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# **A SYNTHESIS OF THE EXISTING SCIENTIFIC DATA ON THE CORAL REEFS IN THE SOUTHERN GULF OF CARPENTARIA**

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## Cover images

Front: Olive sea snake (*Aipysurus laevis*) by Graham Edgar.

Back: Decorated Sandgoby (*Istigobius decoratus*) found on sand patches near reefs by Ian Shaw.

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## List of acronyms and abbreviations

| Acronym | Meaning                                                         |
|---------|-----------------------------------------------------------------|
| AFMA    | Australian Fisheries Management Authority                       |
| AIMS    | Australian Institute of Marine Science                          |
| CLCAC   | Carpentaria Land Council Aboriginal Corporation                 |
| AIS     | Automatic Identification System                                 |
| DCCEEW  | Department of Climate Change, Energy, the Environment and Water |
| GA      | Geoscience Australia                                            |
| GCRMN   | Global Coral Reef Monitoring Network                            |
| GFW     | Global Fishing Watch                                            |
| GOC     | Gulf of Carpentaria                                             |
| GOCMP   | Gulf of Carpentaria Marine Park                                 |
| MPA     | Marine Protected Area                                           |
| NPF     | Northern Prawn Fishery                                          |
| NPFI    | Northern Prawn Fishery Industry                                 |
| RLS     | Reef Life Survey                                                |
| VMS     | Vessel Monitoring System                                        |

## Acknowledgement

The Marine and Coastal Hub acknowledges Aboriginal and Torres Strait Islander people as the first peoples and Traditional Owners and custodians of the land and waterways on which we live and work. In particular, we acknowledge the Lardil, Yangkaal, Kaiadlit and Gangalidda people of the Wellesley Islands, who have a wealth of knowledge about their islands and Sea Country, including responsibilities for their ongoing management. We honour and pay our respects to Elders past, present and emerging.

Aboriginal and Torres Strait Islander peoples represent the world's oldest living culture. We celebrate and respect this continuing culture and strive to empower Aboriginal and Torres Strait Islander peoples.

## Executive summary

Marine Protected Areas (MPAs) are globally recognised as valuable tools for marine conservation and resource management, and scientific studies have shown that they provide a range of ecological, economic and social benefits. As coral reefs and other marine ecosystems face escalating threats, including climate change, overfishing, and habitat degradation, there is an increasing need for establishing more MPAs to increase levels of protection. The Australian government is one of over 190 nations that have committed to the “30 by 30” initiative, which aims to protect at least 30% of terrestrial, freshwater, coastal, and marine areas by 2030.

The Gulf of Carpentaria Marine Park (GOCMP) was established in 2018 and is one in a comprehensive network of 60 offshore MPAs around Australia. It consists of a National Park Zone (or green zone) where no extractive activities are permitted, and two Special Purpose (Trawl) Zones (or blue zones) where recreational fishing is permitted, and commercial trawling and fishing are permitted with prior authorisation.

Most of the scientific research on coral reefs in Australia has been focused on the Great Barrier Reef, and more recently on Ningaloo Reef in western Australia, and there has been very little research on coral reefs in the Gulf of Carpentaria (GOC). This report presents the findings of a desktop study which aimed to summarise, synthesise and analyse the available scientific information in the southern GOC, within and around the GOCMP, in order to inform the 2028 management plan review of the GOCMP. The reefs in this region are deeply known and important to Indigenous communities in the Wellesley Islands, south of the GOCMP. Anecdotally, western researchers have previously visited Sea Country, including reefs, and failed to report their findings back to the Traditional custodians, so this report, and an accompanying summary sheet, aim to rectify this by returning the findings from all known western scientific research to the local community. While this western science data is extremely limited compared to the Indigenous knowledge of the area, it is hoped that it will help to inform and empower Traditional custodians when making decisions on future management and research priorities.

The scientific research examined included bathymetric mapping of the reefs in this region. Between 2003 and 2005, multibeam sonar surveys conducted by Geoscience Australia identified and mapped seven submerged reefs in the southern GOC, four of which are in the GOCMP. These reefs have minimum depths of 18 – 20 m and vary in size and structure. There are large, submerged shoals or patch reefs, and submerged pinnacles with steep sides either rising from the seafloor or from a large platform made up of other smaller bommies and pinnacles.

Three biological studies on coral reefs were also examined in this region. The first two, one in 1997–1998 and the other in 2002, conducted visual observations and collections of coral reef fishes around the Wellesley Islands and produced species lists and estimates of relative abundance. The third was a series of surveys of benthic organisms and habitats, fish and mobile invertebrates carried out by the Reef Life Survey (RLS) program in 2010 and 2015 as part of a larger survey of the reefs in the North Commonwealth Marine Reserves Network. These surveys included five offshore sites within the blue zones of the GOCMP, three of which have been mapped by Geoscience Australia, as well as an additional three offshore sites outside the GOCMP, and six nearshore, fringing reef sites around Mornington Island. Coral cover ranged from 10 to 40 %, with considerable variation among sites. There were no differences in coral cover between offshore and nearshore reefs or between reefs within the GOCMP and those outside the park.



The density, biomass and species richness of reef fishes were higher at offshore reefs compared to nearshore reefs, but there were no differences between reefs within and outside the GOCMP. Species composition of reef fish communities differed between offshore and nearshore reefs. Of the three offshore reefs outside the GOCMP, one had a fish species composition similar to the five reefs inside the park, while the other two differed. When compared with RLS data from other sites around the GOC, reefs in the southern GOC had similar ranges for coral cover and fish metrics to reefs elsewhere in the GOC. Species composition of fish communities in the southern GOC was distinct from those at other RLS sites at similar latitudes in the Great Barrier Reef and Western Australia, and comprised a combination of widespread Indo-Pacific species, species found mainly in northern Australia and species found mainly in the GOC and northwestern Australia.

Apparent fishing effort data for the southern GOC in the last 10 years extracted from Global Fishing Watch indicates that fishing activity within the Special Purpose (Trawl) Zones of the GOCMP has been relatively low compared to areas closer to the coast. Although there was some apparent fishing activity in the Green Zone of the GOCMP, this was very low, ranging from 0 to 26 hours per year. However, this data is based on Automatic Identification System (AIS) data and should be treated as a conservative estimate, given that AIS is compulsory only for larger vessels and is less likely to be carried or consistently transmitted by small-scale, domestic, or nearshore fishing vessels.

Our findings highlight that there are unique coral reef systems in the southern GOC with relatively high coral cover on some reefs and differences in the fish communities between deep offshore reefs and shallower nearshore reefs. The fish communities are also unique and composed of a mixture of species found on the GBR and in northwestern Australia.

The following knowledge/research gaps were identified:

- No mapped reefs or complete surveys of the full extent of reef development in the region.
- No scientific studies on reefs within the National Park Zone of the GOCMP provide comprehensive assessments of the abundance and biodiversity of the coral reef flora and fauna.
- No regular, repeated ecological monitoring surveys on the reefs in and around the GOCMP.
- No systematic evaluation of an MPA network designed to maximise protection of the majority of coral reef species in the region).

# 1. Introduction

Marine Protected Areas (MPAs) are areas of oceans, seas, and coastal environments where human activity is managed, with different levels of protection ranging from multiple-use zones that allow some activities to no-take reserves where extractive activities like fishing and mining are prohibited (Lubchenco et al. 2003). MPAs are globally recognised as valuable tools for marine conservation and resource management, and scientific studies have shown that they provide a range of ecological, economic and social benefits. No-take MPAs support higher abundances and larger sizes of targeted marine species, and they provide a source of juveniles to replenish fish stocks in adjacent fished areas (Halpern et al. 2009, Edgar et al. 2014). They can also preserve biodiversity and promote resilience of marine ecosystems (Lester et al. 2009). By supporting sustainable fisheries and tourism, MPAs can have long-term benefits for local communities (Sala et al. 2013). Marine ecosystems across the globe are facing escalating threats, including climate change, overfishing, and habitat degradation, and MPAs are increasingly recognised as a vital tool in protecting marine ecosystems (Roberts et al. 2017).

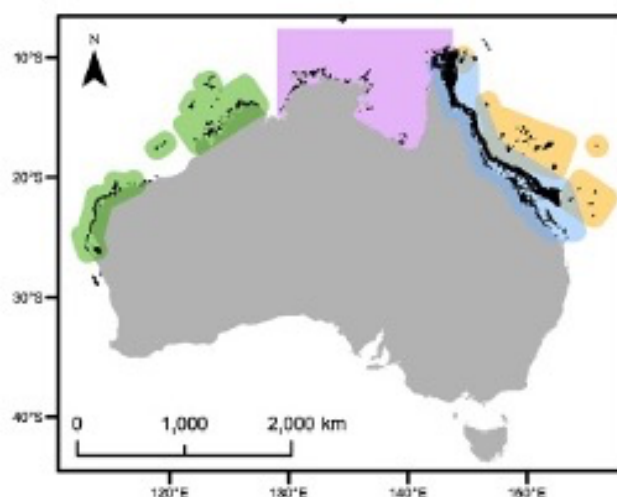
Australia has a large, comprehensive network of MPAs around the country, managed either by the Commonwealth government or by state and territory governments. 51% of Australian waters are in Australian Government-managed marine parks, and about 22% of Australian waters are in no-take areas (DCCEEW 2025). Australia is one of 190 countries that have committed to the '30 by 30' target set by the Kunming-Montreal Global Biodiversity Framework adopted by the Convention on Biological Diversity in 2022. Its goal is to ensure that at least 30% of terrestrial, inland water, coastal and marine areas are effectively conserved and managed. Australia's two largest MPAs, the Coral Sea Marine Park, covering almost 1 million km<sup>2</sup>, and the Great Barrier Reef Marine Park, covering 343,966 km<sup>2</sup> are in coral reef areas in northeastern waters.

Australia's coral reefs cover a total coral reef area of 41,802 km<sup>2</sup>, making up about 16% of the world's coral reefs (GCRMN 2022), and are among the most extensive and diverse in the world. Coral reefs are found in all of Australia's tropical waters and extend south as far as Lord Howe Island (~31.5°S) on the east coast and Rottnest Island (~32°S) on the west coast (Figure 1). They are an important part of Australia's indigenous cultural heritage. They are also economically important. For example, the Great Barrier Reef alone has been estimated to have an economic value of \$6.4 billion per year, supporting 64,000 jobs in tourism, recreation, fisheries and research. Most of the scientific research on coral reefs in Australia has focused on the Great Barrier Reef, due to its iconic status as the world's largest coral reef system, and high population density on the east Australian coast. Research efforts in Western Australia have been considerably lower, but have multiplied over the last decade. By comparison, there has been relatively little western research effort on the northern coast of the Northern Territory, and in the Gulf of Carpentaria where the full extent of reef development and its biodiversity are poorly understood.

Shallow coral reefs have previously been reported to cover an estimated 140 km<sup>2</sup> in the Gulf of Carpentaria (GOC), and predominantly consist of emergent, nearshore fringing reefs around the major islands of Groote Eylandt, Wessel Islands, Mornington Island, and along the western coast of the Gulf (Heap and Harris, 2008; Harris et al. 2008). A series of geomorphological and bathymetric investigations have been conducted over the last few decades, aimed at improving our understanding of the seafloor structure, sedimentary processes, and reef systems of the GOC. Late twentieth century mapping surveys were primarily driven by navigation (Royal Australian Navy, 1970) and hydrocarbon prospecting interests (Weeks Australia Ltd. 1983), while scientific research focused on changing sea-level dynamics variously connecting and isolating the GOC from the surrounding Coral Sea, Torres Strait and Arafura Sea over multiple

geological time-periods (Torgerson et al. 1983, 1988; Woodroffe and Chappell 1993, Chivas et al. 2001, Reeves et al. 2008). More recent efforts have been led by Geoscience Australia (GA) and the Australian Institute of Marine Science (AIMS) into quantifying the region's submerged coral reef systems in the last two decades. Notably, the identification of a coral reef province previously unknown among coral reef scientists by Harris et al. (2004, 2007, 2008) has catalysed further studies into reef formation, biological oceanography and benthic habitats across the GOC (Rothlisberg et al. 2016, Heap et al. 2003, Heap and Harris 2008, Carter et al. 2024).

The Gulf of Carpentaria Marine Park was declared in 2013 and came into effect on 1 July 2018. It is part of the North Marine Parks Network, managed by Parks Australia through the North Marine Parks Network Management Plan 2018 (Director of National Parks 2018). The park covers an area of 23,771 km<sup>2</sup> and consists of: a National Park zone, where all fishing and other extractive or damaging activities are prohibited, but non-extractive activities such as transit, boating, diving and tourism are allowed; and two Special Purpose (Trawl) zones, where recreational fishing is permitted, and commercial fishing and trawling is permitted with prior authorisation (Figure 2). The current management plan expires in 2028. The review period of 2026-2028 will be informed by the best available data, including the research summarised in this report. The park is known to have a network of coral reefs; however, there is a lack of comprehensive scientific data on these reefs and other habitats within the park. Marine reserves in the GOC are likely to have similar benefits to those elsewhere in Australia. Still, so far, most of the scientific data has been exploratory work, mapping reefs and doing baseline surveys. There have not been any biological surveys examining the effectiveness of the marine park since it was established.



*Figure 1: Map of Australia showing coral reef areas (black), with 100km boundaries around the Coral Sea (orange), Great Barrier Reef (blue) and Western Australia (green) coral reef areas, and the entire Northern Territory region (pink). Source: Dixon et al. (2022) Earth's Future. Reproduced under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).*

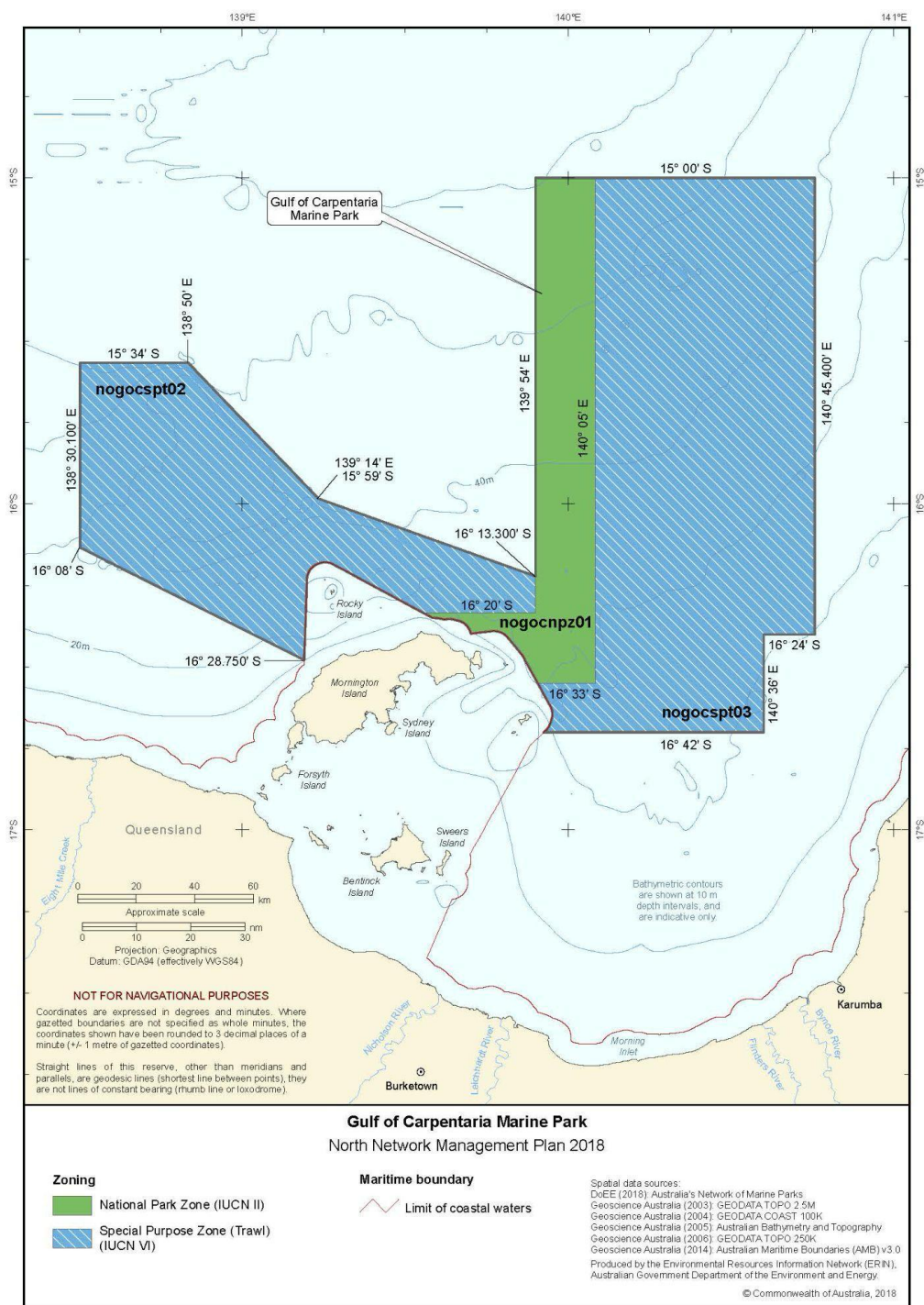


Figure 2: Current zoning map of the Gulf of Carpentaria Marine Park.

The coral reefs in the GOCMP and around the Wellesley Islands are culturally important for several traditional owner groups in the southern gulf. The Thuwathu-Bujimulla Indigenous Protected Area, which spans across the Wellesley Islands and overlaps with the marine park, is made up of over 1.6 million hectares of Sea Country and over 120,000 hectares of land (Carpentaria Land Council Aboriginal Corporation 2006). It is the traditional Country of the Lardil, Yangkaal, Kaiadilt and Gangalidda Peoples. The Wellesley Islands Ranger unit, based on Mornington Island, was established in 2016 to manage Land and Sea Country.

Commercial prawn fishing is an important activity in this region and is managed by the Australian Fisheries Management Authority (AFMA), a Commonwealth government agency (AFMA n.d.). All commercial prawn trawling is conducted under the banner of the Northern Prawn Fishery Industry Pty Ltd, which is a collective of trawler operators, processors and marketers (NPFI n.d.). The fishery has Marine Stewardship Council (MSC) certification as a sustainable and well-managed fishery (NPFI n.d.). Other commercial fisheries in the region include commercial inshore and offshore gillnetting, and offshore line fishing, all managed by Queensland's Department of Primary Industries. Recreational fishing occurs around the Wellesley Islands and is permitted in the Special Purpose (Trawl) Zones of the GOCMP (Business Queensland, n.d.). There is a small fishing lodge on Sweers Island, but there are no fishing charter operators. Due to its remote location, the coral reefs in this region are likely to experience substantially lower recreational fishing pressure than similar inshore island locations on the east coast of Queensland.

There have only been three biological studies carried out on coral reefs in the southern GOC to date (Figure 3). The first underwater visual surveys of coral reef fishes in the southern GOC were conducted around the Wellesley Islands in October 1997 and May 1998 by the QLD Department of Environment (Malcolm 1998). In 2002, collections of nearshore fishes using rotenone, netting and line fishing, as well as underwater observations, were made at Sweers and North Bountiful Island in 2002 as part of an expedition by the Royal Geographical Society of Queensland (Johnson & Gill 2005). Underwater visual surveys of coral reefs in and around the GOCMP were conducted by the Reef Life Survey (RLS) program in 2010 and 2015 as part of a larger survey of the reefs in the North Commonwealth Marine Reserves Network (Edgar et al. 2017).

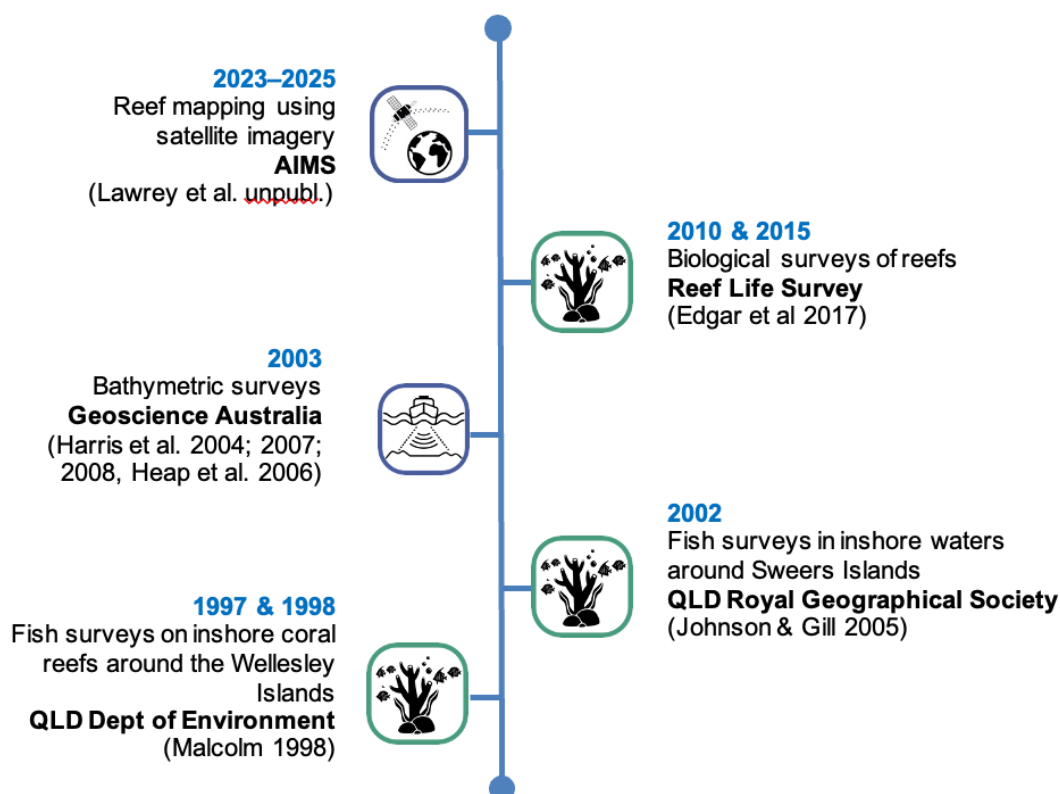


Figure 3: Timeline of scientific research in the southern Gulf of Carpentaria.



**Project objectives and scope:**

The overall aim of this desktop study was to compile, synthesise and analyse available scientific data on the coral reefs in the southern Gulf of Carpentaria, both within and adjacent to the GOCMP. A key intention of the study was to return information from previous scientific studies to the relevant Traditional Owners, recognising that communities have previously raised concerns that scientific data collected on Country has not always been shared back with custodians. By making raw data and summary outputs accessible, this study seeks to support Traditional Owners and other stakeholders in contributing to management decisions and identifying priorities for future research.

The specific objectives were to:

- i. Compile and synthesise existing scientific data on coral reefs in the southern Gulf of Carpentaria, particularly within the Gulf of Carpentaria Marine Park, to identify key knowledge gaps, and to return research results to community, inform management and future research directions.
- ii. Analyse the available biological data on coral reefs in the southern GOC.
- iii. Make recommendations for future research directions.
- iv. Produce a technical report for management agencies and industry stakeholders in the GOC.
- v. Produce a summary factsheet of findings for traditional owners of the Wellesley Islands, to return research results to Country to help inform and empower local communities to make decisions on their priorities for future management.

## 2. Methods

### 2.1. Literature review

A review of available western scientific data and literature was conducted using various search methods. This yielded bathymetry data and data from several biological surveys. Some raw data was available digitally (e.g. Reef Life Survey) but other data had to be entered manually (Malcolm 1998) or was only available in summary form (Johnson and Gill 2005).

A series of meetings were held with the Carpentaria Land Council Aboriginal Corporation (CLCAC), the Department of Primary Industries (DPI), the National Environmental Science Program Marine and Coastal Hub (NESP MAC), the Northern Prawn Fishing Industry (NFPI), Parks Australia, and Reef Life Survey, to share the objectives of the project, exchange relevant information, document stakeholder values, and identify current gaps in knowledge relevant to coral reef management in the southern Gulf of Carpentaria.

#### 2.1.1. Bathymetry and geomorphology

To compile existing biophysical data for the Gulf of Carpentaria, we accessed a range of publicly available and published datasets, with a focus on bathymetry and geomorphological features. High-resolution bathymetric grids and seabed mapping layers were obtained from Geoscience Australia, including national-scale products developed under the Marine and Coastal Community Network and associated seabed mapping programs ([ausseabed.gov.au](http://ausseabed.gov.au)). We also reviewed and extracted relevant findings from peer-reviewed literature (Harris et al. 2004, 2007, 2008, Heap et al. 2006) describing submerged reef structures, pinnacles, and benthic habitats in the southern Gulf.

#### 2.1.2. Coral reef habitats – Allen Coral Atlas

Habitat classifications and spatial extent of reef systems in the Gulf of Carpentaria were sourced from the Allen Coral Atlas, which provides globally consistent benthic and geomorphic maps derived from high-resolution satellite imagery and machine learning classification techniques ([allencoralatlas.org](http://allencoralatlas.org)). These data were used to identify and validate the distribution of shallow reef features across the region.

#### 2.1.3. Surveys of coral reef fishes around the Wellesley Islands

The first underwater visual surveys of coral reef fishes in the southern GOC were conducted around the Wellesley Islands in October 1997 and May 1998 by the QLD Department of Environment (Malcolm 1998). A total of 12 sites were surveyed across the two time periods at Mornington, Rocky, Manowar, Pisonia and Bountiful Islands (Figure 4), with three sites surveyed both times. At each site, one 45-minute timed swim was conducted by a single diver, recording the relative abundance of fish seen within 5 m on either side. The relative abundance of each species was recorded by placing each species in one of three abundance categories based on its relative abundance, i.e. rare/uncommon (1 to 5 individuals), common (6–125 individuals) and abundant (126 to >3125 individuals).

Recording relative abundance in this way allows for rapid surveys of large fish assemblages, but the coarseness of the abundance categories can limit analytical flexibility and reduce the power to detect fine-scale changes in abundance over time. Incidental sightings were made at four additional sites, where the visibility was too poor to conduct visual surveys. We obtained a scanned copy of the unpublished report from the author and entered the raw data, which was in an appendix, into an Excel file. The scanned report and raw data is available in the Project 4.24 repository:

[github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC).

Collections of nearshore fishes using rotenone, netting and line fishing, as well as underwater observations, were made at Sweers and North Bountiful Island in 2002 as part of an expedition by the Royal Geographical Society of Queensland (Johnson & Gill 2005). Each species was placed into a relative abundance category based on the number of individuals caught or observed, i.e. rare (1–3 individuals), uncommon (4–9), common (10–100), or abundant (>100).

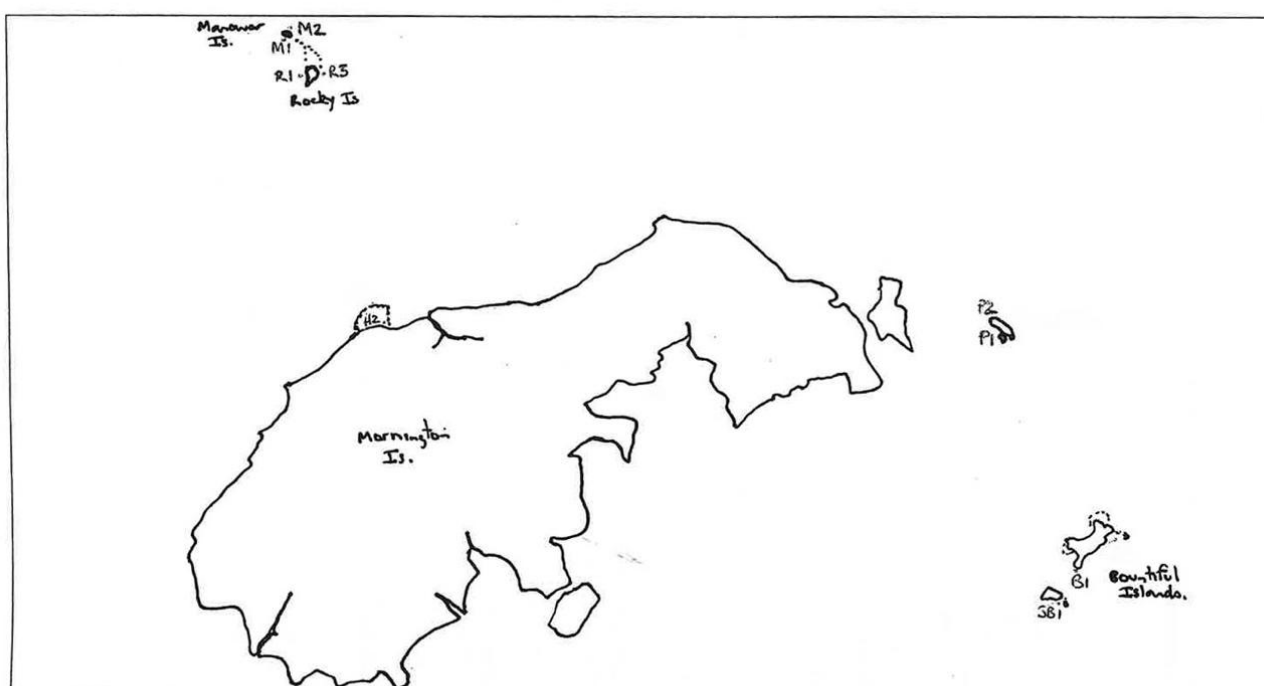


Figure 4: Map of the Wellesley Islands showing the location of survey sites surveyed in October 1997 and May 1998 by Malcolm (1998). (Source: Malcolm 1998).

#### 2.1.4. Surveys of benthic organisms and coral reef fishes – Reef Life Survey

The most comprehensive underwater visual surveys in the region to date were conducted by the Reef Life Survey (RLS) program between 2010 and 2015. They surveyed 238 sites across the northern coast of Australia during this period, including sites around the GOC (Figure 5A). At each site, diver-based visual surveys of fish and invertebrate species were conducted, and photographs were taken to quantify the percent cover of benthic organisms, including corals, macroalgae and other key habitat-forming organisms. We incorporated data from 14 sites within and adjacent to the GOCMP (Figure 5B), which included eight offshore reefs, five within the Special Purpose (Trawl) Zones of the Marine Park and three outside the Marine Park, and six nearshore reefs around Mornington Island. These sites were surveyed either in 2010 or 2015, and two sites (Steve's

Bommie and Manowar Island) were surveyed in both years. Site information, including survey year and GPS coordinates of survey sites, is available in the Project 4.24 repository: [github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC).

RLS data were accessed from the Australian Ocean Data Network, part of the Integrated Marine Observing System (IMOS) at: [portal.aodn.org.au/search](https://portal.aodn.org.au/search). Mean coral cover, total fish density, fish biomass, fish species richness (i.e. number of fish species), and fish diversity (Shannon-Weiner Species Diversity Index) were calculated and compared among sites. Fish biomass is an estimate of the amount of fish in kg per unit area and is calculated using fish counts and size estimates.

We also incorporated RLS data from a further 22 sites around the GOC (Figure 5A), 50 sites in Western Australia and 75 sites on the GBR (Figure 6) in order to:

- i. Compare coral cover and the species composition of fish communities between reefs in the southern GOC and reefs in other parts of the GOC, and between pinnacle (seamount) reefs and fringing reefs.
- ii. Compare fish community structure between reefs in the southern GOC and reefs in the same latitudinal range in Western Australia and on the GBR.

These data were collected using a standardised underwater visual census method developed by RLS and conducted by trained recreational divers. Briefly, each RLS survey consists of a 50 m transect line laid along a consistent depth contour and involves three components:

1. Method 1: Fishes
2. Method 2: Mobile invertebrates and cryptic fishes
3. Method 3: Sessile organisms, e.g. corals and macroalgae

RLS surveys are structured using parallel blocks on either side of the transect line to standardise the area observed. Typically, two divers work together to complete a full survey during a single dive. First, the transect tape is laid out by one diver, and the other diver follows, taking digital photo quadrats to assess habitat composition. Photo-quadrats are taken at 2.5 m intervals along the transect line, yielding 20 images per 50 m transect (Figure 7, Method 3). These images are later analysed to estimate the composition and percent cover of benthic organisms like corals, algae, and sponges. The two divers then swim back along the same transect, each recording mobile and mid-water fishes within a 5 m wide and 5 m high 'block', one on each side of the transect (Figure 7, Method 1). The divers then complete a third swim along the transect, each recording conspicuous mobile invertebrates (e.g. sea stars, urchins, lobsters) and cryptic fish species that are more closely associated with the benthic habitat within a 1 m wide and 2 m high block, one on each side of the transect (Figure 7, Method 2). Detailed descriptions of survey methodologies are available on the RLS website: [reeflifesurvey.com/wp-content/uploads/2019/02/NEW-Methods-Manual\\_150815.pdf](https://reeflifesurvey.com/wp-content/uploads/2019/02/NEW-Methods-Manual_150815.pdf)

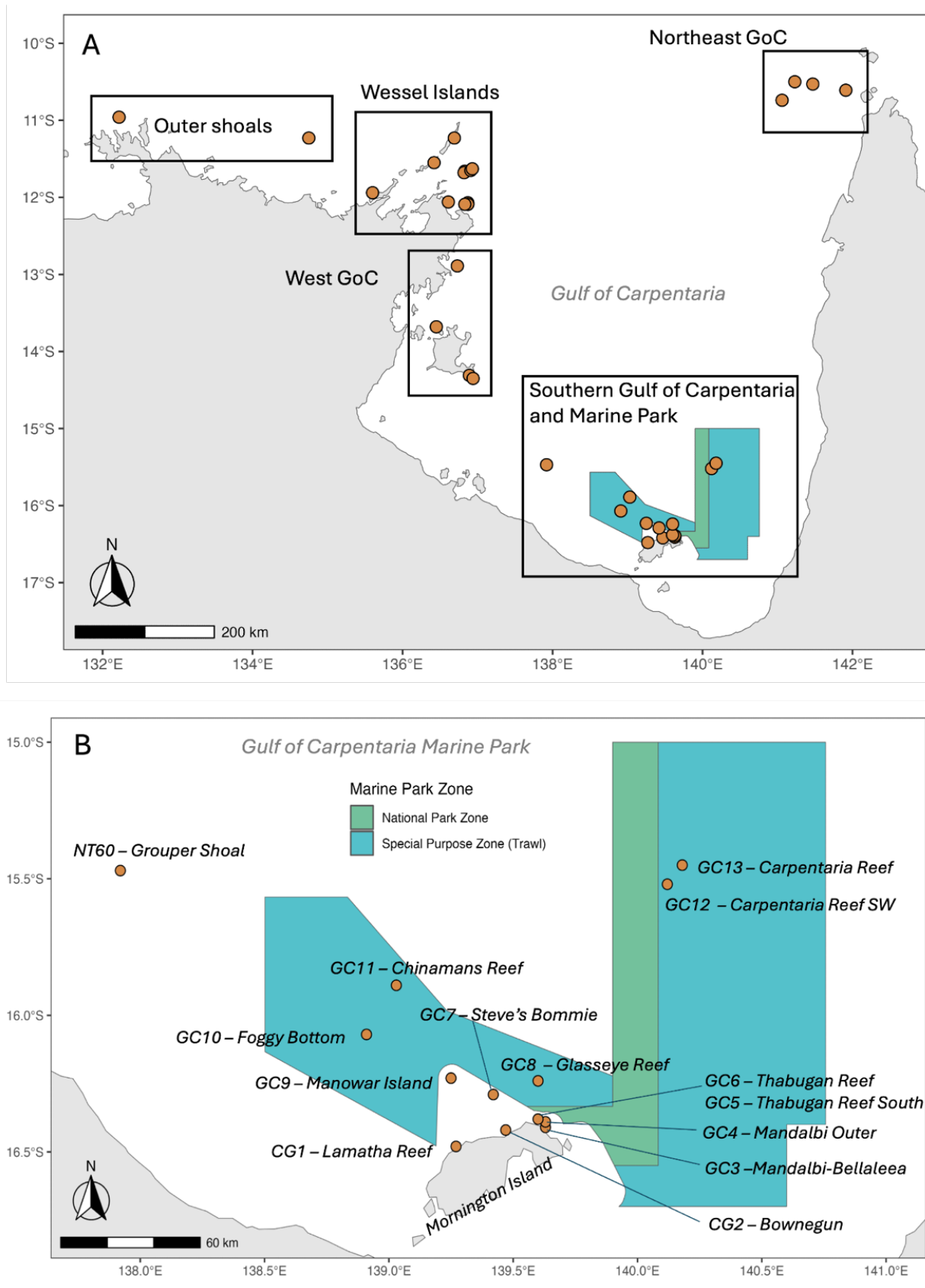


Figure 5: Maps showing locations of Reef Life Survey sites in (A) the Gulf of Carpentaria, and (B) the southern Gulf of Carpentaria, including the Gulf of Carpentaria Marine Park, made in R using the ozmaps package, with marine parks boundaries from [DCCCEW](#).



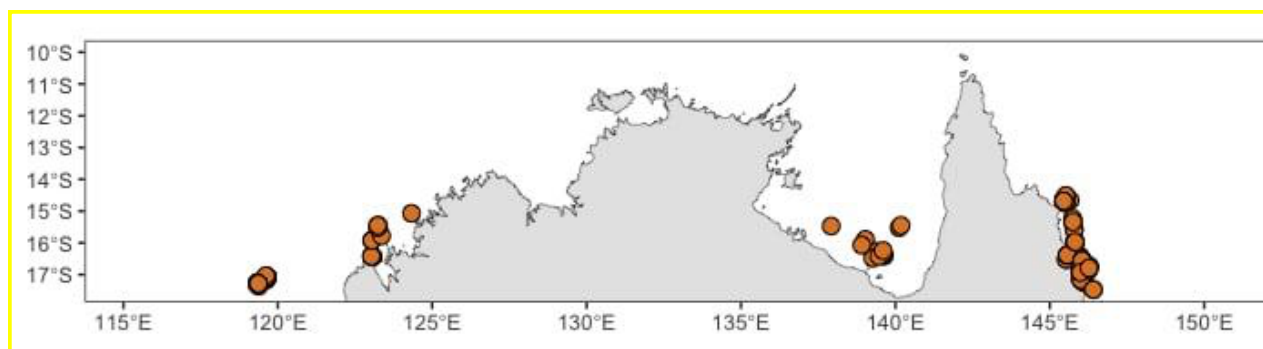


Figure 6: Map of northern Australia showing the locations of RLS sites in Western Australia and in the Great Barrier Reef Marine Park that were within the same latitudinal range as RLS sites in the southern Gulf of Carpentaria.

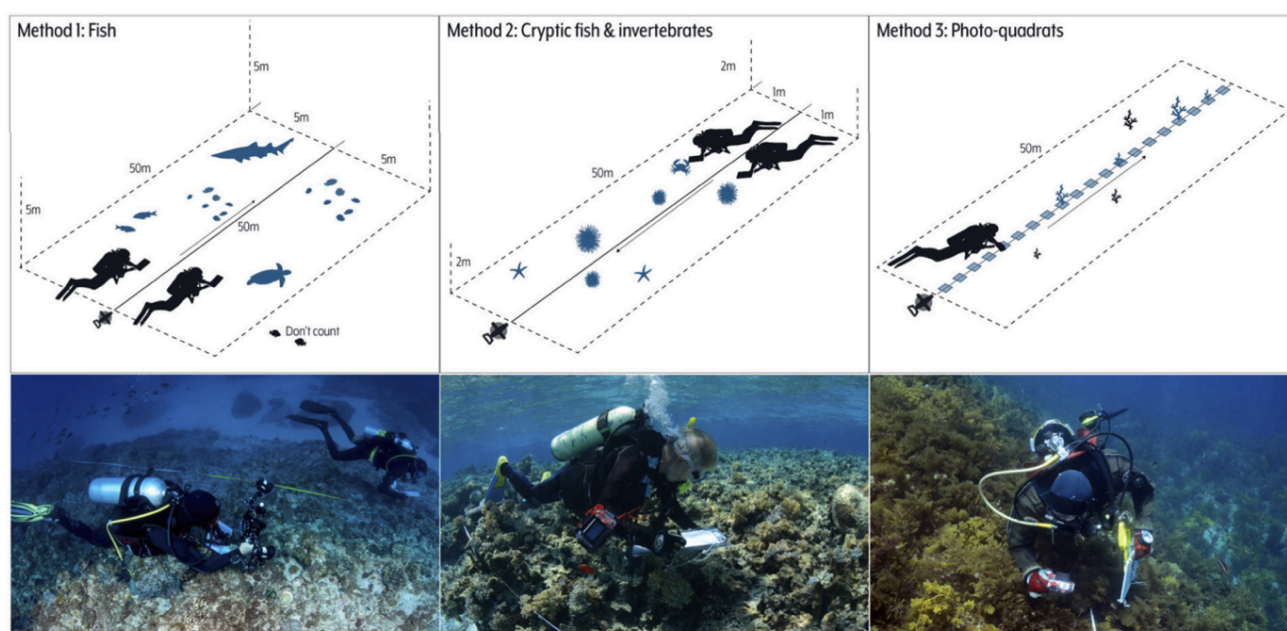


Figure 7: Reef Life Survey underwater visual census methods for reef fish, cryptobenthic fish and invertebrates and benthic photo-quadrats. (Source: Edgar et al. 2020).

### 2.1.5. Fishing activities

To assess fishing activity within the Gulf of Carpentaria, we utilised data from Global Fishing Watch (GFW), an open-access platform that monitors global fishing activity using satellite-derived vessel tracking information. GFW integrates Automatic Identification System (AIS) data, broadcast by vessels for navigational safety, with publicly available Vessel Monitoring System (VMS) data, where accessible. Through machine learning algorithms, GFW interprets vessel movement patterns (e.g. speed, course changes) to infer likely fishing behaviour, which can be visualised using density-shaded spatial mapping tools.

It is important to note that AIS data does not provide a complete representation of fishing activity in the region. Not all vessels are required to carry AIS, and AIS data does not measure actual fishing effort but rather indicates where AIS-equipped vessels were present and approximately how long they remained in an area. Australia has not made its VMS data publicly available; therefore, the analysis primarily reflects AIS-derived vessel activity rather than a comprehensive account of all

fishing operations. Although this can provide some insight and analysis for regional fishing activities, reliance on AIS data may result in underrepresentation of certain fishing activities, particularly those involving vessels that do not use AIS or operate in areas with limited satellite coverage.

Consequently, these data are intended to provide broad scale contextual information regarding human use patterns within the region rather than a definitive measure of absolute fishing pressure.

We accessed the GFW data via the online portal [globalfishingwatch.org](https://globalfishingwatch.org), which offers interactive maps and downloadable datasets. The datasets are available in gridded formats, with resolutions suitable for regional analyses. For the purpose of this review, we focused on the dataset detailing apparent fishing effort by flag state and gear type, aggregated at a 0.01-degree resolution. This granularity allowed for detailed spatial analysis of fishing activities within the Gulf of Carpentaria. We cropped the perceived fishing effort data within regional boundaries to isolate and examine fishing patterns specific to the Gulf of Carpentaria and overlaid the GOCMP boundary. This approach enabled us to identify potential areas of concentrated fishing effort and assess potential overlaps with ecologically sensitive regions and the GOCMP.

## 2.2. Data handling and statistical analysis

All statistical analyses and data visualisation were performed in R Studio version 2024.04.2+764 (R Core Team 2024). For each site from the Reef Life Survey dataset, we assigned the following classifications: reef geomorphology (pinnacle/shoal or fringing reef), depth morphology based on crest depth from survey data and visual inspection of satellite imagery from Allen Coral Atlas (submerged >5 m crest depth no reef visible from imagery or emergent <5 m crest with visible reef from imagery) and situation based on distance from closest mainland or island coast (offshore >10 km, nearshore <10 km). Based on site locations, we were also able to identify which of the reefs mapped and discovered by Geoscience Australia (Harris et al. 2008) corresponded with reefs surveyed by RLS. Refer to Appendix 1 for all RLS sites and associated site metadata. We calculated reef fish species richness (S), diversity (Shannon-Wiener H'), density (number of individuals) and biomass (kg) per block (100 m<sup>2</sup>) for each site in the RLS reef fish data using the package *vegan* (Oksanen et al. 2025). Boxplots were created in *ggplot2* (Wickham 2016) to display the spread, central tendency (median), and potential outliers in reef fish biodiversity metrics at each site.

Non-metric multidimensional scaling (NMDS) was used to visualise patterns in fish community composition among sites based on species abundance data. NMDS was conducted using the *metaMDS* function from the *vegan* package in R, with three dimensions specified ( $k = 3$ ) and a maximum of 100 random starts ( $trymax = 100$ ) to improve the chances of reaching a global solution. Environmental and species vectors were fitted post hoc to the ordination using the *envfit* function with 999 permutations. Site scores were extracted using the *scores* function and merged with environmental metadata to allow for contextual interpretation. Species scores were extracted similarly, and only species vectors with a permutation p-value < 0.001 were retained to highlight the strongest contributors to community differences. Environmental variables were also filtered to retain vectors with significant fits ( $p < 0.001$ ), allowing for interpretation of key gradients structuring fish assemblages across sites, regions within the Gulf of Carpentaria, and reef geomorphology.

Benthic data from analysed photoquadrats were available for 12 sites in and around the Gulf of Carpentaria from RLS. All photo-quadrats and annotation data sets from the RLS program are uploaded to Squiddle+, a centralised marine image data management & annotation platform available at [squiddle.org](https://squiddle.org). Image notation on Squiddle+ was performed by RLS, with benthic

organisms and substrate types identified and classified according to two category lists (see lists here: [github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC)). Four sites had only partially scored survey data available (only hard corals were scored for some surveys in certain years), which limited our ability to compare other benthic groups across sites. We therefore incorporated coral morphology into the analysis of the RLS benthic data by categorising hard corals into two broad morphological groups: complex and branching, and massive and encrusting. Mean hard coral cover per transect was calculated and plotted as bar plots in ggplot2 (Wickham 2016).

Gridded bathymetry data were downloaded for the Gulf of Carpentaria (lat/lon box) from the GEBCO\_2024 Grid ([gebcoset.org/](https://gebcoset.org/)). We used the package Rayshader (Morgan-Wall 2025) in R to create 3D models of relevant bathymetric features within the GOCMP to support subsequent ecological interpretation and provide visualisations of significant benthic habitats, including submerged shoals and pinnacles.

### 2.3. Data management

Data and code used to generate figures and statistical summaries for reef fish and benthic data presented in this report are available in the Project 4.24 repository ([github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC)) under MIT licence. All other data collated for this synthesis are included as appendices to this report or are freely available from the cited source.

### 3. Findings and discussion

#### 3.1. Bathymetry and geomorphology

The bathymetry of the Gulf of Carpentaria is characterised by a shallow basin (max depth 70m) bounded by two shallow sills; the Arafura Sill to the northwest and the Torres Strait Sill to the northeast (Chivas et al. 2001). Broadly, the basin has a flat profile but is punctuated with sand banks, steep-sided pinnacles and flat-topped shoals (Heap et al. 2004, Short 2020). In 2003, three large, submerged patch reefs were reported from multibeam sonar surveys conducted in the southern Gulf of Carpentaria (GA Survey 238 SS-04/2003, Harris et al. 2004, Heap et al. 2006). Following these initial surveys, further work was undertaken in 2005 to conduct geological sampling of the three submerged reefs and to determine the existence of similar bathymetric structures in the region (GA Survey 276; SS04/2005, Harris et al. 2007). This resulted in the identification of four additional submerged coral reefs in the southern Gulf of Carpentaria (Harris et al. 2008, Figure 8).

Submerged reefs are distinct from emergent coral reefs in that they do not breach the sea surface and typically have shallow depths of 10–30m (*sensu* Macintyre 1972). Submerged reef geomorphologies are generally formed by fluctuating sea level over geological time (Harris and Davies 1989). Throughout the Quaternary (2.6 myr BP) and during the most recent post-glacial sea level rise (~9 kyr BP), the Gulf of Carpentaria has been repeatedly submerged and exposed by changing sea-level dynamics (Harris et al. 2008). Over this time, the GOC has transitioned from freshwater to alternating marine and brackish environmental conditions as historic sea levels rose and fell below critical depths that isolate the region from the surrounding Arafura Sea to the northwest and Torres Strait and Coral Sea to the northeast (Figure 8). The submerged reefs mapped by Harris et al. (2004, 2008) formed between 11-7 kyr BP (thousand years before present), during the most recent post-glacial sea level rise, which transformed the GOC from a freshwater lake to a marine environment (Torgersen et al. 1988). However, following the 8.2 - 8.4 cal kyr BP (thousand calibrated years before present) meltwater event (Barber et al. 1999), the majority of the reefs in the southern gulf stopped growing due to increasing sea levels (Harris 1994).

Of the seven submerged reefs mapped by Geoscience Australia between 2003 and 2005, four lie within the GOCMP (R1, R2, R3, and R4; Figure 9). Reef R1 is a large (72.48 km<sup>2</sup>) submerged shoal, with a minimum depth of 20m, located in the north of the eastern Special Purpose (Trawl) Zone (Zone 03) of the GOCMP. Twenty-five kilometres to the southwest of R1 lie two submerged pinnacles R2 (5.54 km<sup>2</sup>) and R3 (1.56 km<sup>2</sup>), which are smaller submerged reefs with steep sides that rise to within 18m of the surface. Reef R4 is within the western Special Purpose (Trawl) Zone (Zone 2) of the GOCMP but lies on an elongate platform of other smaller bommies and pinnacles that extends northwest for ~100km from Mornington Island. R4 rises from 45-50m depth to 18m at the shallowest part of the platform. Of the four submerged reefs within the GOCMP, ecological surveys have been conducted on R2, R3 and R4 by Reef Life Survey in 2015. R6, which lies outside of the GOCMP boundary, was also surveyed by the RLS Programme during this time (Figure 9).

Submerged reefs and pinnacles, such as those found in the Gulf of Carpentaria, can play an important ecological role in supporting distinct patterns in marine biodiversity compared to shallow emergent coral reef habitats (Cooper et al. 2019; Galbraith et al. 2021, 2023). Despite their deeper crests, these habitats exist within the photic limits for shallow coral reef-forming taxa (0-30m). Below 30m, submerged reefs can also support significant areas of Mesophotic Coral Ecosystems (30-150m) which possess distinct ecological communities compared to those of shallow water coral reefs (Rocha et al. 2018, Abdul Wahab et al. 2018, Johnson et al. 2025).



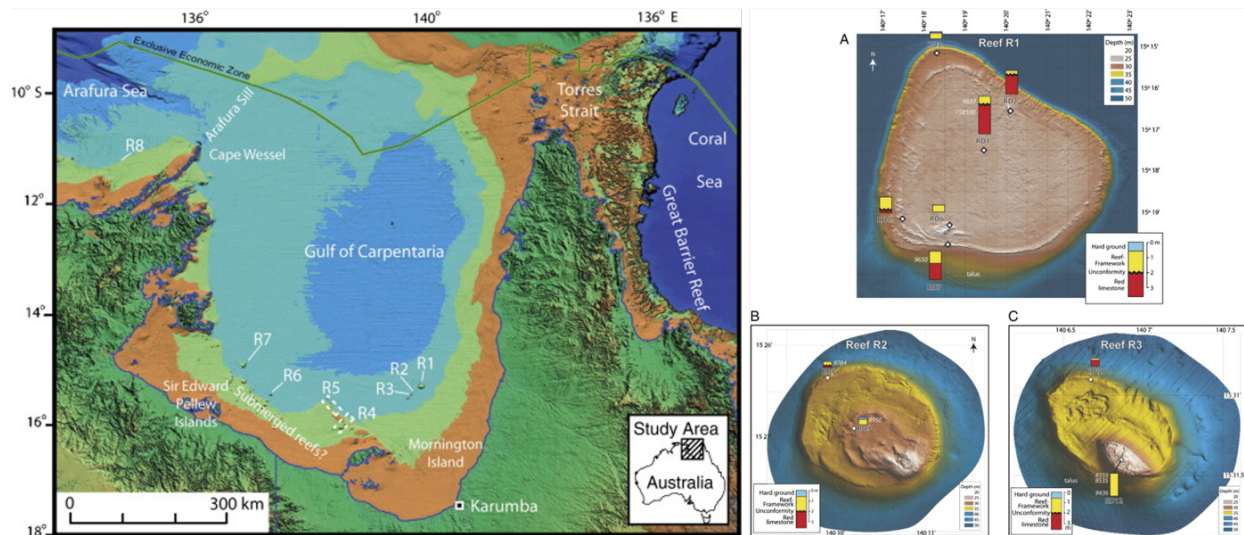


Figure 8: Map showing the locations of submerged coral reefs examined by Harris et al (2008), and multibeam sonar images of three of the reefs in the Gulf of Carpentaria Marine Park. (Source: Harris et al. 2008).

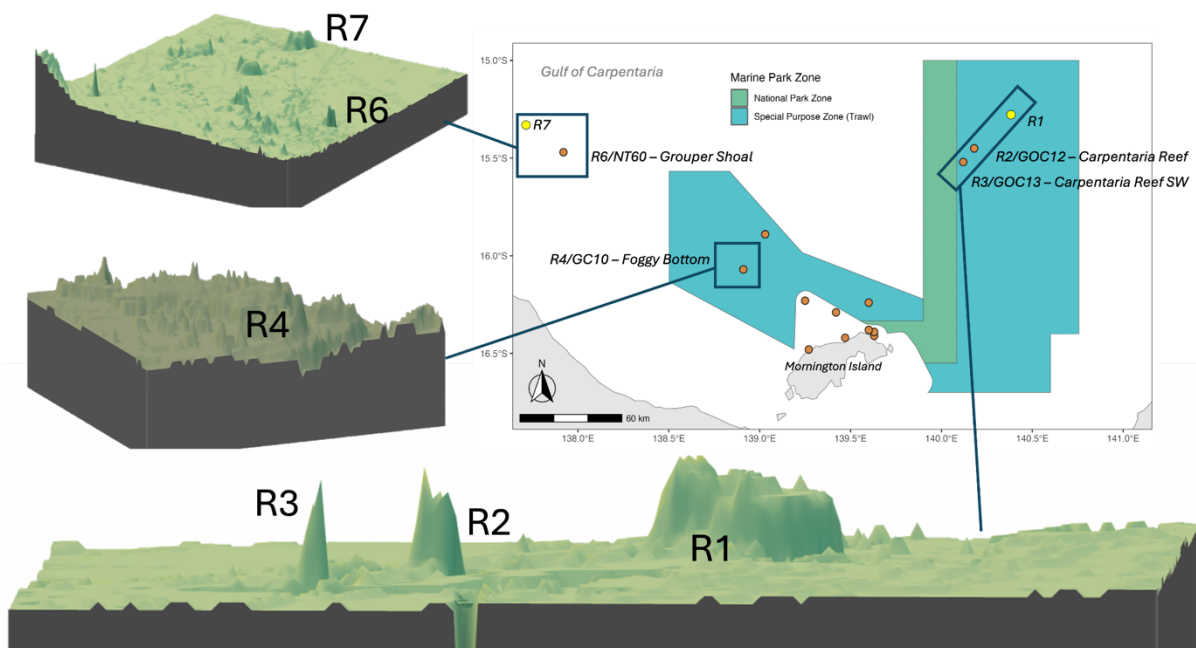


Figure 9: Six of the seven submerged reefs mapped by Geoscience Australia between 2003 and 2005 (Harris et al. 2004, Heap et al. 2006). R1, R2, R3 and R4 lie within the Gulf of Carpentaria Marine Park Special Purpose (Trawl) Zones. R6 and R7 are submerged pinnacles northwest of the marine park boundary. Sites marked by orange circles denote available ecological reef survey data collected by Reef Life Surveys in 2015. Yellow circles mark the submerged reefs R1 and R7 and indicate that no ecological survey data are available for these sites. 3D bathymetry models were generated using the package Rayshader (Morgan-wall 2025) in R (2025 version 4.5) and bathymetry data from GA0276 survey, available from <https://ecat.ga.gov.au/geonetwork/srv/api/records/ddd22d76-2b12-4c00-a6b4-b356a7efca66>.

Steep-sided bathymetric features like pinnacles, seamounts and submerged shoals can also significantly influence local currents, which can enhance vertical mixing and promote high primary productivity (Leitner et al. 2020). In turn, the distinct hydrodynamics can support complex reef-associated communities, including reef fishes, corals, sponges, macroalgae, and mobile invertebrates (McGee 1994, Galbraith et al. 2022, 2023). Notably, these features are also known to act as aggregation sites for apex predators and marine megafauna, serving as spawning, feeding and breeding areas as well as productive hotspots that support both commercial and subsistence fisheries species (Morato et al. 20010, Cresswell et al. 2023, Weber et al. 2025). Moreover, submerged reefs on seamounts, shoals and pinnacles may act as ecological "stepping stones", facilitating larval dispersal, gene flow, and broader connectivity across marine bioregions for a wide range of marine taxa (Simon et al. 2021, Tosetto et al. 2024, Galbraith et al. 2024). Given their high biological productivity and importance as habitat for commercially and ecologically significant species, submerged reefs represent valuable areas for both commercial and subsistence fisheries as well as highly effective conservation units (McCook et al. 2009, Letessier et al. 2019, Thompson et al. 2024). Their ecological significance underscores the need for targeted management and inclusion of deep and distinct reef habitats in marine spatial planning (Goetze et al. 2021), particularly in data-limited regions such as the Gulf of Carpentaria.

### 3.2. Coral reef habitats – Allen Coral Atlas

Allen Coral Atlas estimates the total coral reef area across the entire GOC region as 3,391 km<sup>2</sup> (Figure 10). This is much higher than the 140 km<sup>2</sup> quoted by Heap & Harris (2008) and Harris et al (2008), which was calculated from Reef Base ([www.reefbase.org](http://www.reefbase.org)). The Allen Coral Atlas estimate is likely to be more accurate as it is a more specialised tool for detailed mapping and monitoring of coral reef habitats, while ReefBase is a broader resource for data and information on coral reefs. However, as Allen Coral Atlas is focused on mapping shallow coral reefs (ie. to a maximum of depth of 15–20 m) using satellite images, it is likely to have underestimated the total coral reef area in the GOC, as the deeper, submerged reefs will not have been included. The offshore submerged reefs do not appear on the map (Figure 10).

Allen Coral Atlas estimates the total reef area around Mornington Island to be about 1,004 km<sup>2</sup> (Figure 11). Part of a current NESP project (NESP 3.17) mapping the reefs in the GOC and northwestern coast of Australia involves re-mapping coral reef habitats for Allen Coral Atlas, using composite satellite images. This project is being conducted by the Australian Institute of Marine Science and the University of Queensland. The report for this project is still in progress, but the dataset is available at [doi.org/10.26274/XJ4V-2739](https://doi.org/10.26274/XJ4V-2739). The accuracy of estimates of coral reef habitats will improve as methods for mapping the extent of global ecosystems via remote sensing continue to develop. Given that deeper and submerged reefs in the GOC are currently omitted, forthcoming spatial layers are expected to increase the recognised reef area.

### 3.3. Surveys of coral reef fishes around the Wellesley Islands

A total of 126 species of fish were recorded by Malcolm (1998) in visual surveys and incidental observations on coral reefs around the Wellesley Islands in October 1997 and May 1998. The number of species observed in a 45-minute timed swim at each site ranged from 19 to 62, with the highest numbers of species per site at Manowar and Rocky Islands (Table 1). The fish community was dominated by about 10 species (Table 2), six of which are also abundant on inshore reefs in the GBR. Two of the 10 most abundant species, *Pomacentrus milleri* and *Plectroglyphidodon obreptus* are only



found in Western Australia and on the northern coast of the Australian continent, not on the GBR. It is likely that these two species play similar ecological roles to *Pomacentrus wardi* and *Plectroglyphidodon apicalis*, which are two of the most abundant species on inshore reefs of the GBR (Figure 11).

Another species, *Chelmon marginalis*, is found on the GBR but at very low abundance, and this species likely replaces *Chelmon rostratus*, which is abundant on the GBR but not found in the GOC (Figure 11).

Species richness at the Wellesley Islands reefs is low compared to inshore reefs in the GBR, and several groups that are common on the GBR are either not represented or are less abundant in the GOC (Malcolm 1998). For example, the wrasse genus, *Cheilinus* (which includes the iconic maori wrasse, *Cheilinus undulatus*), which is common on the GBR, is not found in the GOC. There were also fewer planktivores at the Wellesley Islands compared to inshore reefs on the GBR. The barcheek

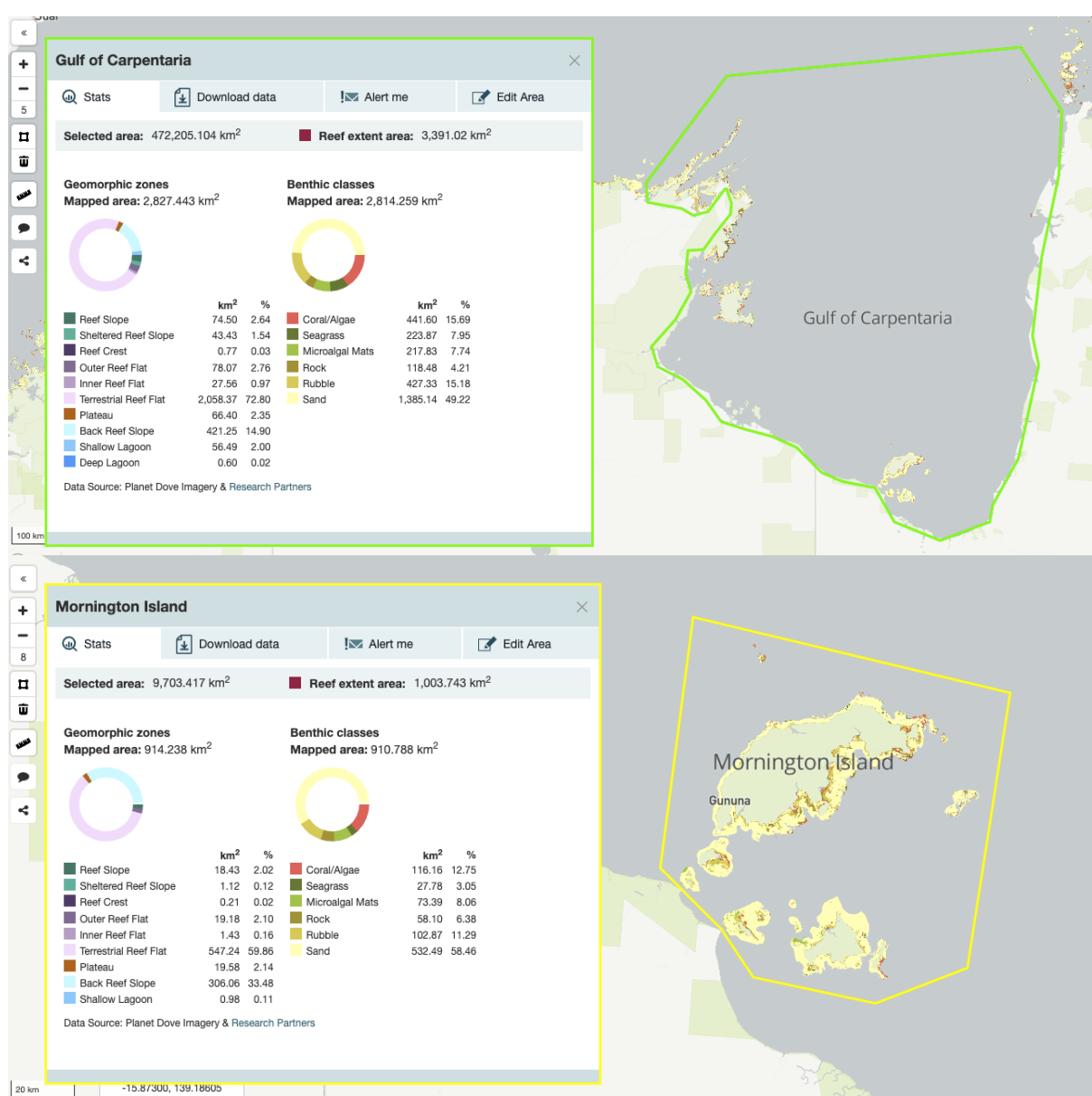


Figure 10: Allen Coral Atlas analysis of geomorphic zones and benthic cover classes: (A) around the Gulf of Carpentaria, and (B) around Mornington Island.

coral trout, *Plectropomus maculatus*, the only coral trout species recorded around the Wellesley Islands was abundant and large (>50 cm) individuals were recorded at most of the reefs where there was reasonable coral habitat or structural complexity (Malcolm 1998).

Johnson and Gill (2005) reported a total of 162 fish species around Sweers Island and 63 around North Bountiful Island from collections and observations made in 2002 from a range of different habitat types, i.e. not just coral reefs. They reported that the coral assemblages at Sweers Island were depauperate and suggested that there may have been some habitat degradation of coral reefs in this area.

Table 1. Number of fish species counted in a 45-minute timed swim at each site (Source: Malcolm 1998).

| Site | Island                     | Survey period | Number of species |
|------|----------------------------|---------------|-------------------|
| H1   | Mornington (Hall's Reef)   | Oct 1997      | 29                |
| H2   | Mornington (Hall's Reef)   | Oct 1997      | 28                |
| H2   | Mornington (Hall's Reef)   | May 1998      | 34                |
| G1   | Mornington (Gilitja Point) | Oct 1997      | 26                |
| R1   | Rocky                      | Oct 1997      | 62                |
| R1   | Rocky                      | May 1998      | 53                |
| R3   | Rocky                      | May 1998      | 30                |
| M1   | Manowar                    | Oct 1997      | 49                |
| M1   | Manowar                    | May 1998      | 59                |
| M2   | Manowar                    | May 1998      | 57                |
| P2   | Pisonia                    | Oct 1997      | 37                |
| P3   | Pisonia                    | Oct 1997      | 35                |
| B1   | North Bountiful            | Oct 1997      | 19                |
| B2   | North Bountiful            | Oct 1997      | 30                |
| SB1  | South Bountiful            | Oct 1997      | 30                |

Table 2. The most common coral reef fish species at Manowar (Ma), Rocky (R), Pisonia (P), Mornington (Mo) and Bountiful (B) Islands (recreated from Malcolm 1998) and their relative abundance. Sites at Mornington Island were divided into those at Hall's Reef (H) and Gilitja Point (G). Relative abundance categories: rare (r) = 1 to 5 individuals per timed swim, common (c) = 6 to 125 individuals; abundant = 126 to >3125 individuals.

| Common name             | Genus and species               | Island |   |   |        |        |   |
|-------------------------|---------------------------------|--------|---|---|--------|--------|---|
|                         |                                 | Ma     | R | P | Mo (H) | MO (G) | B |
| Bar-cheeked coral trout | <i>Plectropomus maculatus</i>   | c      | c | c | c      | c      | c |
| Stripey snapper         | <i>Lutjanus carponotatus</i>    | c      | a | a | a      | c      | c |
| Grass emperor           | <i>Lethrinus laticaudus</i>     | c      | c | c | c      | c      | c |
| Margined coralfish      | <i>Chelmon marginalis</i>       | r      | c | c | c      | c      | c |
| Blue tuskfish           | <i>Choerodon cyanodus</i>       | c      | c | c | c      | a      | c |
| Blackspot tuskfish      | <i>Choerodon schoenleinii</i>   | c      | c | c | c      | r      | c |
| Goldlined butterflyfish | <i>Chaetodon aureofasciatus</i> | c      | c | c | c      | c      | c |
| Bengal sergeant         | <i>Abudefduf bengalensis</i>    | c      | c | c | c      | a      | a |
| Miller's damselfish     | <i>Pomacentrus milleri</i>      | c      | a | c | c      | c      | a |
| Western gregory         | <i>Stegastes obreptus</i>       | c      | c | c | c      | c      | c |
| Blackspot tuskfish      | <i>Choerodon schoenleinii</i>   | c      | c | c | c      | r      | c |

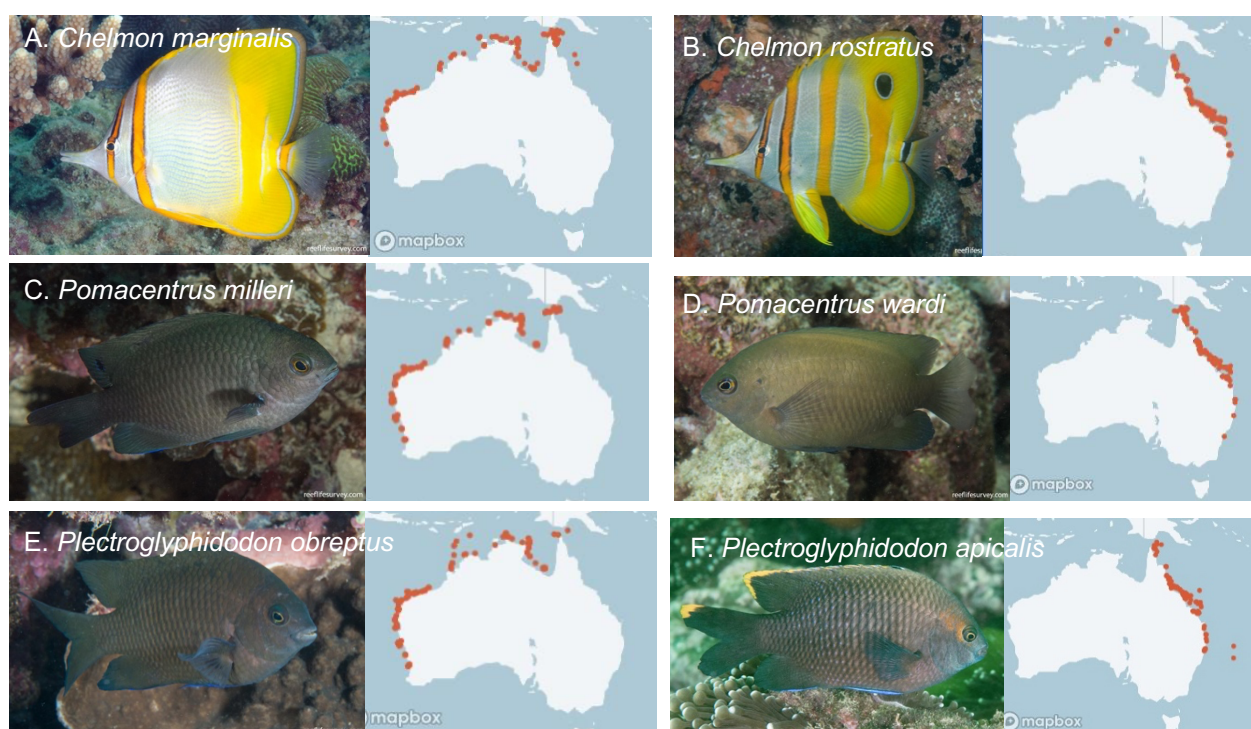
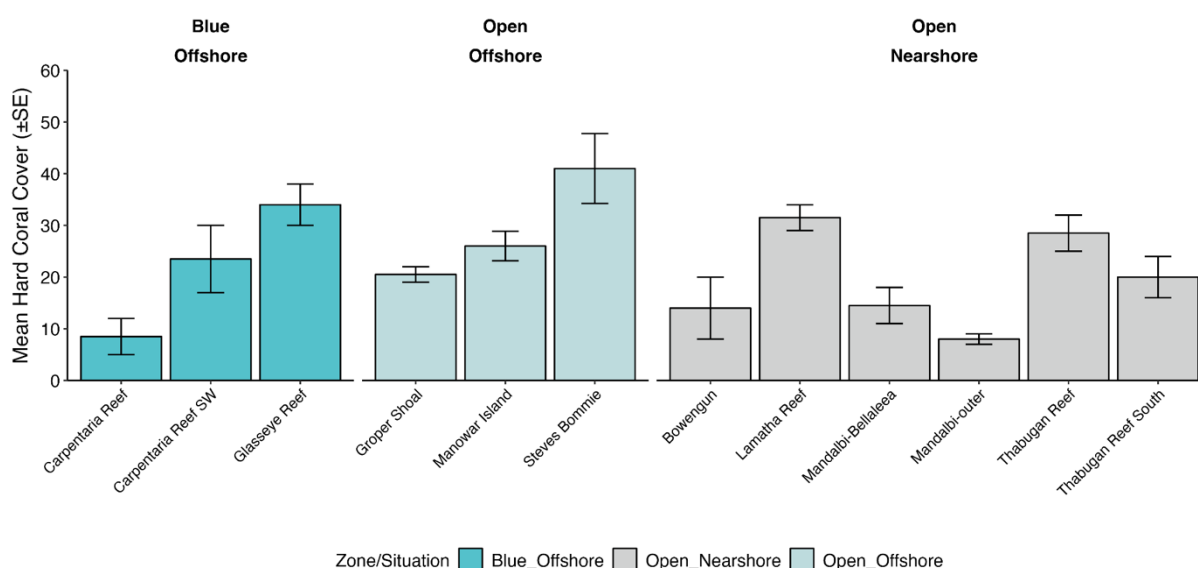


Figure 11: Examples of fish species that are abundant around the Wellesley Islands (left-hand side) but are either rare (A) or not found (C and E) on the GBR, and similar species (right-hand side) that are abundant on inshore reefs in the GBR but are not found around the Wellesley Islands. Photos and distribution maps from RLS website [reeflifesurvey.com](http://reeflifesurvey.com).

### 3.4. Surveys of benthic organisms and coral reef fishes – Reef Life Survey

#### 3.4.1. Reefs in the southern Gulf of Carpentaria: coral cover

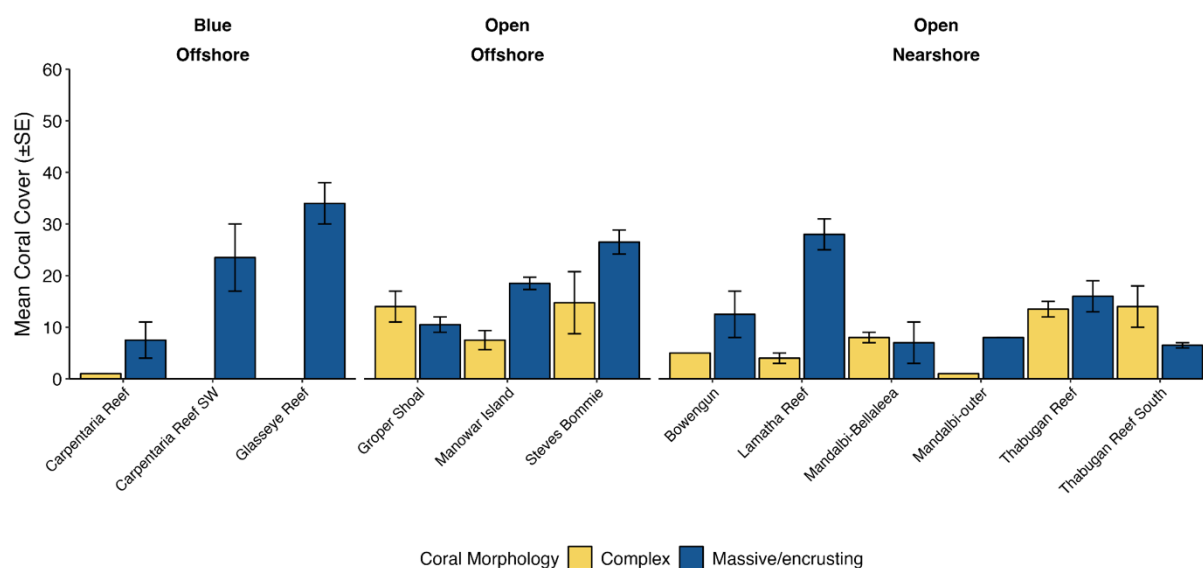
Hard coral cover was relatively high overall, though it varied considerably among sites in the southern GOC, ranging from 10 to 40% at the 12 sites for which benthic data were available (Figure 12). There was no obvious difference between offshore reefs and nearshore reefs. Two of the highest mean coral cover values were at offshore reefs (Steve's Bommie and Glasseye Reef), but one of the two lowest coral cover values was at an offshore reef (Carpentaria Reef). Benthic data were not available for 2 offshore sites within the GOCMP, Chinaman's Reef and Foggy Bottom.



*Figure 12:* Mean percent cover of hard corals at each site in the southern Gulf of Carpentaria, divided into offshore pinnacle reefs within the Gulf of Carpentaria Marine Park, offshore pinnacle reefs open to fishing (i.e. outside the Marine Park) and nearshore fringing reefs around Mornington Island. Coral data was not available for two of the offshore sites within the GOCMP (Chinaman's Reef and Foggy Bottom).

Corals were divided into two morphological categories, i.e. complex (e.g. branching, foliose and tabulate corals) and massive/encrusting. We found that while some sites had equal cover of both morphologies, generally there was a higher proportion of massive/encrusting corals on both offshore pinnacles and nearshore fringing reefs. Additionally, the coral assemblage at two of the sites on offshore pinnacles (Carpentaria Reef SW and Glasseye Reef) consisted solely of massive/encrusting corals (Figure 13).

Data for other kinds of benthic organisms, e.g. macroalgae, soft corals and sponges, from the photo-quadrats were not available. The photo-quadrats (examples in Figure 14) are publicly accessible online, but annotating these images to quantify other benthic organisms would be time-consuming and was beyond the scope of this project. RLS are in the process of re-annotating the photo-quadrats and identifying the corals to species level, so more detailed benthic data will be available in the near future.



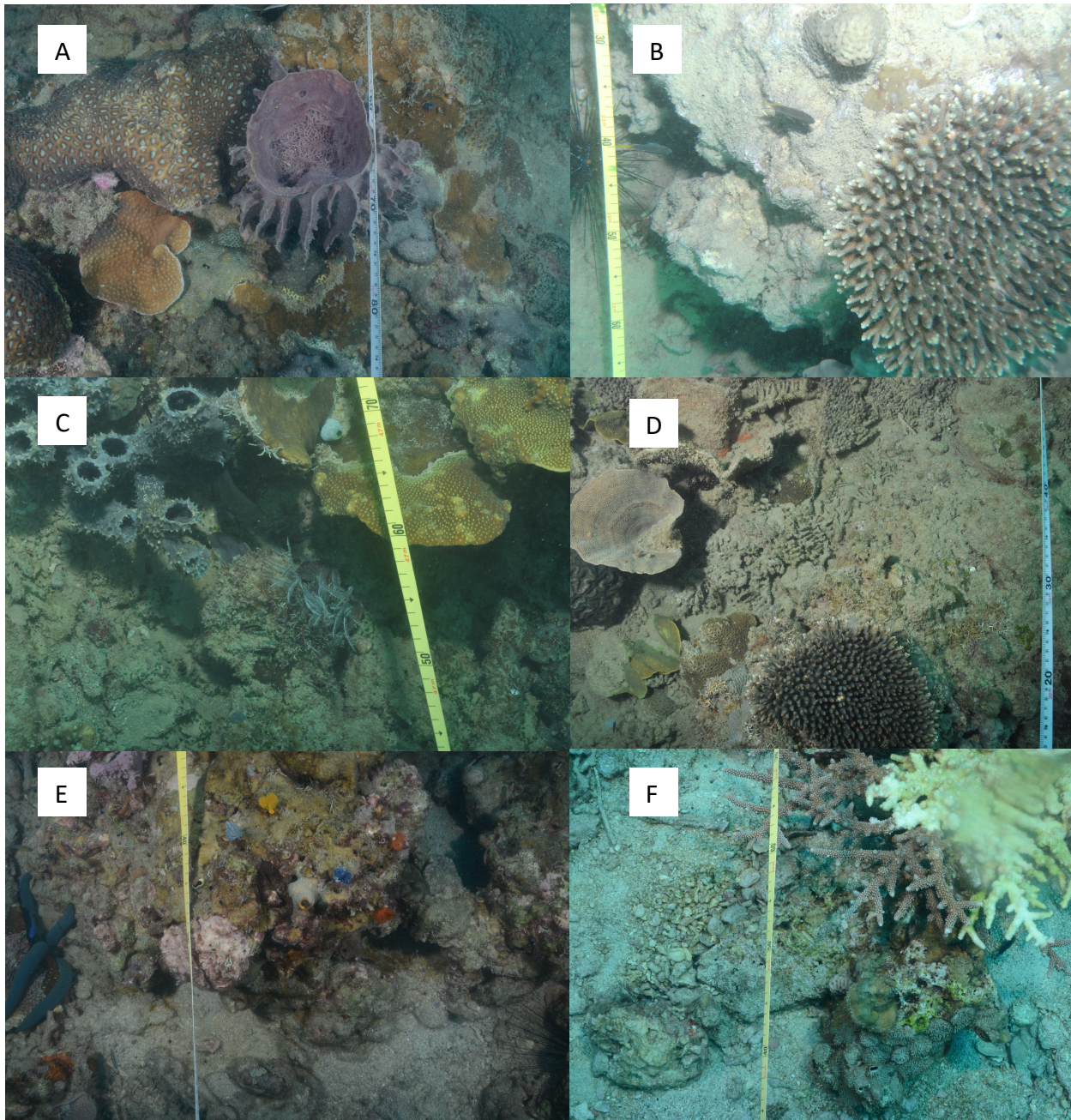
*Figure 13: Mean percent cover of corals in two broad morphological categories, i.e. complex corals (yellow bars) and massive/encrusting corals (dark blue bars) at each site in the southern Gulf of Carpentaria, divided into offshore pinnacle reefs within the Gulf of Carpentaria Marine Park, offshore pinnacle reefs open to fishing (i.e. outside the Marine Park) and nearshore fringing reefs around Mornington Island. Coral data was not available for two of the offshore sites within the GOCMP (Chinaman's Reef and Foggy Bottom).*

### 3.4.2. Reefs in the southern Gulf of Carpentaria: fish density, biomass and diversity

A total of 147 fish species were recorded from the 14 sites in the southern GOC, 19 of which were only recorded in the GOCMP (Figure 15, full species list available at [github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC)). Total fish density, biomass and species richness were higher at the offshore pinnacle sites compared to nearshore sites around Mornington Island (Figure 16). All three of these metrics varied considerably among the offshore pinnacles, but there were no differences between those within the marine park and those outside the park. This was expected given that these surveys were conducted in 2010 and 2015, prior to the establishment of the marine park in 2018. Although there were no obvious differences in coral cover between the offshore pinnacles and the nearshore reefs, these two types of reefs are very different in their physical structure, water depth, and distance from shore, which can affect fish abundance, size, and species composition. On the Great Barrier Reef, for example, reef fish densities, biomass and diversity vary significantly across the continental shelf due to various factors including reef type, complexity of the reef habitat and water quality (Williams 1982, Hoey & Bellwood 2008). Steep-sided pinnacles, seamounts and submerged shoals can significantly influence local currents, which can enhance vertical mixing and promote high primary productivity (Leitner et al. 2020), thus supporting higher abundances of organisms. In Papua New Guinea, pinnacle reefs support higher densities and biomass of fish, particularly large, predatory species (Cresswell et al. 2023, Galbraith et al. 2021, 2022).



There was no significant difference in Shannon-Weiner's diversity index ( $H$ ) between offshore pinnacle sites and nearshore sites (Figure 16). This index differs from species richness in that it considers both the number of species (i.e. species richness) and how evenly distributed the species are in terms of their relative abundance. Although the offshore pinnacle sites have higher fish species richness than the nearshore sites, there may be a small number of species that are numerically dominant, while there is greater evenness in the abundance of different species at the nearshore sites. Manowar Island had the highest value for  $H$  and was also one of the sites with the highest species richness (Figure 16).



*Figure 14: Examples of Reef Life Survey photo-quadrats from reefs in the southern Gulf of Carpentaria: A) Carpentaria Reef SW; B) Bownegun, Mornington Is.; C) Mandalbi-Bellaleea, Mornington Is.; D) Thabugan Reef South, Mornington Is.; E) Foggy Bottom; and F) Grouper Shoal. All RLS benthic survey images are available to download at [squiddle.org](https://squiddle.org).*



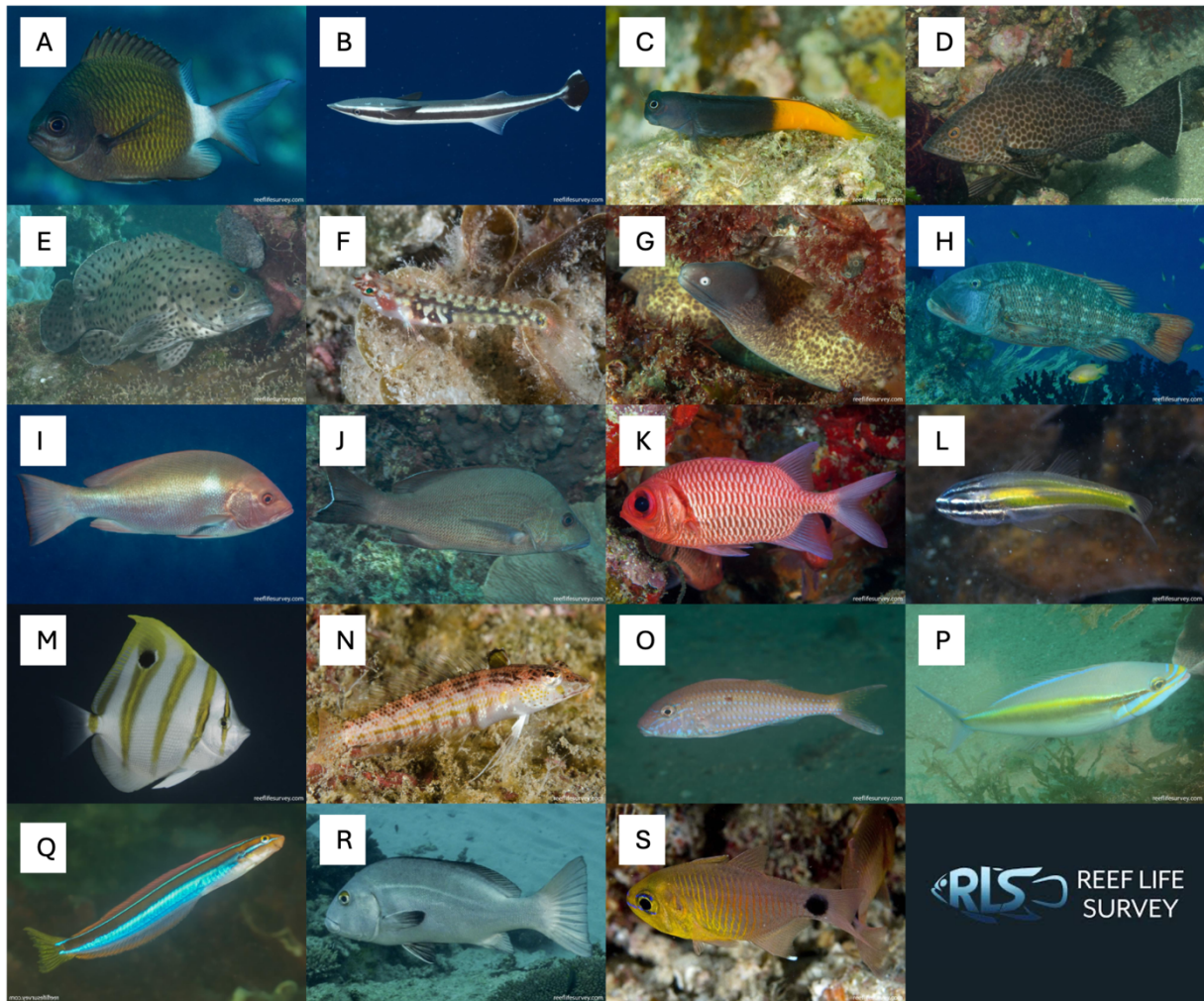
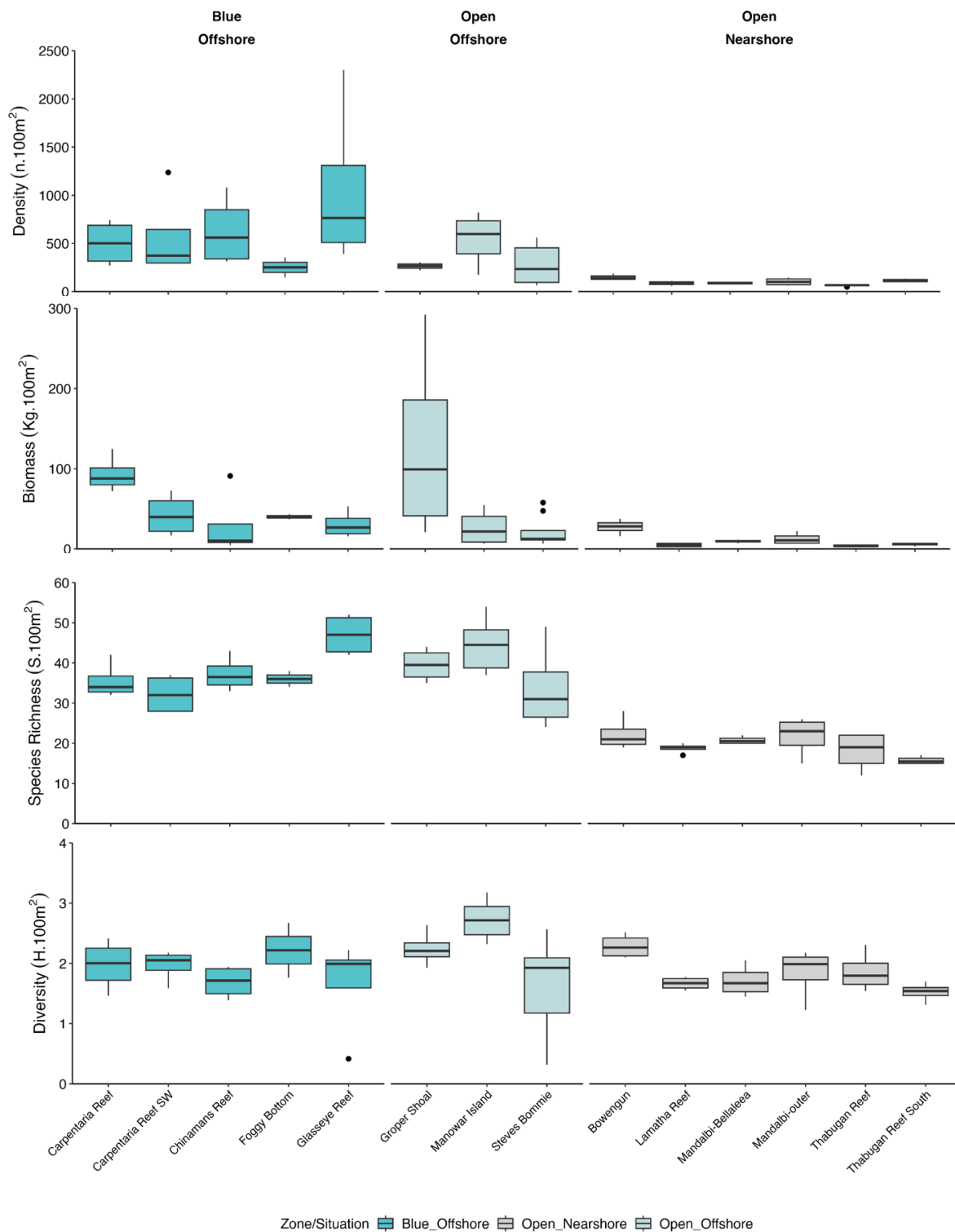


Figure 15: Nineteen species of reef fish only recorded by RLS in the five sites within the GOCMPA: A) *Chromis chrysura*, B) *Echeineis naucrates*, C) *Ecsenius bicolor*, D) *Epinephelus areolatus*, E) *Epinephelus corallicola*, F) *Eviota sigillata*, G) *Gymnothorax thyrsoideus*, H) *Lethrinus erythracanthus*, I) *Lutjanus erythropterus*, J) *Lutjanus lemniscatus*, K) *Myripristis hexagona*, L) *Ostorhinchus cavitensis*, M) *Parachaetodon ocellatus*, N) *Parapercis snyderi*, O) *Parupeneus heptacanthus*, P) *Pentapodus porosus*, Q) *Plagiotremus rhinorhynchus*, R) *Plectorhinchus caeruleonothus*, S) *Taeniamia fucata*. Photos from RLS website ([reeflifesurvey.com](http://reeflifesurvey.com)).



**Figure 16:** Boxplots of reef fish metrics at each of the 14 southern GOC sites: A) Total density (number of individuals of all fish species per 100 m<sup>2</sup>); B) Biomass (kg of fish per 100 m<sup>2</sup>); C) Species richness (number of species per 100 m<sup>2</sup>); and D) Shannon-Weiner Diversity Index. Darker blue boxes indicate offshore pinnacle sites within the Special Purpose (Trawl) Zone of the GOCMP, light blue boxes indicate offshore pinnacle sites outside the GOCMP, and grey boxes indicate nearshore fringing reefs around Mornington Island.

Non-metric multidimensional scaling (NMDS) ordination of fish species composition across sites in the southern GOC showed a clear separation of sites, with distinct clustering according to reef type (offshore pinnacle vs. nearshore fringing), and marine park status (blue zone vs open to fishing), although there was some overlap (Figure 17). The five offshore sites in the GOCMP and one of the offshore sites outside the GOCMP were in a distinct cluster, possibly due to their location (i.e. further north than the other sites) and depth. On the GBR, reef fish community structure is known to change considerably across the continental shelf due to a variety of factors, including water quality, reef type, and habitat complexity (Williams 1982).

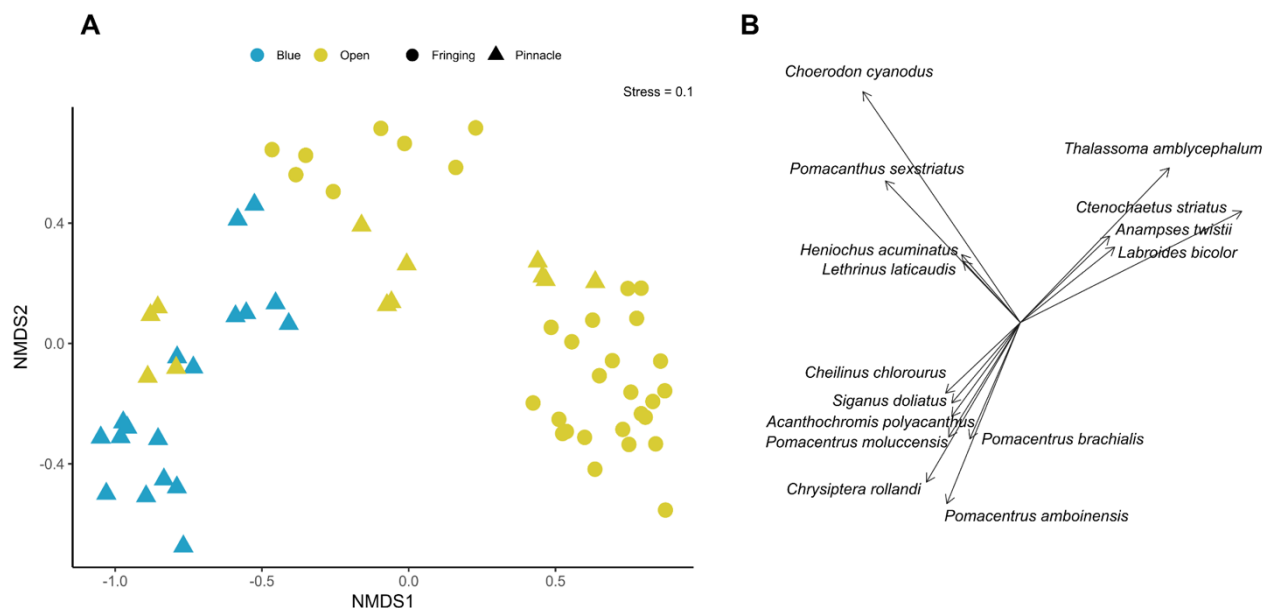


Figure 17: Non-metric multidimensional scaling (NMDS) ordination of fish species composition across reefs in the southern Gulf of Carpentaria with a species biplot. Points represent replicate survey blocks (i.e. 4 per site), with colours indicating marine park status (i.e. blue/yellow for within/outside the GOCMP) and shapes representing the two reef types (i.e. circle/triangle for offshore pinnacle/nearshore fringing). Vectors indicate the species that most strongly influence variation in community structure, with direction and length representing the strength and orientation of species associations with the ordination axes.

### 3.4.3. Coral cover and reef fish metrics at reefs in the southern Gulf of Carpentaria: how do they compare with reefs in other areas of the Gulf?

Mean coral cover values at sites in the southern GOC were in the same range as sites in other parts of the GOC (Figure 18). There were two sites on the western side of the GOC with much higher mean coral cover: East Bremer Islet Bay (76%) and Cape Beatrice SW (61%). As with the southern GOC sites, there were many sites in other parts of the GOC that had a higher proportion of massive/encrusting corals than complex corals, but there were also a few sites with a higher proportion of complex corals than massive/encrusting corals (Figure 19).

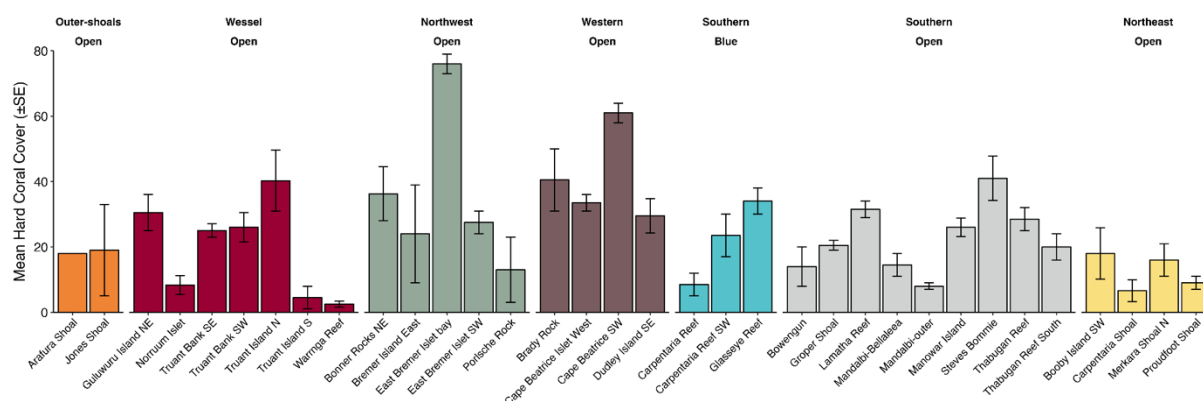


Figure 18: Mean hard coral cover per site at 34 sites across the Gulf of Carpentaria surveyed by Reef Life Survey in 2010 and 2015, including the 12 sites in the southern GOC (blue and grey bars) for which coral cover data were available.

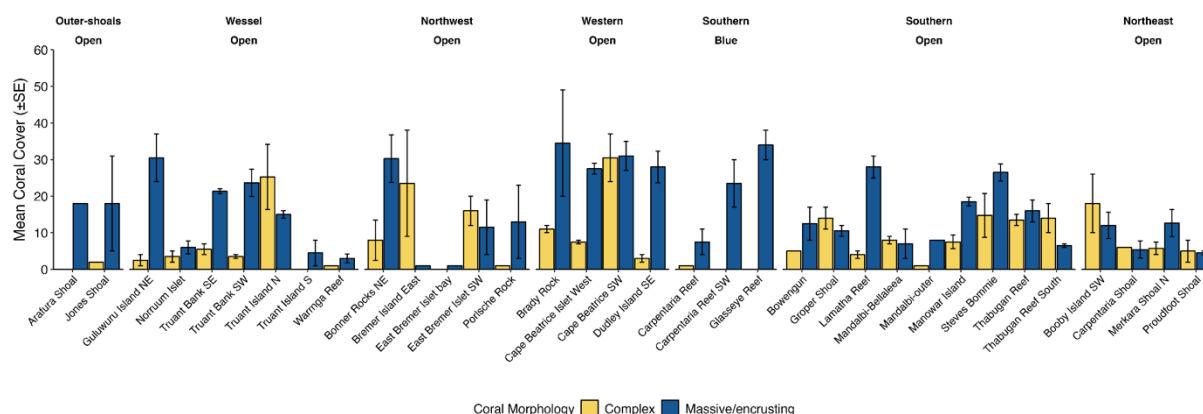


Figure 19: Mean percentage hard coral cover per site, divided in two broad morphological categories (i.e. complex corals (yellow bars) and massive encrusting corals (dark blue bars)) at 34 sites across the Gulf of Carpentaria surveyed by Reef Life Survey in 2010.

Total fish density and biomass were both relatively high at some of the southern GOC sites, particularly those in the Special Purpose (Trawl) Zones of the GOCMP, compared to sites elsewhere in the GOC (Figure 20). One of the sites in the southern GOC, Carpentaria Reef, had the highest biomass out of the 36 sites in the GOC that were examined. Species richness and diversity (H) varied considerably among sites within regions across the GOC, and sites in the southern GOC had similar ranges in species richness and diversity (H) as sites elsewhere in the GOC (Figure 20). One of the southern GOC sites, Manowar Island, had the highest species richness and one of the highest H values among the 36 sites (Figure 20).



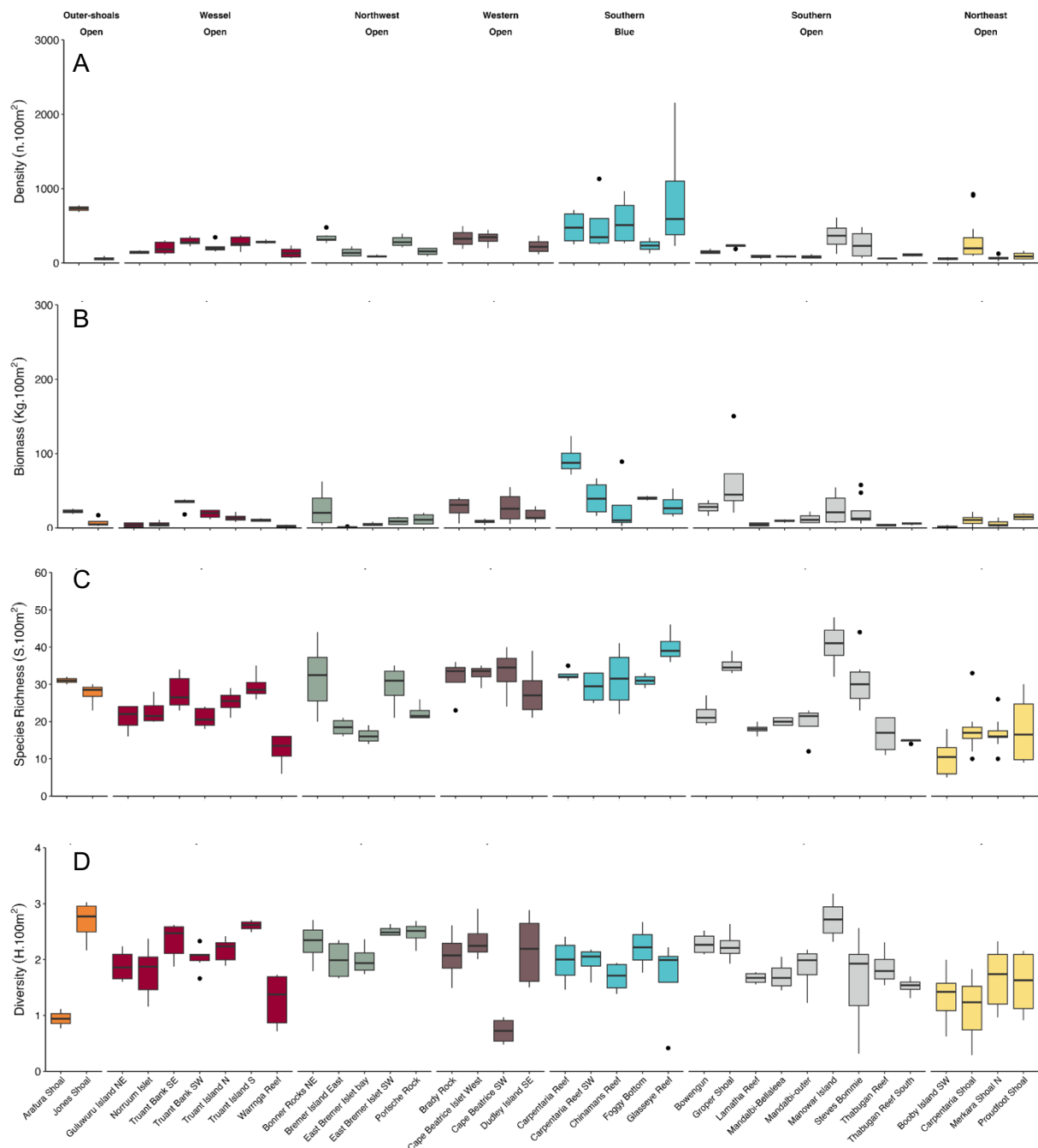
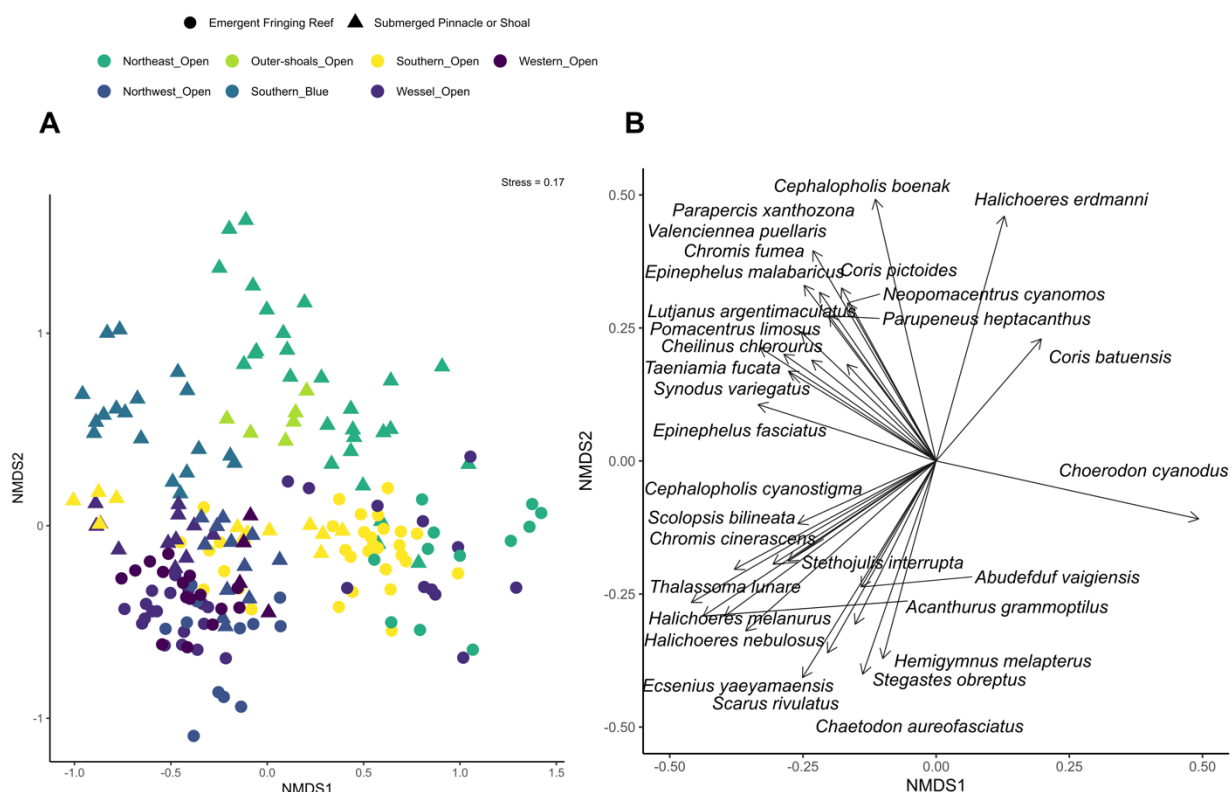


Figure 20: Boxplots of reef fish metrics at 36 sites across the Gulf of Carpentaria, including the 14 southern GOC sites: A) Total density (number of individuals of all fish species per 100 m<sup>2</sup>); B) Biomass (kg of fish per 100 m<sup>2</sup>); C) Species richness (number of species per 100 m<sup>2</sup>); and D) Shannon-Weiner Diversity Index.

Non-metric multidimensional scaling (NMDS) ordination of fish species composition across 36 sites in the southern GOC showed a clear separation of sites, with distinct clustering according to reef type (offshore pinnacle vs. nearshore fringing), i.e. there is a difference in fish species composition between offshore submerged reefs and emergent fringing reefs across the GOC (Figure 21).



**Figure 21:** Non-metric multidimensional scaling (NMDS) ordination of reef fish species composition across 36 sites in the Gulf of Carpentaria with a species biplot. Points represent replicate survey blocks (i.e. 4 per site), with colours indicating GOC region and fishing status (i.e. blue/yellow for southern GOC reefs within/outside the GOCMP, other colours for reefs in other GOC regions) and shapes representing the two reef types (i.e. circle/triangle for offshore pinnacle/nearshore fringing). Vectors indicate the species that most strongly influence variation in community structure, with direction and length representing the strength and orientation of species associations with the ordination axes.

### 3.4.4. Reef fish species composition at reefs in the southern Gulf of Carpentaria compared to reefs in Western Australia and the GBR

Non-metric multidimensional scaling (NMDS) ordination of fish species composition across sites at similar latitudes in the southern GOC, Western Australia (WA) and the GBR showed a clear separation of sites according to region (Figure 22). Sites in the GOC were clustered together and distinct from most of the WA and GBR sites, although there were a few WA and GBR sites that had similar species composition to sites in the GOC. The fish communities on reefs in the southern GOC are a mixture of widespread Indo-Pacific species, species that are found throughout northern Australia, and species that are only found in the GOC and northwestern Australia (Figure 23).

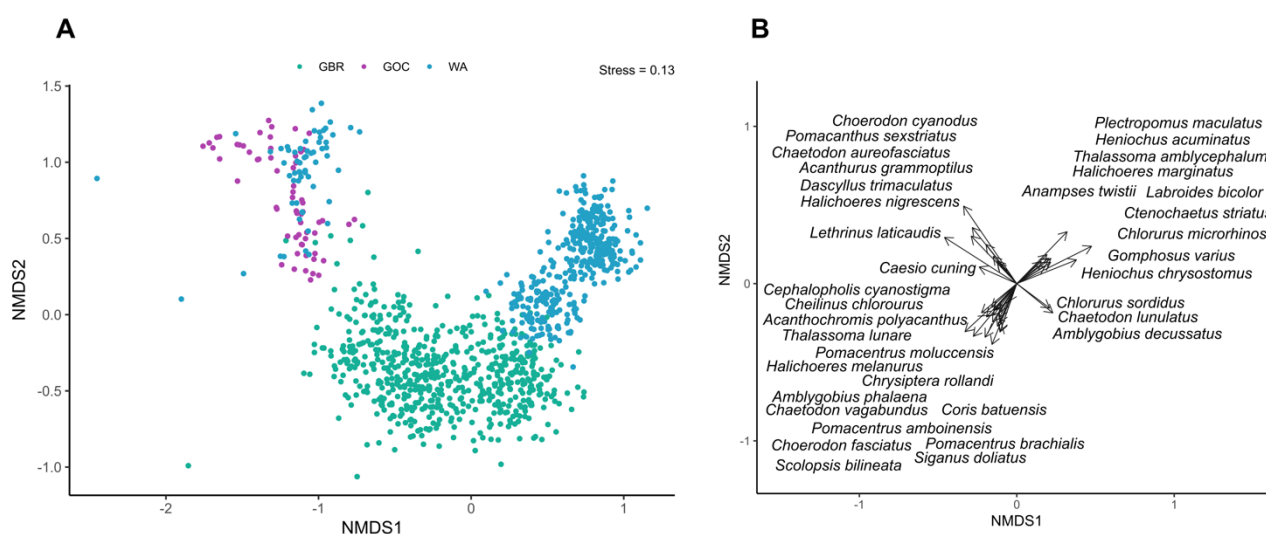


Figure 22: Non-metric multidimensional scaling (NMDS) ordination of fish species composition across reefs in a similar latitudinal range in the southern Gulf of Carpentaria, Western Australia and the GBR, with a species biplot. Points represent replicate survey blocks (i.e. four per site), with colours indicating region (i.e. green for GBR, purple for southern GOC and blue for Western Australia). Vectors indicate the species that most strongly influence variation in community structure, with direction and length representing the strength and orientation of species associations with the ordination axes.

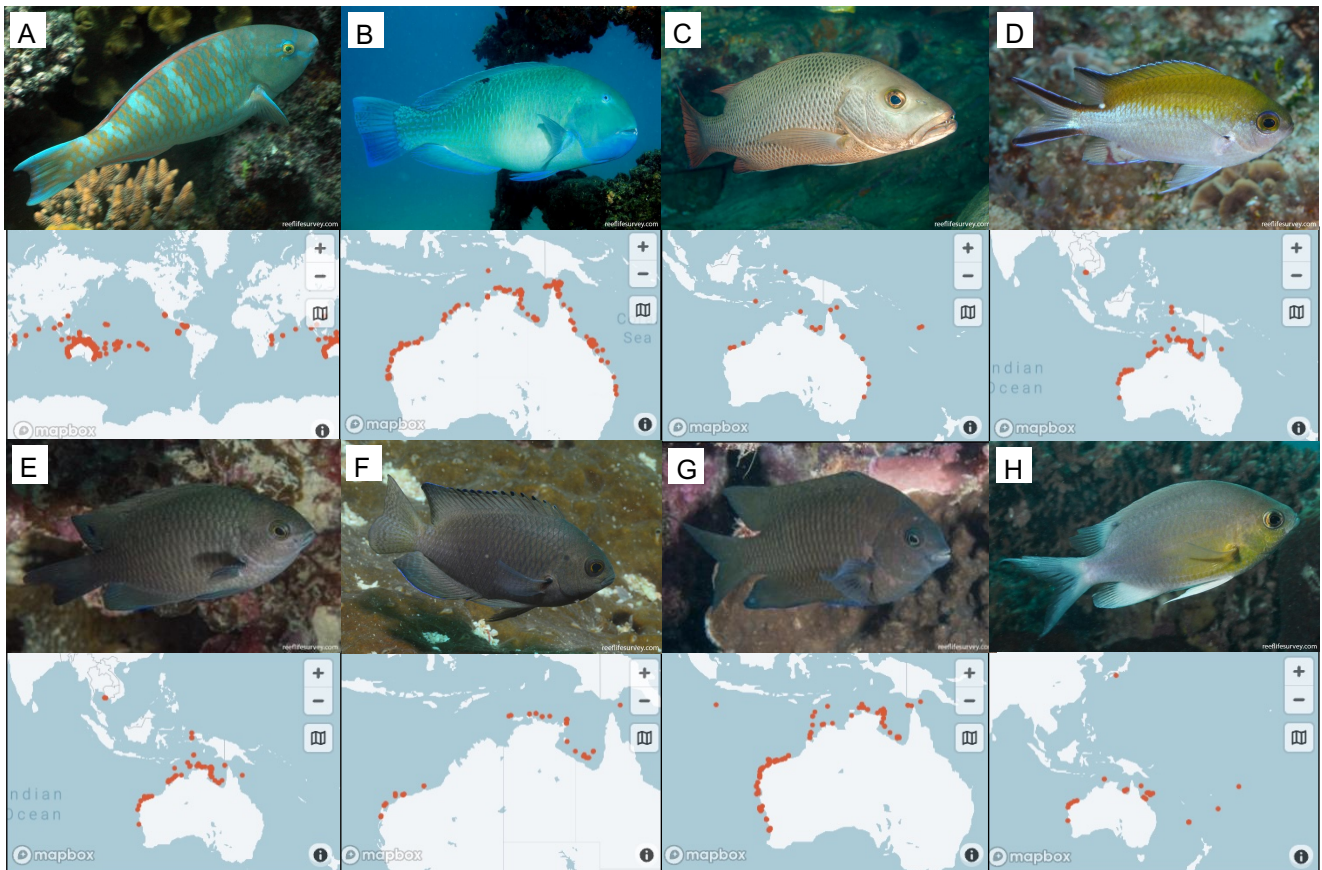


Figure 23: Examples of fish species with different geographic distributions that are abundant in the southern Gulf of Carpentaria, including widespread Indo-Pacific species: (A) bluebarred parrotfish (*Scarus ghobban*); species found mainly throughout northern Australia: (B) blackspot tuskfish (*Choerodon schoenlini*), (C) mangrove jack (*Lutjanus argentimaculatus*), and (D) green puller (*Chromis cinerascens*); and species found only in the Gulf of Carpentaria, northwestern Australia and parts of Papua New Guinea/West Papua: (E) Miller's damsel (*Pomacentrus milleri*), (F) muddy damsel (*Pomacentrus limosus*), (G) western gregory (*Plectroglyphidodon obreptus*), and (H) smoky puller (*Chromis fumea*).

### 3.4.5. Other reef organisms

Twenty unique species of sessile and reef-associated invertebrates were recorded by RLS from the 14 sites in the southern GOC, with an additional nine genera not identified to species level. This included four species of sea cucumber (family Holothuriidae and Synaptidae), five species of nudibranch, giant clams (genus *Tridacna*) and spiny lobster (genus *Panulirus*). *Acanthaster cf. planci* (Crown of Thorns Starfish) was only recorded from three sites in benthic surveys (2010 and 2015) and in very low densities, i.e. one individual each at Steve's Bommie and Manowar Island in 2010, and one and five individuals at Steve's Bommie and Foggy Bottom, respectively, in 2015.

The raw data is available in the Project 4.24 repository: [github.com/gfgalbraith/NESP\\_4.24\\_GOC](https://github.com/gfgalbraith/NESP_4.24_GOC).

### 3.4.6. Potential limitations of RLS methods

While the RLS method is efficient and well-standardised, and the program is valuable for assessing reef health and biodiversity over a large geographic area, both around Australia and internationally, it has received some criticisms. These include potential observer bias in species identification and counts, as surveys are often conducted by volunteer, recreational divers, though RLS conducts diver training to ensure consistency among observers and minimise errors, and data are checked by experts. The RLS survey trips to the GOC in 2010 and 2015 were led by Graham Edgar, the founder of RLS, who oversaw all aspects of data collection; therefore, we consider the data to be reliable. Another criticism is the limited number of transects per site (i.e. two) and the use of 5 m wide 'blocks' on either side of the same transect as replicates. Non-independent replicates on either side of the same transect may inflate apparent patterns and reduce the reliability of statistical tests. In addition, there are known methodological issues with laying the transect line prior to conducting reef fish surveys (Dickens et al. 2011, Emslie et al. 2018). The process of laying the transect line involves a diver swimming directly along the survey area, often causing larger, more mobile or wary species (e.g. sharks, trevallies, groupers) to move away from the area temporarily. This can lead to underestimation of fish abundance, particularly for large, mobile or diver-shy species, which can lead to biased assessments of community composition, trophic structure or predation pressure (Kulbicki 1998, Emslie et al. 2018).

## 3.5. Fishing activities in the southern Gulf of Carpentaria

### 3.5.1. Commercial fishing

The main commercial fishing activities in the southern GOC are commercial prawn trawling, managed by the Australian Fisheries Management Authority (a federal government agency) and commercial line and net fishing, managed by the Queensland Department of Primary Industries. All commercial prawn trawling is conducted under the banner of the Northern Prawn Fishery Industry Pty Ltd (NPF), and there are 52 licenced vessels operating in the GOC and northern Australian waters (Figure 24). The NPF has been recognised for effective co-management, with long-term access arrangements, robust data collection, regular stock assessments, and stakeholder participation (Stone 2004). In a meeting with the NPF CEO, Annie Jarret and Projects Manager, Brandon Meteyard, we were informed that their vessels are equipped with sonar and that operators are aware of the reefs in areas where they trawl, including uncharted reefs. Areas of reef are actively avoided in order to protect trawling equipment, all trawling equipment is fitted with turtle



excluder and bycatch reduction devices, and crew members collect data on bycatch levels and interactions with threatened species (NPFI website: [npfindustry.com.au](http://npfindustry.com.au)).

Commercial line fishing is managed under the GOC Line Fishery (GOCLF) and commercial net fishing is managed under the GOC Inshore Fin Fish Fishery (GOCIFFF), which includes four operating areas, N3, N11, N12 and N13 (Figure 25). The GOCLF is a multispecies line fishery primarily targeting Spanish mackerel, and the GOCIFFF targets a range of species. The inshore net component (N3) primarily targets river and nearshore fish species such as barramundi and threadfin, the commercial bait netting component (N11) targets small species commonly used as bait, the offshore net component (N12 and N13) targets sharks and grey mackerel. Fishing effort is quantified in fishing-days and is assessed by the fisheries manager using data from logbooks, VMS, and catch reporting, which allows for spatial comparisons of fishing pressure. Fishing effort maps between 2015 and 2017 indicate that, at that time, all of the effort was in inshore areas managed under N3 and N12 fishery symbols (Fisheries Queensland 2019, Figure 26). Fishing effort was low to moderate around the Wellesley Islands (Figure 26).

It is a requirement that commercial fishers record interactions with threatened species. This is defined as any physical contact, including contact with fishing gear and vessel collisions. The majority of interactions logged between 2003 and 2017 involved sawfish, crocodiles and turtles, but also included a small number of cetaceans, rays and sea snakes (Fisheries Queensland 2019).

### 3.5.2. Recreational fishing

Recreational fishing occurs around Wellesley Island, and there is a small fishing lodge on Sweers Island, but there are no fishing charter operators. Due to its remote location, this region has much lower pressure from recreational fishing than similar inshore island locations on the east coast of Queensland. There were no data available on recreational fishing effort for Mornington Island coastal waters in the statewide recreational fishing survey (Business Queensland website: [dpi.qld.gov.au/business-priorities/fisheries/monitor/rec/statewide-survey](http://dpi.qld.gov.au/business-priorities/fisheries/monitor/rec/statewide-survey)).

### 3.5.3. Apparent fishing activity

Apparent fishing activity data for the southern GOC since 2014, extracted from Global Fishing Watch (GFW), indicates that fishing activity within the Special Purpose (Trawl) Zones of the GOCMP ranged between 8 and 460 hours per year (Table 3). This is relatively low compared to areas closer to the coast, where apparent fishing effort reached a maximum of 3,770 hrs per year (in 2023) during the same time period (Figure 27). Although there was some apparent fishing activity in the Green Zone of the GOCMP, this was also very low, ranging from 0 to 26 hours per year, even in the years prior to the establishment of the marine park in 2018 (Table 3). The highest apparent fishing activity per year over the whole GOC occurred in 2023, followed by 2024 and 2018 (Figure 27). High apparent fishing activity in a particular year may indicate periods of lower catch per unit effort.

Spatial data visualising perceived fishing effort from GFW should be treated as a conservative estimate given that AIS is compulsory only for larger vessels (typically those over 300 gross tonnage) (International Maritime Organisation 2002), it is more commonly used by international and industrial fishing fleets (e.g., longliners, trawlers) and is therefore less likely to be carried or consistently transmitted by small-scale, domestic, or nearshore fisheries, which are common in Australian waters. As a result, the absence of VMS data means GFW likely underrepresents

domestic commercial fishing effort (e.g. inshore trawl or trap fisheries), small vessel operations targeting reef fish, crustaceans, or other demersal species and activities within the Exclusive Economic Zone (EEZ) that do not require AIS broadcasting. Consequently, these data are presented as a visual indicator of broad scale human use patterns within the region rather than as a measure of absolute, localised fishing pressure.

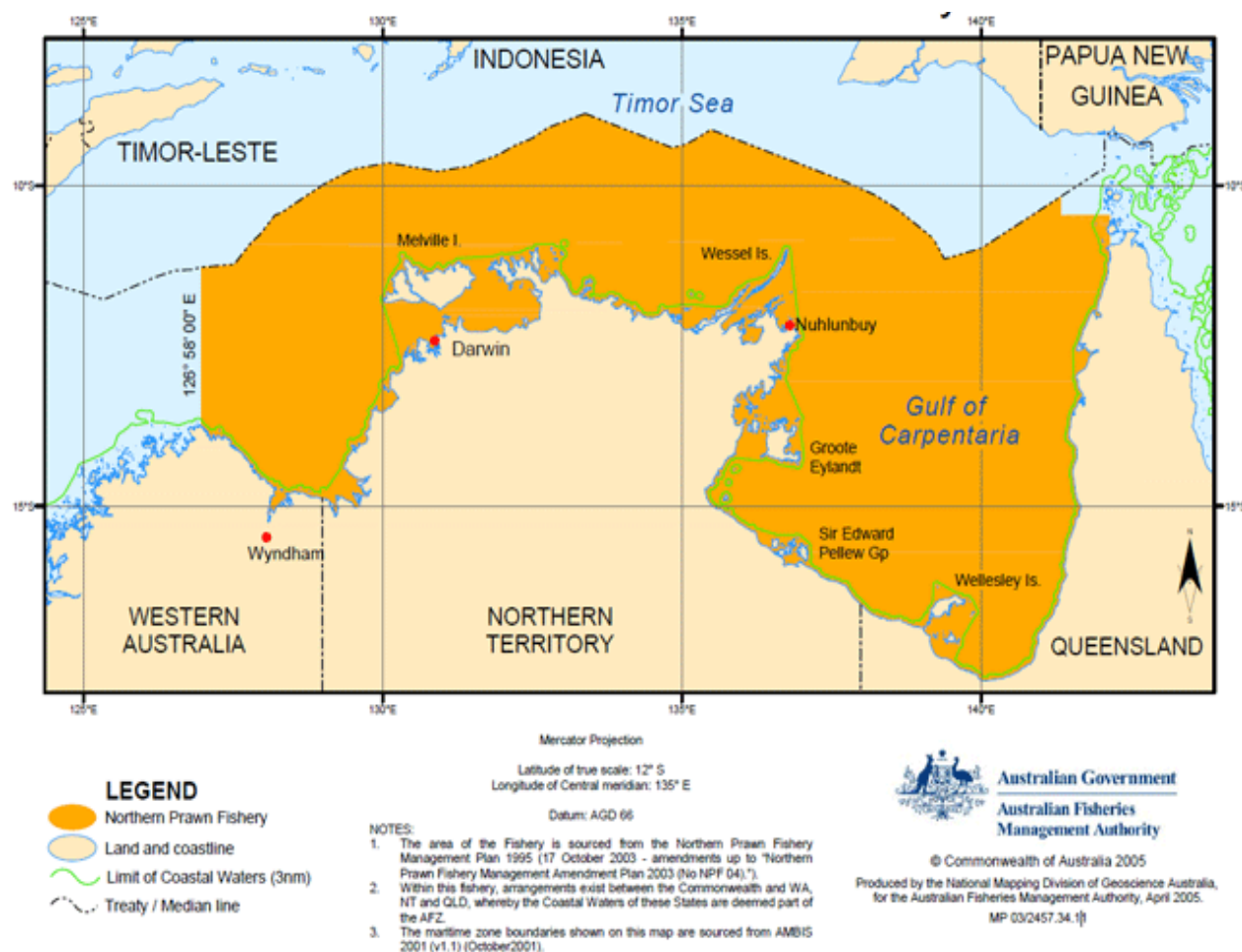


Figure 24: Map of northern Australia showing the area of the Northern Prawn Fishery. Source: Australian Fisheries Management Authority ([afma.gov.au/fisheries/northern-prawn-fishery](http://afma.gov.au/fisheries/northern-prawn-fishery)).

In a meeting with NPFI's CEO and Projects Manager, it was suggested that spatial patterns of actual fishing effort were similar to apparent fishing effort, though actual fishing effort was slightly higher in the blue zones of the GOCMPA. A few of the hotspots for apparent fishing effort were in areas of complex bathymetry that trawl operators would generally avoid, as they have the navigation equipment and experience to avoid areas of reef. These hotspots are therefore more likely to reflect activity by line fishers operating on reefs.

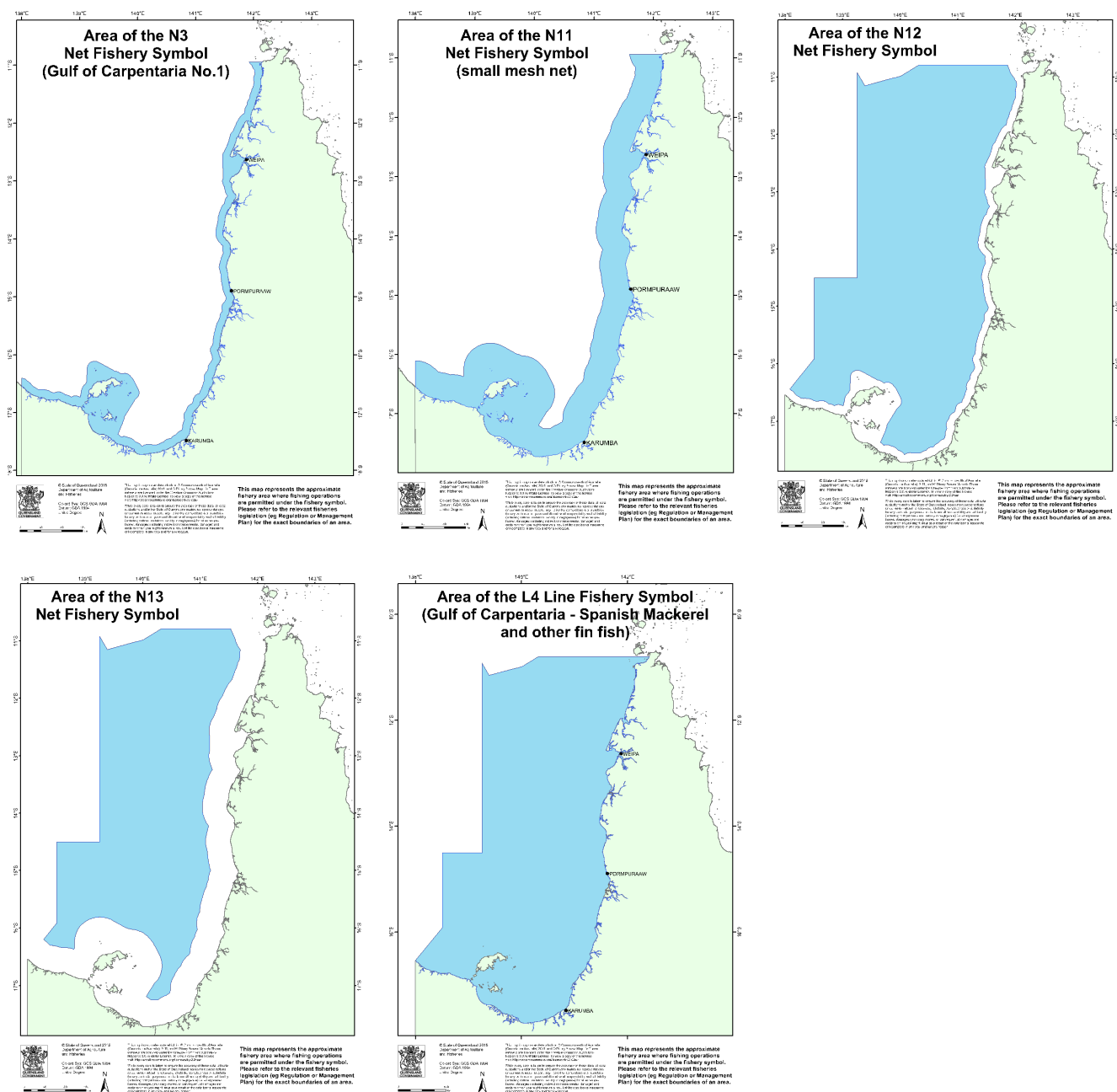


Figure 25: Operating areas of the Gulf of Carpentaria Inshore Fin Fish Fishery (N3, N11, N12 and N13) and the Gulf of Carpentaria Line Fishery (L4). Source: Business Queensland ([business.qld.gov.au/industries/farms-fishing-forestry/fisheries/commercial/profile/net/gulf](https://business.qld.gov.au/industries/farms-fishing-forestry/fisheries/commercial/profile/net/gulf)).

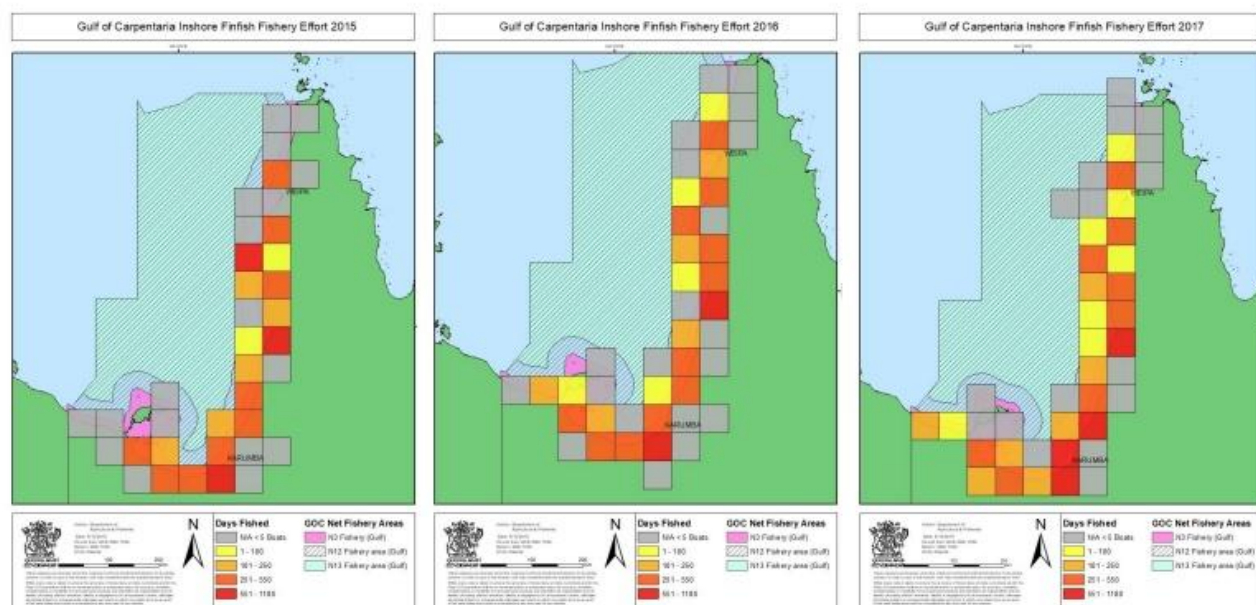


Figure 26: Distribution of fishing effort for the GOC Inshore Fin Fishery for 2015, 2016 and 2017. Grey squares are areas where effort has been reported, but information is protected by commercial-in-confidence provisions (i.e. contains < 5 boats). Source: QLD Dept of Agriculture and Fisheries 2019.

Table 3: Number of vessels and apparent fishing activity (hrs fishing) in the Gulf of Carpentaria Marine Park. Data downloaded from [globalfishingwatch.org](https://globalfishingwatch.org) 11/06/2025.

| Year             | Special Purpose Zone (Trawl) |                        | Green Zone (NTMR) |                        |
|------------------|------------------------------|------------------------|-------------------|------------------------|
|                  | Number of Vessels            | Apparent Fishing Hours | Number of Vessels | Apparent Fishing Hours |
| 2014             | 2                            | 220                    | 1                 | 0.7                    |
| 2015             | 1                            | 15                     | 0                 | 0                      |
| 2016             | 3                            | 300                    | 1                 | 0.3                    |
| 2017             | 2                            | 8                      | 1                 | 11                     |
| 2018             | 7                            | 192                    | 2                 | 6                      |
| 2019             | 2                            | 181                    | 1                 | 5                      |
| 2020             | 10                           | 236                    | 3                 | 26                     |
| 2021             | 10                           | 173                    | 2                 | 9                      |
| 2022             | 7                            | 133                    | 1                 | 8                      |
| 2023             | 14                           | 460                    | 3                 | 2                      |
| 2024             | 11                           | 177                    | 1                 | 1                      |
| 2025 (until May) | 3                            | 32                     | 0                 | 0                      |



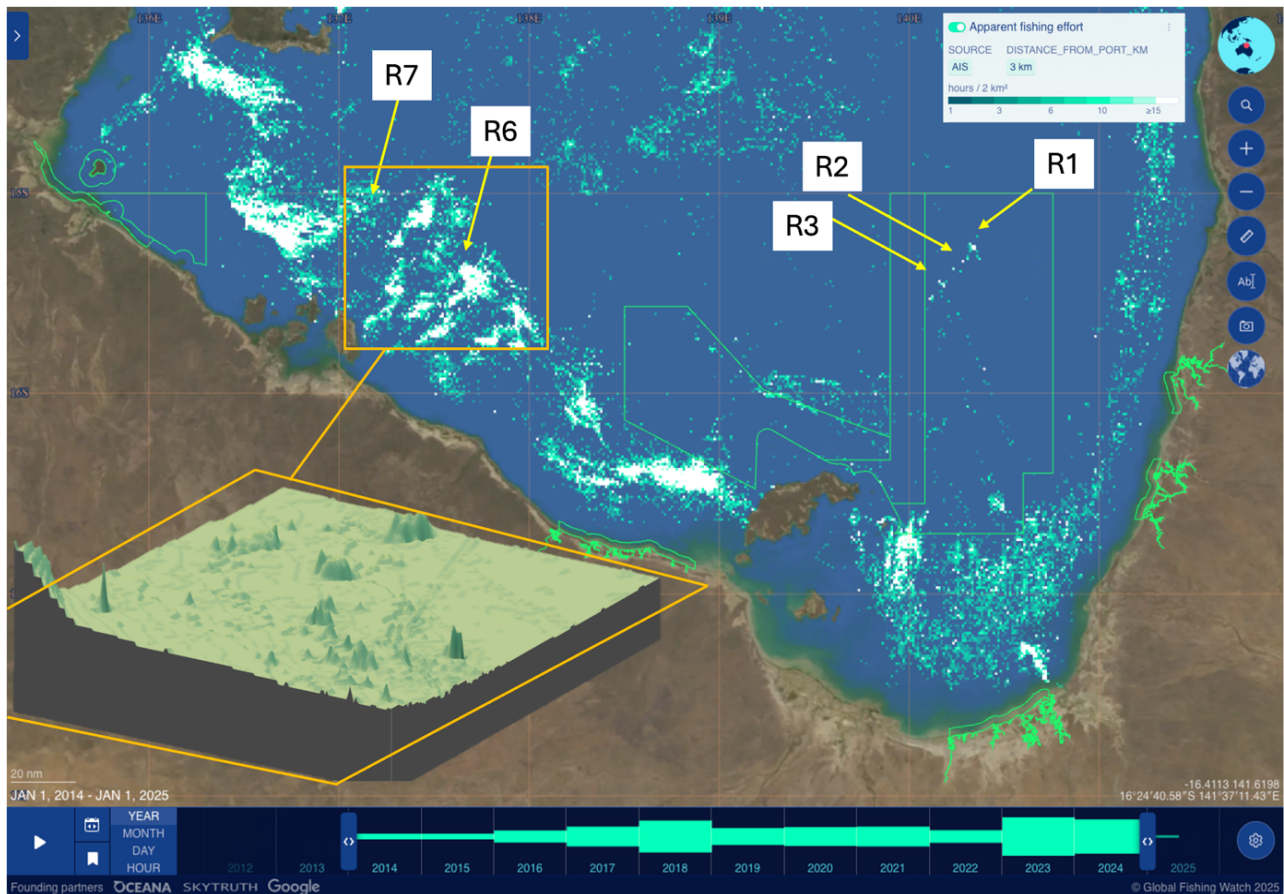


Figure 27: Apparent fishing effort (hrs) in the Southern Gulf of Carpentaria between 2014 and 2024 relative to five submerged reefs mapped by Harris et al. 2008 and the underlying bathymetry of submerged reefs in the south west Gulf of Carpentaria. Heat maps generated from data available at [globalfishingwatch.org](https://globalfishingwatch.org).

### 3.6. Potential impacts from disturbance events on the southern GOC reefs

There has been an alarming trend of coral decline on reefs worldwide in the last three decades as reefs face increasing frequencies of disturbance events like coral bleaching, severe weather events and crown-of-thorns starfish (COTS) outbreaks. The GBR has experienced seven mass coral bleaching events, with five of these events occurring in the last 10 years, and there have been five coral bleaching events documented on Western Australian reefs. The frequency of severe weather events such as cyclones and flooding has been increasing due to climate change. Terrestrial runoff during flooding events can significantly reduce salinity and increase sedimentation on reefs. For example, in 2011, a flood plume from the Fitzroy River caused widespread mortality of corals at the Keppel Islands (Jones & Berkelmans 2014), and some reefs have undergone a shift to macroalgal-dominated reefs with very low coral cover (M. Srinivasan, pers. obs., 2024). COTS outbreaks are one of the primary, non-climate related causes of coral decline on the GBR, with 42% of the loss in coral cover on the GBR between 1985 and 2012 attributed to COTS outbreaks (De'ath et al. 2012).

The only comprehensive ecological surveys of coral reefs in the southern GOC were conducted in 2010 and 2015, and the results presented here may not be indicative of the current condition of these reefs. There is a range of potential impacts that could have impacted benthic and fish communities in the past 10 years. Johnson and Gill (2005) mentioned anecdotal reports of large stands of coral on the southeastern side of Sweers Island in the early 1970s, and suggested that



these reefs had degraded due to some disturbance event. Malcolm (1998) reported that although there was a major bleaching event on inshore fringing reefs in the GBR during the 1997–1998 wet season, which was still ongoing in May 1998, he observed only minor partial bleaching during his surveys around the Wellesley Islands over the same time period. A total of two COTS observations (Figure 28) were recorded from two sites during RLS surveys in 2010 and in 2015, there was one individual recorded at one site and five at another. Abundances of one or two individuals per site are likely to be natural densities; however, the five individuals at one site in 2015 may be indicative of the beginnings of a COTS outbreak, which is characterised by densities above 10–15 individuals per hectare.

A recent study examining freshwater plumes from the Flinders and Gilbert River systems, which flow into the southern GOC, showed that a flood plume from the Flinders River reached the Wellesley Islands during the wet season of 2019 (Figure 29, Burford et al. 2024). There are other river systems entering the southern Gulf closer to the Wellesley Islands, e.g. the Albert and Leichhardt Rivers, but freshwater plumes from these rivers have yet to be examined.

There are long-term monitoring programs surveying coral reefs across the GBR and in WA, which have documented the impacts of disturbance events and subsequent recovery, but there has been no regular monitoring of coral reefs in the GOC to date. The only replicated, ecological surveys in the GOC have been conducted by RLS at just two time periods (2010 and 2015), and mainly at different sites each time. There have not been any reefs mapped and or scientific studies conducted on reefs within the Marine National Park Zone of the GOCMP; however, Indigenous Rangers on Mornington Island have shared their local knowledge that reefs are present in this area.

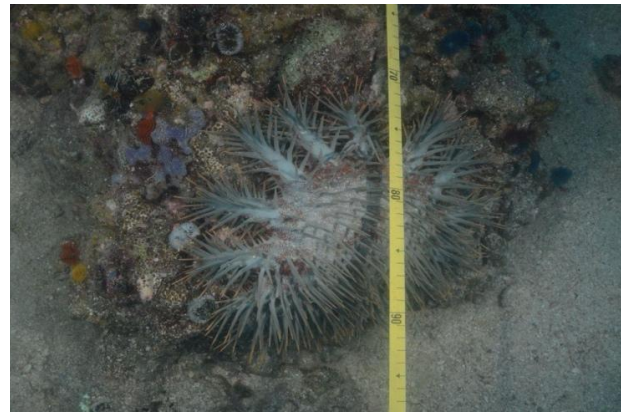


Figure 28: Crown-of-thorns starfish at Steve's Bommie(RLS photo-quadrat from [squiddle.org](https://www.squiddle.org)).

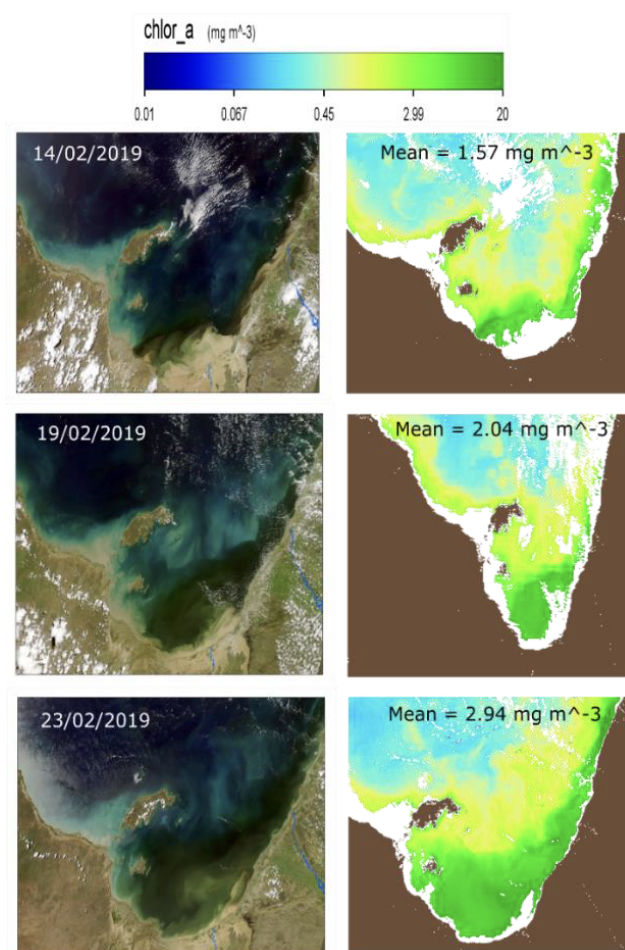


Figure 29: True colour satellite images (left) and chlorophyll-a reflectance band data (right) immediately following a large flood event in the 2019 wet season. Source: Burford et al. 2024.

## 4. Summary and future research priorities

### 4.1. Summary of findings

Multibeam sonar surveys conducted by Geoscience Australia between 2003 and 2005 identified and mapped seven submerged reefs in the southern GOC, four of which are in the GOCMP. These reefs have minimum depths of 18–20 m and vary in size and structure. There are large, submerged shoals or patch reefs, and submerged pinnacles with steep sides either rising from the seafloor or from a large platform made up of other smaller bommies and pinnacles.

We examined two datasets from ecological surveys conducted in the southern GOC, one in 1997–1998 around the Wellesley Islands, and one in and around the GOCMP and around Mornington Island in 2010 and 2015. The surveys in 1997–1998 were focused on reef fish and consisted of a single timed swim at each site (i.e. no replication) with fish placed into relative abundance categories. The northernmost and offshore sites, Manowar and Rocky Islands, had the highest numbers of species observed, but it was found that species richness at the Wellesley Islands was low compared to inshore reefs in the GBR. Data from RLS surveys conducted in 2010 and 2015 showed that coral cover was variable among sites and ranged from 10 to 40 %, which is comparable to coral cover at inshore fringing reefs in the GBR. Many of the reefs had coral communities dominated by massive or encrusting corals. The density, biomass and species richness of reef fishes were higher at offshore reefs compared to nearshore reefs, and there were no differences between reefs within and outside the GOCMP. Species composition of reef fish communities varied between offshore and nearshore reefs. Among the three offshore reefs outside the GOCMP, one had a different fish species composition compared with the five reefs within the marine park, while the other two overlapped in species composition. As the RLS surveys were conducted prior to the establishment of the GOCMP, any observed differences in species composition cannot be attributed to marine park protection. When compared with RLS data from other sites around the GOC, reefs in the southern GOC had similar ranges for coral cover and fish metrics as reefs elsewhere in the GOC. Species composition of fish communities in the southern GOC was distinct from those from RLS sites at similar latitudes in the Great Barrier Reef and Western Australia, and was made up of a combination of widespread Indo-Pacific species, species found mainly in northern Australia and those found mainly in the GOC and northwestern Australia.

We accessed a proxy for fishing effort via the Global Fishing Watch initiative. Although this data set may provide an underestimate of fishing activity, it indicates low levels of commercial fishing effort within the GOCMP, certainly much less than occurs in nearby coastal waters of the GOC.

### 4.2. Identified knowledge gaps

The deep, submerged reefs in and around the GOCMP were only recently identified and mapped by western scientists, and although several of them have had ecological surveys conducted on them, these will have been at their shallowest depths, and there are large areas of deep reef that remain completely unstudied.

Ecological surveys of the coral reefs in and around the GOCMP have not been conducted in the last decade, leaving a knowledge gap regarding their current condition. Twelve of the 14 reefs surveyed by RLS were surveyed just once, either in 2010 or 2015. There is no recent data on the condition of

benthic and fish communities on these reefs, and there is no scientific information on how these reefs may have been impacted by disturbance events, such as marine heatwaves or flooding, over the past 10–15 years. The resilience of these reefs and their vulnerability to threats are unknown.

There are no mapped or charted reefs, and there have not been any biological surveys within the National Park Zone (green zone) of the GOCMP. However, local Indigenous knowledge indicates that there are reefs present in the green zone. The reasons for selecting this area are unknown.

Although there is data on commercial fishing effort, which is lower in and around the GOCMP compared to areas closer to the coast, there is very little data available on recreational fishing effort and its impact, particularly around the shallow fringing reefs around the Wellesley Islands.

### 4.3. Future research priorities

There is a need for further research on both the deep, submerged reefs in and around the GOCMP and on the shallow fringing reefs around the Wellesley Islands. There is limited ecological information available about these reefs, but what we do know indicates that they are unique systems that warrant further study. The complete lack of any scientific information on coral reefs and benthic habitats more generally within the National Park Zone of the GOCMP also warrants further investigation.

There is a need for a structured, regular monitoring program to be established in order to track changes over time on the reefs in the southern GOC and to examine their vulnerability to disturbances and capacity for recovery. The depths of the offshore reefs and the crocodile risk on nearshore fringing reefs mean that diver-based surveys may not be feasible due to Workplace Health and Safety concerns, but the relatively recent innovation of Remotely Operated Vehicle Surveys (ROVS) would be ideal for this region. As there is a well-organised indigenous ranger program on Mornington Island, there is the potential for local community-based monitoring of the reefs in this region. The use of photo quadrats to monitor shallow fringing reef slopes or reef flat habitats, where images are uploaded to an online AI-based platform such as ReefCloud for quantifying the percent cover of benthic organisms and habitats, is an ideal method for this type of monitoring program. In addition, a community-based reporting system for impacts such as coral bleaching, COTS outbreaks and flood plumes could be established.

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Global Coral Reef Monitoring Network (GCRMN):

<https://gcrmn.net/australia/>

Global Fishing Watch:

<https://globalfishingwatch.org>

National Environment Science Program Marine and Coastal Hub:

<http://www.nespmarinecoastal.edu.au/>

Northern Prawn Fishery Industry (NPFI):

<https://npfindustry.com.au>

## 8. Supplementary material available online

- Site information for sites surveyed by Reef Life Survey in the southern Gulf of Carpentaria in 2010 and 2015.
- Fish species list from RLS surveys.
- Malcolm (1998) – unpublished report on fish surveys around the Wellesley Islands.
- Malcolm (1998) data set.

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