
213	*Psammocora superficialis*	1				
214	*Sandalolitha robusta*	1				
215	*Scapophyllia cylindrica*	1	1		1	
216	*Seriatopora caliendrum*		1	1	1	
217	*Seriatopora hystrix*		1		1	
218	*Siderastrea savignyana*			1		
219	*Stylocoeniella armata*			1		
220	*Stylocoeniella guentheri*			1		
221	*Stylophora pistillata*	1	1	1	1	
222	*Stylophora subseriata*			1		
223	*Turbinaria frondens*		1		1	
224	*Turbinaria heronensis*				1	
225	*Turbinaria mesenterina*	1	1	1		
226	*Turbinaria reniformis*	1				
227	*Turbinaria stellulata*	1			1	

11 APPENDIX 5.

List of scleractinian (hard) coral species recorded during the current 3-year project plus a voyage to the central CSMP in 2016. Uncertainties in species identifications are indicated with the use of a series of open nomenclature qualifiers that allow the assignment of specimens to a nominal species with varying degrees of certainty. Specimens that closely resemble the type of a nominal species are given the qualifier '*cf*.' Specimens that have morphological affinities to a nominal species are given the qualifier '*aff*.' Specimens with the qualifier *aff.* are either geographical variants of species with high morphological plasticity or undescribed species. Species that could not be matched with the type material of any nominal species were labelled as 'sp.' These specimens are almost certainly undescribed species.

Count	Species	South	Central	North
1	*Acanthastrea echinata*	1	1	1
2	*Acropora aff abrotanoides*	1		
3	*Acropora aff hyacinthus*	1		
4	*Acropora aff nasuta*	1		
5	*Acropora aff paniculata*	1		
6	*Acropora anthocercis*	1		1
7	*Acropora cf abrotanoides*	1	1	1
8	*Acropora cf aculeus*	1	1	
9	*Acropora cf acuminata*	1		1
10	*Acropora cf austera*	1	1	
11	*Acropora cf batuni*	1		
12	*Acropora cf caroliniana*			1
13	*Acropora cf cerealis*	1	1	
14	*Acropora cf clathrata*	1	1	1
15	*Acropora cf cytherea*	1	1	1
16	*Acropora cf desalwi*	1		
17	*Acropora cf digitifera*	1		
18	*Acropora cf divaricata*	1		
19	*Acropora cf donei*	1		
20	*Acropora cf granulosa*	1	1	1
21	*Acropora cf humilis*	1	1	1
22	*Acropora cf hyacinthus*	1	1	1
23	*Acropora cf intermedia*	1		
24	*Acropora cf kimbeensis*		1	
25	*Acropora cf laxa*	1		
26	*Acropora cf listeri*	1	1	1
27	*Acropora cf longicyathus*	1		
28	*Acropora cf lutkeni*	1		1
29	*Acropora cf microclados*	1		1
30	*Acropora cf microphthalma*	1		
31	*Acropora cf monticulosa*	1		1
32	*Acropora cf muricata*	1		1
33	*Acropora cf nana*	1	1	1
34	*Acropora cf nasuta*	1	1	1
35	*Acropora cf palmerae*			1
36	*Acropora cf paniculata*	1	1	1
37	*Acropora cf pectinata*	1		
38	*Acropora cf pectinatus*	1		
39	*Acropora cf plana*	1		
40	*Acropora cf robusta*	1		1
41	*Acropora cf samoensis*	1		
42	*Acropora cf secale*	1	1	1

43	*Acropora cf selago*	1	1	
44	*Acropora cf spathulata*	1		1
45	*Acropora cf speciosa*	1	1	
46	*Acropora cf subulata*	1		
47	*Acropora cf surculosa*	1		
48	*Acropora cf valida*	1		
49	*Acropora cf willisae*	1	1	1
50	*Acropora cf yongei*	1		1
51	*Acropora chesterfieldensis*	1	1	1
52	*Acropora gemmifera*	1		1
53	*Acropora grandis*	1		1
54	*Acropora kenti*	1	1	1
55	*Acropora latistella*	1	1	
56	*Acropora loripes*	1	1	1
57	*Acropora sarmentosa*	1		1
58	*Acropora solitaryensis*	1		1
59	*Acropora verweyi*	1	1	1
60	*Acroporacf florida*	1	1	1
61	*Alveopora cf spongiosa*	1		
62	*Alveopora cf verrilliana*	1		
63	*Aphrastrea pentagona*	1		1
64	*Astrea annuligera*	1	1	1
65	*Astrea curta*	1		1
66	*Astreopora cf gracilis*	1		1
67	*Astreopora cf incrustans*			1
68	*Astreopora cf listeri*	1		1
69	*Astreopora cf macrostoma*		1	
70	*Astreopora cf moretonensis*	1		1
71	*Astreopora cf myriophthalma*	1	1	1
72	*Astreopora cf ocellata*	1		
73	*Astreopora cf scabra*	1	1	1
74	*Bernardpora stutchburyi*	1	1	
75	*Blastomussa wellsi*	1		
76	*Caulastrea furcata*	1		1
77	*Coeloseris mayeri*			1
78	*Coscinaraea aff columna*	1		
79	*Coscinaraea cf columna*	1	1	
80	*Coscinaraea cf exesa*	1	1	
81	*Ctenactis echinata*	1	1	1
82	*Cycloseris costulata*	1		
83	*Cycloseris cyclolithes*	1		
84	*Cycloseris explanulata*	1		
85	*Cycloseris vaughani*	1		
86	*Cycloseris wellsi*	1		1
87	*Cyphastrea aff decadia*	1		
88	*Cyphastrea chalcidicum*	1	1	1
89	*Cyphastrea japonica*	1	1	
90	*Cyphastrea microphthalma*	1	1	1
91	*Cyphastrea ocellina*		1	
92	*Cyphastrea serailia*		1	1
93	*Danafungia horrida*	1		1
94	*Danafungia scruposa*	1		
95	*Diploastrea heliopora*		1	1
96	*Dipsastraea danae*	1		
97	*Dipsastraea helianthoides*	1	1	
98	*Dipsastraea laxa*			1
99	*Dipsastraea lizardensis*			1
100	*Dipsastraea pallida*	1		1
101	*Dipsastraea rotumana*	1	1	1
102	*Dipsastraea truncata*	1		1
103	*Dipsastrea laddi*	1		

104	*Dipsastrea matthai*	1		1
105	*Duncanopsammia peltata*	1	1	
106	*Echinophyllia aspera*	1		1
107	*Echinophyllia orpheensis*			1
108	*Echinopora hirsutissima*	1	1	
109	*Echinopora horrida*	1	1	1
110	*Echinopora lamellosa*	1	1	1
111	*Echinopora mammiformis*	1		
112	*Euphyllia cristata*	1		1
113	*Euphyllia divisa*	1		
114	*Euphyllia glabrescens*	1	1	
115	*Favites abdita*	1		1
116	*Favites bestae*	1	1	
117	*Favites complanata*	1		
118	*Favites flexuosa*	1		1
119	*Favites magnistellata*	1	1	1
120	*Favites proneri*	1	1	
121	*Favites rotundata*	1	1	1
122	*Favites valenciennesi*	1	1	1
123	*Fungia fungites*	1	1	1
124	*Galaxea astreata*	1		
125	*Galaxea fascicularis*	1	1	1
126	*Galaxea horrescens*	1	1	
127	*Gardineroseris planulata*	1	1	1
128	*Goniastrea edwardsi*	1	1	1
129	*Goniastrea favulus*			1
130	*Goniastrea pectinata*	1	1	1
131	*Goniastrea retiformis*	1		1
132	*Goniastrea stelligera*	1		1
133	*Goniopora columna*	1		1
134	*Goniopora tenuidens*		1	1
135	*Halomitra pileus*			1
136	*Heliofungia actiniformis*	1		1
137	*Herpolitha limax*	1	1	
138	*Homophyllia australis*	1		
139	*Hydnophora exesa*	1		
140	*Hydnophora grandis*			1
141	*Hydnophora microconos*	1	1	1
142	*Hydnophora rigida*			1
143	*Isopora cuneata*	1	1	
144	*Isopora elizabethensis*	1		
145	*Isopora palifera*	1	1	1
146	*Leptastrea agassizi*	1		1
147	*Leptastrea gibbosa*	1	1	1
148	*Leptastrea purpurea*	1	1	1
149	*Leptastrea transversa*	1	1	1
150	*Leptoria phrygia*	1		1
151	*Leptoseris aff glabra*	1		
152	*Leptoseris aff mycetoceriodes*	1		
153	*Leptoseris glabra*	1		
154	*Leptoseris incrustans*	1	1	1
155	*Leptoseris mycetoceriodes*	1	1	1
156	*Leptoseris scabra*	1		1
157	*Leptoseris yabei*	1		1
158	*Lithophyllon repanda*	1	1	1
159	*Lobactis scutaria*	1		1
160	*Lobophyllia agaricia*			1
161	*Lobophyllia corymbosa*	1		
162	*Lobophyllia hataii*	1		
163	*Lobophyllia hemprichi*	1	1	1
164	*Lobophyllia radians*	1		1

165	*Lobophyllia recta*	1		1
166	*Lobophyllia robusta*	1		
167	*Lobophyllia valenciennesi*			1
168	*Lobophyllia vitiensis*	1		1
169	*Merulina ampliata*	1	1	
170	*Merulina scabricula*			1
171	*Micromussa pacifica*	1		
172	*Montipora aff spongodes*	1		
173	*Montipora australiensis*	1		
174	*Montipora cf calcarea*	1	1	1
175	*Montipora cf caliculata*	1	1	1
176	*Montipora cf crassituberculata*	1		1
177	*Montipora cf danae*	1	1	1
178	*Montipora cf efflorescens*	1	1	1
179	*Montipora cf effusa*	1	1	
180	*Montipora cf foveolata*	1	1	1
181	*Montipora cf grisea*			1
182	*Montipora cf hispida*	1		1
183	*Montipora cf informis*	1	1	1
184	*Montipora cf monasteriata*	1	1	
185	*Montipora cf nodosa*	1	1	1
186	*Montipora cf peltiformis*	1	1	1
187	*Montipora cf spongodes*	1		
188	*Montipora cf sulcata*	1		1
189	*Montipora cf tuberculosa*	1	1	1
190	*Montipora cf undata*	1		1
191	*Montipora cf verrucosa*	1	1	1
192	*Mycedium elephantotus*	1	1	1
193	*Mycedium robokai*	1		
194	*Oulophyllia bennettae*	1		1
195	*Oulophyllia crispa*	1	1	1
196	*Oxypora lacera*	1		1
197	*Pachyseris rugosa*	1		
198	*Pachyseris speciosa*	1	1	1
199	*Paragoniastrea australensis*	1	1	
200	*Paragoniastrea cf stylifera*	1	1	
201	*Paragoniastrea russelli*	1		
202	*Pavona aff varians*	1		
203	*Pavona bipartita*	1		1
204	*Pavona duerdeni*	1		1
205	*Pavona explanulata*	1	1	1
206	*Pavona felix*	1		
207	*Pavona maldivensis*	1	1	1
208	*Pavona minuta*	1		
209	*Pavona varians*	1	1	1
210	*Pavona venosa*	1		1
211	*Pectinia paeonia*			1
212	*Physogyra lichtensteini*		1	1
213	*Platygyra contorta*			1
214	*Platygyra daedalea*	1	1	1
215	*Platygyra lamellina*	1		1
216	*Platygyra pini*	1	1	1
217	*Platygyra sinensis*	1	1	1
218	*Platygyra verweyi*			1
219	*Platygyra yaeyamaensis*	1	1	1
220	*Plerogyra sinuosa*	1		1
221	*Pleuractis granulosa*	1		
222	*Pleuractis paumotensis*	1		1
223	*Pocillopora acuta*	1		
224	*Pocillopora bairdi*	1	1	1
225	*Pocillopora damicornis*	1	1	1

226	*Pocillopora eydouxi*	1		
227	*Pocillopora meandrina*	1		
228	*Pocillopora verrucosa*	1	1	1
229	*Pocillopora woodjonesi*			1
230	*Podabacia crustacea*			1
231	*Podabacia motuporensis*	1		
232	*Polyphyllia talpina*	1		
233	*Porites aff lichen*	1		
234	*Porites cf vaughani*			1
235	*Porites cylindrica*	1		1
236	*Porites flavus*	1	1	
237	*Porites lichen*	1	1	1
238	*Porites lobata*	1		1
239	*Porites lutea*	1	1	
240	*Porites myrmidonensis*	1	1	1
241	*Porites rus*	1		1
242	*Psammocora digitata*	1	1	1
243	*Psammocora haimiana*	1		
244	*Psammocora nierstraszi*		1	1
245	*Psammocora profundacella*	1		
246	*Rhizopsammia verrilli*	1		1
247	*Sandolithia dentata*	1		1
248	*Sandolithia robusta*	1		1
249	*Scapophyllia cylindrica*	1	1	1
250	*Seriatopora caliendrum*	1		
251	*Seriatopora hystrix*	1	1	1
252	*Seriatopora stellata*			1
253	*Stylocoeniella armata*	1		1
254	*Stylocoeniella guentheri*	1	1	
255	*Stylophora pistillata*	1		1
256	*Turbinaria cf frondens*	1		
257	*Turbinaria mesenterina*	1	1	1
258	*Turbinaria reniformis*	1		
259	*Turbinaria stellulata*	1		1
		229	**108**	**161**

12 APPENDIX 6.

List on conspicuous (i.e., non-cryptic) fish species recorded and/or observed within each region of the CSMP during 2018-2020. A separate list is provided for cryptobenthic fish species that were identified during targeted collections using clove oil

Count	Species	Southern	Central	Northern	Cryptobenthic
1	*Abudefduf sexfasciatus*	1		1	
2	*Abudefduf vaigiensis*	1	1	1	
3	*Acanthochromis polyacanthus*		1	1	1
4	*Acanthurus albipectoralis*	1	1	1	
5	*Acanthurus blochii*	1	1	1	
6	*Acanthurus dussumieri*	1	1	1	
7	*Acanthurus grammoptilus*		1		
8	*Acanthurus guttatus*	1	1	1	
9	*Acanthurus lineatus*	1	1	1	
10	*Acanthurus mata*		1	1	
11	*Acanthurus nigricans*	1	1	1	
12	*Acanthurus nigricauda*	1	1	1	
13	*Acanthurus nigrofuscus*	1	1	1	1
14	*Acanthurus nigroris*	1	1	1	
15	*Acanthurus nubilis*		1		
16	*Acanthurus olivaceus*	1	1	1	
17	*Acanthurus pyroferus*	1	1	1	
18	*Acanthurus thompsoni*	1	1	1	
19	*Acanthurus triostegus*	1	1	1	
20	*Acanthurus xanthopterus*	1	1	1	
21	*Aethaloperca rogaa*			1	
22	*Aetobatus narinari*		1		
23	*Aetobatus ocellatus*	1			
24	*Aluteres scriptus*	1	1	1	
25	*Amanses scopas*	1		1	
26	*Amblycirrhitus bimacula*				1
27	*Amblyeleotris steinitzi*		1	1	
28	*Amblyglyphidodon aureus*	1	1	1	
29	*Amblyglyphidodon curacao*	1	1		
30	*Amblyglyphidodon leucogaster*	1	1	1	
31	*Amphiprion akindynos*	1	1		
32	*Amphiprion chrysopterus*		1	1	
33	*Amphiprion clarkii*	1		1	
34	*Amphiprion melanopus*	1	1	1	
35	*Amphiprion perideraion*		1	1	
36	*Anampses caeruleopunctatus*	1	1	1	
37	*Anampses femininus*	1	1		
38	*Anampses meleagrides*	1			
39	*Anampses neoguinaicus*	1	1	1	
40	*Anampses twistii*	1	1	1	
41	*Antennarius nummifer*				1
42	*Antennarius pictus*				1
43	*Anyperodon leucogrammicus*			1	
44	*Aphareus furca*	1	1	1	
45	*Apogon crassiceps*				1
46	*Apogon doederleini*			1	
47	*Apogon doryssa*				1
48	*Apogon seminigricaudus*				1
49	*apogonid sp.*				1
50	*Apolemichthys trimaculatus*			1	
51	*Aprion virescens*	1	1	1	

52	*Arothron hispidus*	1			
53	*Arothron nigropunctatus*	1	1	1	
54	*Arothron stellatus*	1	1		
55	*Aseraggodes sp.*				1
56	*Assessor flavissimus*			1	
57	*Asterropteryx semipunctata*				1
58	*Aulostomus chinensis*	1	1	1	
59	*Balenoperca chabanaudi*		1	1	
60	*Balistapus undulatus*	1	1	1	
61	*Balistoides conspicillum*	1	1	1	
62	*Balistoides viridescens*	1	1	1	
63	*Bodianus anthioides*		1		
64	*Bodianus axillaris*	1	1	1	
65	*Bodianus dictynna*		1	4	
66	*Bodianus loxozonus*		1	1	
67	*Bodianus mesothorax*	1	1	1	
68	*Bodianus perditio*	1			
69	*Bolbometopon muricatum*		1	1	
70	*Brachaluteres prionurus*		1		
71	*Brosmophyciops pautzkei*				1
72	*Bryaninops sp.*				1
73	*bythitid sp.*				1
74	*Cabillus tongarevae*				1
75	*Caesio cuning*		1		
76	*Caesio lunaris*		1	1	
77	*Caesio teres*		1	1	
78	*Callogobius sclateri*				1
79	*Calotomus carolinus*	1	1	1	
80	*Cantherhines dumerilii*	1	1		
81	*Canthigaster amboinensis*	1	1		
82	*Canthigaster axiologus*	1			
83	*Canthigaster bennetti*	1	1		
84	*Canthigaster papua*		1		1
85	*Canthigaster valentini*	1	1	1	1
86	*Caracanthus maculatus*	1	1	1	1
87	*Caracanthus unipinna*				1
88	*Carangoides ferdau*		1	1	
89	*Carangoides orthogrammus*	1	1	1	
90	*Carangoides plagiotaenia*			1	
91	*Caranx ignobilis*	1	1	1	
92	*Caranx lugubris*		1	1	
93	*Caranx melampygus*	1	1	1	
94	*Caranx sexfasciatus*	1	1	1	
95	*Caranx sp.*			1	
96	*Carcharhinus albimarginatus*	1	1	1	
97	*Carcharhinus amblyrhynchos*	1	1	1	
98	*Celotomus carolinus*	1			
99	*Centropyge bicolor*	1	1	1	
100	*Centropyge bispinosa*	1	1	1	1
101	*Centropyge fisheri*		1		
102	*Centropyge flavissima*	1	1	1	
103	*Centropyge heraldi*	1	1	1	1
104	*Centropyge hybrid 'smokey'*	1	1		1
105	*Centropyge loricula*	1	1	1	
106	*Centropyge tibicen*	1			1
107	*Centropyge vrolikii*	1	1	1	
108	*Centropyge woodheadi*	1			
109	*Cephalopholis argus*	1	1	1	
110	*Cephalopholis leopardus*		1	1	1
111	*Cephalopholis miniata*		1	1	
112	*Cephalopholis spiloparaea*		3		

113	*Cephalopholis urodeta*	1	1	1	1
114	*Cercamia eremia*				1
115	*Cetoscarus ocellatus*	1	1	1	1
116	*Chaetodon auriga*	1	1	1	
117	*Chaetodon baronessa*			1	
118	*Chaetodon bennetti*	1		1	
119	*Chaetodon citrinellus*	1	1	1	
120	*Chaetodon ephippium*	1	1	1	
121	*Chaetodon flavirostris*	1	1	1	
122	*Chaetodon kleinii*	1	1	1	
123	*Chaetodon lineolatus*	1	1	1	
124	*Chaetodon lunula*	1	1	1	
125	*Chaetodon lunulatus*	1	1	1	
126	*Chaetodon melannotus*	1	1	1	
127	*Chaetodon mertensii*	1	1	1	
128	*Chaetodon meyeri*		3	1	
129	*Chaetodon ocellicaudus*	1			
130	*Chaetodon ornatissimus*	1	1	1	
131	*Chaetodon oxycephalus*			1	
132	*Chaetodon pelewensis*	1	1	1	
133	*Chaetodon plebeius*	1	1	1	
134	*Chaetodon punctatofasciatus*			1	
135	*Chaetodon rafflesi*		1		
136	*Chaetodon reticulatus*	1	1	1	
137	*Chaetodon semeion*		1	1	
138	*Chaetodon speculum*	1	1	1	
139	*Chaetodon trifascialis*	1	1	1	
140	*Chaetodon ulietensis*	1	1	1	
141	*Chaetodon unimaculatus*	1	1	1	
142	*Chaetodon vagabundus*	1	1	1	
143	*Chanos chanos*			1	
144	*Cheilinus chlorourus*	1	1	1	
145	*Cheilinus fasciatus*		1	1	
146	*Cheilinus oxycephalus*	1	1	1	
147	*Cheilinus trilobatus*	1	1	1	
148	*Cheilinus undulatus*	1	1	1	
149	*Cheilodipterus macrodon*		1		
150	*Chlorurus bleekeri*			1	
151	*Chlorurus frontalis*	1	1		
152	*Chlorurus japanensis*	1		1	
153	*Chlorurus microrhinos*	1	1	1	
154	*Chlorurus spilurus*	1	1	1	
155	*Choerodon fasciatus*		1		
156	*Chromis agilis*	1	1	1	
157	*Chromis alpha*		1		
158	*Chromis amboinensis*	1	1	1	
159	*Chromis atripectoralis*	1	1	1	
160	*Chromis atripes*	1	1	1	
161	*Chromis chrysura*	1	1	1	
162	*Chromis flavomaculata*	1			
163	*Chromis iomelas*	1	1	1	1
164	*Chromis lepidolepis*	1	1	1	
165	*Chromis margaritifer*	1	1	1	1
166	*Chromis retrofasciata*	1	1	1	
167	*Chromis ternatensis*	1	1	1	
168	*Chromis vanderbilti*	1	1	1	1
169	*Chromis viridis*	1	1		
170	*Chromis weberi*		1	1	
171	*Chromis xanthochira*	1	1		
172	*Chromis xanthura*	1	1	1	
173	*Chrysiptera biocellata*	1	1	1	

174	*Chrysiptera brownriggii*		1	1	
175	*Chrysiptera flavipinnis*		1		
176	*Chrysiptera glauca*	1			
177	*Chrysiptera rollandi*		1		1
178	*Chrysiptera talboti*			1	
179	*Chrysiptera taupou*	1	1	1	1
180	*Cirrhilabrus exquisitus*	1	1	1	
181	*Cirrhilabrus laboutei*	1	1		1
182	*Cirrhilabrus lineatus*		1		
183	*Cirrhilabrus punctatus*	1	1	1	1
184	*Cirrhilabrus scottorum*	1	1	1	
185	*Cirrhitichthys falco*	1	1		1
186	*Cirrhitus pinnulatus*	1			
187	*Cirripectes castaneus*		1	1	1
188	*Cirripectes filamentosus*				1
189	*Cirripectes stigmaticus*	1	1		1
190	*Coris aygula*	1	1	1	
191	*Coris batuensis*			1	1
192	*Coris dorsomacula*	1	1		
193	*Coris gaimard*	1	1	1	
194	*Cosmocampus banneri*				1
195	*Crossosalarias macrospilus*				1
196	*Ctenochaetus binotatus*	1	1	1	
197	*Ctenochaetus cyanocheilus*	1	1	1	
198	*Ctenochaetus striatus*	1	1	1	
199	*Ctenogobiops pomastictus*				1
200	*Cypho purpurascens*	1	1	1	1
201	*Dascyllus aruanus*	1			
202	*Dascyllus reticulatus*	1	1	1	1
203	*Dascyllus trimaculatus*	1	1	1	
204	*Dasyatis kuhlii*		1		
205	*Decapterus macarellus*		1		
206	*Dinematichthys ilucoetiodes*				1
207	*Dinematichthys sp.?*				1
208	*Diodon hystrix*		1		
209	*Diplogrammus goramensis*				1
210	*Dischistodus melanotus*	1			
211	*Dischistodus pseudochrysopoecilus*	1			
212	*Doryrhamphus melanopleura*				1
213	*Doryrhamphus sp.**				1
214	*Echeneis naucrates*	1	1	1	
215	*Echidna polyzona*				1
216	*Ecsenius bicolor*			1	
217	*Ecsenius fourmanoiri*	1			
218	*Ecsenius stictus*				1
219	*Ecsenius tigris*				1
220	*Elegatis bipinnulata*		1	1	
221	*Encheliophis homei?*				1
222	*Enneapterygius atrogulare?*				1
223	*Enneapterygius flavoccipitis*				1
224	*Enneapterygius sp.*				1
225	*Enneapterygius sp. 1*				1
226	*Enneapterygius sp. 1*				1
227	*Enneapterygius tutuilae*				1
228	*Epibulus insidiator*	1	1	1	
229	*Epinephelus coioides*		1		
230	*Epinephelus cyanopodus*	1			
231	*Epinephelus fasciatus*	1		1	
232	*Epinephelus fuscoguttatus*			1	
233	*Epinephelus hexagonatus*	1	1	1	
234	*Epinephelus howlandensis*	1			

235	*Epinephelus lanceolatus*		1		
236	*Epinephelus merra*	1	1	1	
237	*Epinephelus polyphekadion*	1	1	1	
238	*Epinephelus quoyanus*		1		
239	*Epinephelus tauvina*		1		
240	*Epinephelus tukula*			1	
241	*Euthynnus affinis*	1			
242	*Eviota afelei*				1
243	*Eviota ancora**				1
244	*Eviota atriventris*				1
245	*Eviota cf. teresae**				1
246	*Eviota cometa*				1
247	*Eviota distigma*				1
248	*Eviota fallax**				1
249	*Eviota fasciola*				1
250	*Eviota flebilis**				1
251	*Eviota guttata*		1		
252	*Eviota herrei*				1
253	*Eviota infulata*				1
254	*Eviota latifasciata*				1
255	*Eviota melanosphena*				1
256	*Eviota melasma*				1
257	*Eviota monostigma*				1
258	*Eviota nebulosa*				1
259	*Eviota occasa**				1
260	*Eviota prasites*	1			1
261	*Eviota punctulata*				1
262	*Eviota queenslandica*				1
263	*Eviota readeri**				1
264	*Eviota sigillata*				1
265	*Eviota singula**				1
266	*Eviota sp.*				1
267	*Eviota sp. 1**				1
268	*Eviota sp. 1**				1
269	*Eviota sp. 1a**				1
270	*Eviota sp. 3**				1
271	*Eviota sp. 4**				1
272	*Eviota sp. 5**				1
273	*Eviota sparsa*				1
274	*Eviota specca**				1
275	*Eviota variola*				1
276	*Eviota zebrina*				1
277	*Exallias brevis*	1	1		
278	*Fistularia commersonii*	1	1	1	
279	*Forcipiger flavissimus*	1	1	1	
280	*Forcipiger longirostris*	1	1	1	
281	*Fowleria aurita*				1
282	*Fowleria vaiulae*				1
283	*Fusigobius gracilis*				1
284	*Fusigobius humeralis*				1
285	*Fusigobius neophytus*				1
286	*Fusigobius sp.*				1
287	*Galeocerdo cuvier*	1			
288	*Genicanthus melanospilos*		1	1	
289	*Genicanthus watanabei*		1		
290	*Glyptoparus delicatulus*				1
291	*Gnathanodon speciosus*	1			
292	*Gnathodentex aureolineatus*	1	1	1	
293	*Gnatholepis cauerensis*		1		1
294	*Gnatholepis sp.*				1
295	*gobiid sp.*				1

296	*Gobiodon prolixus*				1
297	*Gobiodon quinquestrigatus*				1
298	*Gobiodon rivulatus*				1
299	*Gomphosus varius*	1	1	1	
300	*Gracila albomarginata*			1	
301	*Grammistes sexlineatus*		1	1	
302	*Gymnapogon philippinus*				1
303	*Gymnapogon sp.*				1
304	*Gymnocranius euanus*	1	1		
305	*Gymnocranius grandoculis*			1	
306	*Gymnocranius microdon*	1	1		
307	*Gymnosarda unicolor*	1	1	1	
308	*Gymnothorax favagineus*		1		
309	*Gymnothorax flavimarginatus*				1
310	*Gymnothorax fuscomaculatus*				1
311	*Gymnothorax gracilicauda*				1
312	*Gymnothorax javanicus*	1	1	1	
313	*Gymnothorax meleagris*	1			
314	*Gymnothorax sp.*				1
315	*Gymnothorax zonipectis*				1
316	*Halicampus dunckeri*				1
317	*Halichoeres biocellatus*	1	1	1	1
318	*Halichoeres chrysus*			1	
319	*Halichoeres hortulanus*	1	1	1	
320	*Halichoeres margaritaceus*	1	1	1	
321	*Halichoeres marginatus*	1	1	1	
322	*Halichoeres melanurus*				1
323	*Halichoeres melanurus*			1	
324	*Halichoeres nebulosus*	1			
325	*Halichoeres ornatissimus*	1	1	1	
326	*Halichoeres prosopeion*		1	1	
327	*Halichoeres trimaculatus*	1	1	1	1
328	*Helcogramma sp.*				1
329	*Helcogramma striatum*				1
330	*Hemigymnus fasciatus*	1	1	1	
331	*Hemitaurichthys polylepis*	1	1	1	
332	*Heniochus acuminatus*		1	1	
333	*Heniochus chrysostomus*	1	1	1	
334	*Heniochus monoceros*	1	1	1	
335	*Heniochus varius*	1	1	1	
336	*Heteropriacanthus carolinus*				1
337	*Heteropriacanthus cruentatus*			1	
338	*Himantura fai*		1		
339	*Hipposcarus longiceps*	1	1	1	
340	*Hologymnosus annulatus*	1	1	1	
341	*Hologymnosus doliatus*	1	1		
342	*Hoplolatilus starcki*			1	
343	*Kaupichthys brachychirus*				1
344	*Kyphosus bigibbus*	1			
345	*Kyphosus cinerascens*	1	1	1	
346	*Kyphosus vaigiensis*	1	1	1	
347	*Labrichthys unilineatus*			1	1
348	*labrid sp.*				1
349	*Labroides bicolor*	1	1	1	
350	*Labroides dimidiatus*	1	1	1	1
351	*Labroides pectoralis*	1		1	
352	*Labropsis australis*	1	1	1	
353	*Labropsis xanthonota*		1	1	
354	*Lepadichthys frenatus*				1
355	*Lepadichthys sp.*				1
356	*Lepidozygus tapeinosoma*		1	1	

357	*Lethrinus erythracanthus*		1	1	
358	*Lethrinus nebulosus*	1	1	1	
359	*Lethrinus olivaceus*	1	1	1	
360	*Lethrinus sp. 1*		1		
361	*Lethrinus xanthocheilus*	1	1	1	
362	*Limnichthys fasciatus*				1
363	*Liopropoma susumi*	1			1
364	*Luposicya lupus*				1
365	*Lutjanus argentimaculatus*			1	
366	*Lutjanus bohar*	1	1	1	
367	*Lutjanus fulvus*		1	1	
368	*Lutjanus gibbus*	1	1	1	
369	*Lutjanus kasmira*	1	1	1	
370	*Lutjanus monostigma*		1	1	
371	*Lutjanus rivulatus*	1	1	1	
372	*Lutjanus semicinctus*			1	
373	*Luzonichthys sp*			1	
374	*Luzonichthys waitei*			1	
375	*Macolor macularis*	1	1	1	
376	*Macolor niger*	1	1	1	
377	*Macropharyngodon choati*		1		
378	*Macropharyngodon kuiteri*		1		
379	*Macropharyngodon meleagris*	1	1	1	
380	*Macropharyngodon negrosensis*	1	1		
381	*Macropharyngodon ornatus*		1		
382	*Malacanthus latovittatus*	1	1	1	
383	*Meiacanthus atrodorsalis*		1	1	1
384	*Melichthys vidua*	1	1	1	
385	*Monotaxis grandoculis*	1	1	1	
386	*Monotaxis heterodon*	1	1	1	
387	*Mulloidichthys flavolineatus*	1	1		
388	*Mulloidichthys vanicolensis*	1	1	1	
389	*Myripristis adusta*			1	
390	*Myripristis kuntee*	1	1	1	
391	*Myripristis murdjan*		1		
392	*Myripristis vittata*		1		
393	*Naso annulatus*	1	1	1	
394	*Naso brachycentron*		1	1	
395	*Naso brevirostris*	1	1	1	
396	*Naso caesius*	1	1	1	
397	*Naso hexacanthus*	1	1	1	
398	*Naso lituratus*	1	1	1	
399	*Naso tonganus*	1	1	1	
400	*Naso unicornis*	1	1	1	
401	*Naso vlamingii*	1	1	1	
402	*Neamia octospina*				1
403	*Nebrius ferrugineus*	1	1	1	
404	*Nemateleotris magnifica*	1		1	1
405	*Neocirrhites armatus*	1	1		1
406	*Neoniphon sammara*	1	1	1	
407	*Neopomacentrus cf cyanomos*		1		
408	*Neosynchiropus morrisoni*				1
409	*Neotrygon kuhlii*	1	1		
410	*Norfolkia thomasi*				1
411	*Novaculichthys taeniourus*	1	1		1
412	*Odonus niger*		1		
413	*Ogilbyina queenslandiae*				1
414	*Opistognathus seminudus*				1
415	*Opistognathus stigmosus*				1
416	*Ostorhinchus cyanosoma*				1
417	*Ostracion cubicus*	1	1		

418	*Ostracion meleagris*		1	1	
419	*Oxycheilinus digramma*	1	1	1	
420	*Oxycheilinus orientalis*	1	1	1	1
421	*Oxycheilinus unifasciatus*	1	1	1	
422	*Oxymonacanthus longirostris*	1	1	1	
423	*Paracaesio sordida*			1	
424	*Paracanthurus hepatus*	1	1	1	
425	*Paracentropyge multifasciatus*		1	1	
426	*Paracirrhites arcatus*				1
427	*Paracirrhites arcatus*	1	1	1	
428	*Paracirrhites forsteri*	1	1	1	
429	*Paracirrhites hemistictus*	1	1		
430	*Paragobiodon echinocephalus*				1
431	*Paragobiodon lacunicolus*				1
432	*Paragobiodon xanthosoma*				1
433	*Parapercis clathrata*				1
434	*Parupeneus barberinoides*		1		
435	*Parupeneus barberinus*	1	1	1	
436	*Parupeneus ciliatus*	1	1	1	
437	*Parupeneus crassilabris*	1	1	1	
438	*Parupeneus cyclostomus*	1	1	1	
439	*Parupeneus multifasciatus*	1	1	1	
440	*Parupeneus pleurostigma*	1	1	1	
441	*Pempheris oualensis*	1			
442	*Pervagor alternans*	1	1		
443	*Pervagor janthinosoma*	1			1
444	*Plagiotremus rhinorhynchos*		1	1	
445	*Plagiotremus tapeinosoma*		1	1	
446	*Platax pinnatus*		1		
447	*Platax teira*		1		
448	*platycephalid sp.*				1
449	*Plectorhinchus albovittatus*		1	1	
450	*Plectorhinchus chaetodonoides*	1	1	1	
451	*Plectorhinchus lessonii*		1	1	
452	*Plectorhinchus lineatus*		1	1	
453	*Plectorhinchus picus*	1	1		
454	*Plectranthias nanus*				1
455	*Plectroglyphidodon dickii*	1	1	1	
456	*Plectroglyphidodon imparipennis*	1	1	1	
457	*Plectroglyphidodon johnstonianus*	1	1	1	
458	*Plectroglyphidodon lacrymatus*	1	1	1	1
459	*Plectroglyphidodon leucozonus*			1	
460	*Plectroglyphidodon phoenixensis*	1	1		
461	*Plectropomus areolatus*		1	1	
462	*Plectropomus laevis*	1	1	1	
463	*Plectropomus leopardus*	1	1	1	
464	*Plectropomus oligacanthus*			1	
465	*Plectrypops lima*				1
466	*Plesiops caeruleolineatus*				1
467	*Pleurosicya mossambica*				1
468	*Plotosus lineatus*	1			1
469	*Pomacanthus imperator*	1	1	1	
470	*Pomacanthus sexstriatus*			1	
471	*Pomacentrus amboinensis*			1	1
472	*Pomacentrus auriventris*			1	
473	*Pomacentrus bankanensis*	1	1	1	
474	*Pomacentrus brachialis*	1		1	1
475	*Pomacentrus chrysurus*		1	1	
476	*Pomacentrus coelestis*	1	1	1	
477	*Pomacentrus imitator*	1	1	1	
478	*Pomacentrus lepidogenys*	1	1	1	

479	*Pomacentrus moluccensis*	1	1	1	
480	*Pomacentrus nagasakiensis*				1
481	*Pomacentrus pavo*			1	
482	*Pomacentrus philippinus*	1		1	1
483	*Pomacentrus vaiuli*	1	1	1	1
484	*Pomacentrus wardi*	1			
485	*Pomachromis richardsoni*	1	1	1	
486	*Priacanthus blochii*		1		
487	*Priacanthus hamrur*		1		
488	*Priolepis cincta*				1
489	*Priolepis compita*				1
490	*Priolepis inhaca*				1
491	*Priolepis kappa*				1
492	*Priolepis pallidicincta*				1
493	*Priolepis psygmophila*				1
494	*Priolepis sp.*				1
495	*Prionurus maculatus*	1			
496	*Pristiapogon exostigma*				1
497	*Prteragogus sp.*	1			
498	*Pseudanthias cooperi*		1		
499	*Pseudanthias pascalus*	1	1	1	
500	*Pseudanthias pleurotaenia*		1	1	
501	*Pseudanthias squamipinnis*	1	1	1	
502	*Pseudanthias tuka*	1	1	1	
503	*Pseudobalistes flavimarginatus*		1	1	
504	*Pseudobalistes fuscus*	1	1	1	
505	*Pseudocheilinus evanidus*	1	1	1	1
506	*Pseudocheilinus hexataenia*	1	1	1	1
507	*Pseudochromis sp.*				1
508	*Pseudochromis tapeinosoma*				1
509	*Pseudocoris yamashiroi*			1	
510	*Pseudodax moluccanus*	1	1	1	
511	*Pseudogramma polyacanthus*				1
512	*Pseudojuloides cerasinus*		1		
513	*Pseudoplesiops annae*				1
514	*Pseudoplesiops sp.*				1
515	*Pseudoplesiops wassi*				1
516	*Pteragogus cryptus*	1	1		1
517	*Pteragogus sp.*	1	1		
518	*Ptereleotris evides*	1	1	1	
519	*Ptereleotris zebra*		1	1	
520	*Pterocaesio digramma*	1	1		
521	*Pterocaesio marri*		1	1	
522	*Pterocaesio tile*	1	1	1	
523	*Pterocaesio trilineata*	1	1	1	
524	*Pterois volitans*	1		1	1
525	*Pygoplites diacanthus*	1	1	1	1
526	*Rhinecanthus aculeatus*			1	
527	*Rhinecanthus rectangulus*	1	1	1	
528	*Sargocentron caudimaculatum*		1		
529	*Sargocentron ittodai*				1
530	*Sargocentron spiniferum*	1	1	1	
531	*Saurida gracilis*	1			
532	*Scarini sp.*				1
533	*Scarus altipinnis*	1	1	1	
534	*Scarus chameleon*	1	1	1	
535	*Scarus dimidiatus*		1	1	
536	*Scarus forsteni*	1	1	1	
537	*Scarus frenatus*	1	3	1	
538	*Scarus globiceps*	1	1	1	
539	*Scarus longipinnis*	1	1	1	

540	*Scarus niger*	1	1	1	
541	*Scarus oviceps*	1	1	1	
542	*Scarus psittacus*	1	1	1	
543	*Scarus rubroviolaceus*	1	1	1	
544	*Scarus schlegeli*	1	1	1	
545	*Scarus spinus*	1	1	1	
546	*Scarus viridifucatus*			1	
547	*Scarus xanthopleura*	1	1	1	
548	*Scolopsis bilineata*	1		1	
549	*Scomberoides commersonianus*		1		
550	*Scomberoides lysan*		1	1	
551	*Scomberoides sp*			1	
552	*Scomberomorus commerson*			1	
553	*scorpaenid sp.*				1
554	*Scorpaenodes corallinus*				1
555	*Scorpaenodes guamensis*				1
556	*Scorpaenopsis macrochir*				1
557	*Scorpaenopsis sp.*				1
558	*Sebastapistes corallinus*				1
559	*Sebastapistes cyanostigma*				1
560	*Sebastapistes cyanostigma*			1	
561	*Serranocirrhites latus*	1	1	1	
562	*Siganus argenteus*	1	1	1	
563	*Siganus corallinus*	1	1		
564	*Siganus puellus*	1			
565	*Siganus punctatissimus*		1		
566	*Siganus punctatus*	1	1	1	
567	*Siganus stellatus*		1		
568	*Siganus vulpinus*	1	1	1	
569	*Siganus woodlandi*	1	1		
570	*Siphamia tubifer*				1
571	*Sphyraena barracuda*	1	1	1	
572	*Sphyraena forsteri*		1		
573	*Stegastes fasciolatus*	1	1	1	
574	*Stegastes gascoynei*	1			
575	*Stegastes nigricans*	1	1	1	1
576	*Stegostoma fasciatum*	1	1		
577	*Stethojulis bandanensis*	1	1	1	1
578	*Stethojulis interrupta*	1			
579	*Stethojulis strigiventer*	1	1	1	
580	*Sufflamen bursa*	1	1	1	
581	*Sufflamen chrysopterum*	1	1	1	
582	*Suttonia lineata*				1
583	*Synodus binotatus*				1
584	*Synodus dermatogenys*				1
585	*Synodus variegatus*	1	1	1	
586	*Synodus varigatus*				1
587	*Taeniura lymma*		1		
588	*Taeniura meyeni*	1	1		
589	*Thalassoma amblycephalum*	1	1	1	1
590	*Thalassoma hardwicke*	1	1	1	
591	*Thalassoma lunare*	1	1	1	
592	*Thalassoma lutescens*	1	1	1	1
593	*Thalassoma nigrofasciatum*	1	1	1	
594	*Thalassoma purpureum*	1	1	1	
595	*Thalassoma quinquevittatum*	1	1	1	
596	*Thalassoma trilobatum*		1	1	
597	*Thysanophrys celebicus*				1
598	*Trachinotus baillonii*			1	
599	*Trachinotus blochii*			1	
600	*Triaenodon obesus*	1	1	1	

601	*Trimma caesiura*				1
602	*Trimma emeryi*				1
603	*Trimma lantana*				1
604	*Trimma macrophthalma*				1
605	*Trimma maiandros*				1
606	*Trimma milta*				1
607	*Trimma necopinna*				1
608	*Trimma okinawae*				1
609	*Trimma sp.*				1
610	*Trimmatom eviotops*				1
611	*Trimmatom macropodus*				1
612	*Trimmatom nanus*				1
613	*Trimmatom sp.*				1
614	*Ucla xenogrammus*				1
615	*Valenciennea strigata*		1	1	
616	*Variola albimarginata*		1	1	
617	*Variola louti*	1	1	1	
618	*Xenisthmus eirospilus*				1
619	*Zanclus cornutus*	1	1	1	
620	*Zebrasoma scopas*	1	1	1	
621	*Zebrasoma velifer*	1	1	1	
		317	**375**	**343**	**213**

13 APPENDIX 7.

List of locations, depths, colony ages (earliest dated growth band) for cores of *Porites* corals collected within the CSMP. (NB MEL01D and MEL01E were dead at the surface, so only number of dated years provided)

Core ID	Collected	Reef	Latitude	Longitude	Depth (m)	IYS	IYE
CS01	Dec-17	Bougainville	-15.48429	147.10564	1	N/A	2017
CS02	Dec-17	Bougainville	-15.48394	147.10576	2	1986	2017
CS03	Dec-17	Bougainville	-15.48378	147.10583	2	1990	2017
CS04	Dec-17	Bougainville	-15.48195	147.10500	4	1922	2017
CS05	Dec-17	Bougainville	-15.48341	147.11203	2	1976	2017
CS06	Dec-17	Bougainville	-15.48341	147.11203	2	1989	2017
CS07	Dec-17	Bougainville	-15.51208	147.13206	9	N/A	2017
CS08	Dec-17	Bougainville	-15.51208	147.13206	12	N/A	2017
CS09	Dec-17	Bougainville	-15.51208	147.13206	14	N/A	2017
CS10	Dec-17	Moore	-15.88387	149.15414	5	1914	2017
CS11	Dec-17	Moore	-15.87998	149.15758	8	1988	2017
CS12	Dec-17	Moore	-15.87998	149.15758	8	1988	2017
CS13	Dec-17	Moore	-15.89456	149.16384	16	2008	2017
CS14	Dec-17	Moore	-15.96871	149.19270	2	N/A	2017
CS15	Dec-17	Diane	-15.72173	149.61452	7	1871	2017
CS16	Dec-17	Diane	-15.72331	149.61786	20	N/A	2017
CS17	Dec-17	Diane	-15.72095	149.61618	10	1960	2017
CS18	Dec-17	Willis	-16.13444	149.97911	10	N/A	2017
CS19	Dec-17	Willis	-16.21289	149.98933	11	N/A	2017
CS20	Dec-17	Willis	-16.29156	149.96413	8	2010	2017
CS21	Dec-17	Magdalene	-16.52323	150.27562	14	1908	2017
CS22	Dec-17	Magdalene	-16.52425	150.27684	13	1898	2017
CS23	Dec-17	Magdalene	-16.52420	150.27827	14	1894	2017
CS24	Dec-17	Magdalene	-16.59631	150.33476	10	N/A	2017
CS25	Dec-17	Magdalene	-16.59631	150.33476	10	N/A	2017
CS26	Dec-17	Magdalene	-16.59955	150.32698	17	N/A	2017
CS27	Dec-17	Magdalene	-16.59955	150.32698	13	N/A	2017
CS28	Dec-17	Flinders	-17.70472	148.46541	4	1832	2017
CS29	Dec-17	Flinders	-17.70472	148.46541	5	1931	2017
CS30	Dec-17	Flinders	-17.71715	148.44731	6	1958	2017
CAT01A	Dec-18	Cato Reef	-23.24671	155.53773	10	1988	2018
CAT02A	Dec-18	Cato Reef	-23.24671	155.53773	10	1961	2018
CAT03A	Dec-18	Cato Reef	-23.24566	155.53708	14.5	1909	2018
WRK01A	Dec-18	Wreck Reefs	-22.18267	155.16959	9	1993	2018
WRK01B	Dec-18	Wreck Reefs	-22.18267	155.16959	9	1978	2018
SUA01A	Dec-18	Saumarez Reef	-21.88628	153.64813	14	1839	2018
SUA02A	Dec-18	Saumarez Reef	-21.88628	153.64813	15.6	1889	2018
KNT01A	Dec-18	Kenn Reef	-21.25441	155.76112	7	1951	2018
KNT02A	Dec-18	Kenn Reef	-21.24863	155.76573	10.7	1907	2018
MEL01A	Dec-18	Mellish Reef	-17.40151	155.86169	15.6	1918	2018
MEL01B	Dec-18	Mellish Reef	-17.40151	155.86169	15.6	1910	2018
MEL01C	Dec-18	Mellish Reef	-17.40151	155.86169	11.4	1978	2018
MEL01D	Dec-18	Mellish Reef	-17.40151	155.86169	11.4	77	N/A
MEL01E	Dec-18	Mellish Reef	-17.40151	155.86169	11.4	87	N/A
MEL02A	Dec-18	Mellish Reef	-17.3943	155.86246	13	1875	2018
MEL03A	Dec-18	Mellish Reef	-17.3943	155.86246	12	1922	2018
MEL04A	Dec-18	Mellish Reef	-17.41789	155.85825	8.6	1918	2018
MEL05A	Dec-18	Mellish Reef	-17.41784	155.85843	9	1921	2918