Australian Government

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Long-Term Monitoring Program Survey Sampling Design

Long-term Monitoring of the Great Barrier Reef
Standard Operating Procedure Number 13 (Edition 2)

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SOP 13- Edition 2 (2025)

AIMS: Australia's tropical marine research agency.

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This Standard Operating Procedure (SOP) should be cited as:
Osborne, K., Jonker, M. J., Bray, P., Crossman, K. A., Emslie, M. J., Logan, M., & Sinclair-Taylor, T. H. (2025). Long-Term Monitoring Program Survey Sampling Design. Standard Operating Procedure Number 13 (Edition 2). Australian Institute of Marine Science. https://doi.org/10.25845/SPCS-PX71
(18 pp)

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Cover photo:

Current picture 'RV Solander in Western Australia. Image: N. Thake

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1 PREFACE

The Australian Institute of Marine Science's (AIMS) Long-Term Monitoring Program (LTMP) monitors the status and trends of coral reef benthic and reef fish assemblages, crown-of-thorns starfish populations, and other agents of coral mortality (bleaching, coral diseases, and *Drupella*) across a large swathe of the Great Barrier Reef (GBR).

The purpose of this Standard Operational Procedure (SOP) Number 13 Edition 2 is to outline the changes to reefs surveyed by the LTMP from 2022. The sampling design at each reef has remained unchanged and is described in Edition 1 of this SOP, along with details of the LTMP sampling design up to 2021. Details specific to the methods in use to collect data for benthic, fish communities, agents of coral mortality and three-dimensional habitat structure are found in separate SOPs, which have been produced relating to the specific survey type (e.g. fish and benthic surveys on fixed sites - Emslie and Cheal 2018 for reef fish surveys, Jonker et al 2020 for benthic surveys on fixed sites, Gonzalez Rivero et al. 2021 for three-dimensional habitat structure on fixed sites, Miller et al 2020 for agents of coral mortality surveys on fixed sites and manta tow surveys Miller et al 2019) (https://www.aims.gov.au/docs/research/monitoring/reef/sops.html).

2 INTRODUCTION

Spanning approximately 2300 kilometres along the Queensland coastline and covering an area of 344,000 square kilometres, the GBR is the world's largest coral reef system comprising of approximately 3100 individual reefs supporting a range of users including traditional owners, fisheries, tourism, research, recreation, and shipping.

In 1975 the *Great Barrier Reef Marine Park Act 1975* was established by the Australian Government, with the objective to provide for the long-term protection and conservation of the environment, biodiversity, and heritage values of the GBR. Subsequently, the Great Barrier Reef Marine Park Authority (GBRMPA) was created to manage the GBR Marine Park (GBRMP).

From 1985 to 1991, the GBRMPA provided funding for the first large-scale monitoring program using manta tow surveys (Moran et al. 1988). These data were used in the reporting and subsequent evaluation of management effectiveness of the GBRMP. In 1991, the Australian Government provided funding to the AIMS to conduct in-depth monitoring of the GBR. This led the creation of the LTMP, tasked with collecting and reporting detailed information on the coral reef benthic and reef fish community assemblages and their spatiotemporal trends.

Since 1993, the LTMP has been performing fixed site surveys on SCUBA along permanently marked transects to quantify the abundance, diversity, and assemblage structure of fish and benthic organisms on Australia's Great Barrier Reef (GBR). These fixed site surveys (Jonker et al 2020, Miller et al 2020, Emslie & Cheal 2018) are complemented with manta tow surveys (Miller et al 2019) around the entire perimeter of survey reefs. The sampling design, described fully in Edition 1 (Bray

et al 2025) was developed to provide a balance between geographically small scale, intensive sampling and large scale, less intensive sampling to detect and quantify spatio-temporal change across selected ecological surrogates (Emslie et al 2020).

Fixed site surveys were conducted annually on 46 reefs from 1993 until 2005 (hereafter 'RM'). In 2004, the area of the GBRMP protected inside No Take Marine Reserves (NTMRs) was increased to 33% under the Representative Areas Program (RAP - Day et al 2003, Fernandes et al. 2005). From 2006-2021, biennial surveys were introduced to accommodate a monitoring program that was dedicated to assessing the effectiveness of changes to management within the GBRMP under the Representative Areas Program (hereafter 'RAP'). In 2006 the LTMP commenced biennial RAP surveys, alternating years with RM surveys, to examine the effect of expanding the area of NTMRs within the GBRMP. RAP surveys were conducted on 56 reefs, (with 10 reefs surveyed in both the RM and RAP programs). Reefs were paired according to management zone, with each reef pair consisting of a reef located in a NTMR, and another closely located (with similar characteristics including shelf position, exposure, bioregion, geomorphology, and community composition), which remained open to fishing. Commencing in 2019, both RAP and RM surveys were expanded north to the Cape Grenville and Princess Charlotte Bay sectors of the GBRMP.

The Reef Integrated Monitoring and Reporting Program (RIMReP) is a key component of the *Reef 2050 Long-term Sustainability Plan* aimed at providing a framework to build resilience and ameliorate threats to the GBR. In preparation for the transition to RIMReP, GBRMPA commissioned reports and desktop studies that provided recommendations for the design of the coral reef theme of RIMReP. There were several key recommendations 1) annual sampling, 2) inclusion of far northern GBR and 3) retaining ability to examine effectiveness of rezoning GBR (Schaffelke et al 2018). Considering this, the decision was made for the LTMP to return to annual sampling. In doing so, it was desirable to retain the spatial coverage of the RM surveys, including the Cape Grenville and Princess Charlotte Bay sectors in the far northern GBR which had also been identified as a key knowledge gap (Schaffelke et al 2018), as well as maintain the ability to examine the effectiveness of zoning on the GBR. The re-design of the LTMP necessitated rationalising the number of reefs surveyed from 103 in the biennial design utilised from 2006 to 2021, to around 70 reefs which was considered logistically feasible to survey annually. However, it was important to assess what the implications of changing the sampling design were and so an internal modelling study was undertaken to examine the implications of the removal of various survey reefs.

3 ANNUAL SAMPLING REEF SELECTION

3.1 Principles of Reef Selection

To implement a logistically feasible and reliable sampling regime in the RIMReP program, the number of reefs was reduced from 103 biennially to around 70 annually. The following principles were applied:

1. Discontinue surveys on reefs that have been logistically challenging to safely collect good quality data.

- Discarding reefs with logistical/data issues was performed by an expert panel of LTMP cruise leaders. Relevant concerns were mainly safety issues such as being unable to anchor or dangerous site locations, or site locations that were unrepresentative of the typical habitat selected for monitoring.

2. Prioritise continuing surveys on reefs with long survey histories.
    - RM reefs that had been surveyed since 1993 had high value data due to the length of the time series and were retained unless they had logistical issues. Of the 46 reefs in the original monitoring reef set, 40 were retained.
3. Maximise NTMR/open zone pairings and maximise spatial coverage of different reef bioregions.
    - 30 reefs were selected from the RAP reefs. After the exclusion of reefs based on logistics, the Monitoring Site Planner aided with the identification of sampling redundancies and the reshuffling of green/blue pairs to allow maximum pairing within each regional setting, including reef bioregion, AIMS latitudinal sector, and NRM region. These spatial hierarchies will correspond with data summaries for the three regions (Northern GBR, Central GBR, Southern GBR) in the LTMP Annual Summary Report of Coral Reef Condition for the GBR.
4. A statistical validation method was applied. Old and new sampling regimes were statistically compared for variables such as hard coral, target fish and their trend over time. This showed that temporal trends for the major groups of biota (corals, fishes) were robust to the changes that were planned and implemented in 2022 at the spatial scales of most significance in reporting frameworks (Figure 1). The modelling results are on GitHub http://10.10.42.9/LTMP-sampling/LTMP_13_statisticalAnalyses_MPA.html and are accessible to AIMS account holders.

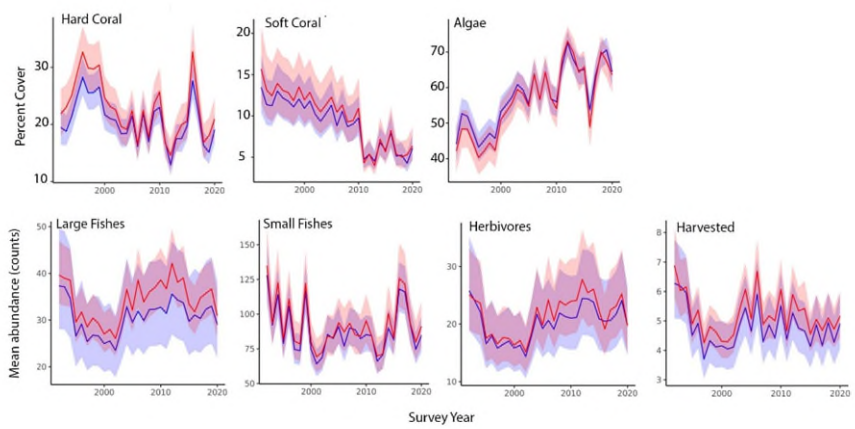

Figure 1. Modelled comparison of temporal trends in major groups of corals and fishes. Blue trend is from reefs surveyed 1993-2021. Red trend is based on the new annual sampling design from 2022.

4 REEFS SELECTED FOR ANNUAL SURVEYS FROM 2022

Following the principles of reef selection and statistical validation, the LTMP implemented changes to the sampling frequency and the number of reefs surveyed from August 2022. The LTMP increased the number of reefs with annual sampling of fixed site surveys to 71 reefs. The reefs selected for annual sampling consisted of 43 reefs sampled since 1993, 18 reefs sampled since 2006 and 10 reefs

from the far northern GBR sampled since 2019 (Figure 2). This new sampling design comprises fixed site surveys within in ten latitudinal sectors while retaining the cross-shelf distribution of reefs where feasible.

A more detailed view of each region as defined by the LTMP Annual Summary Report of Coral Reef Condition for the GBR is in Appendix 1 and more information on the spatial configuration of the new annual sampling regime for the LTMP is in Appendix 2.

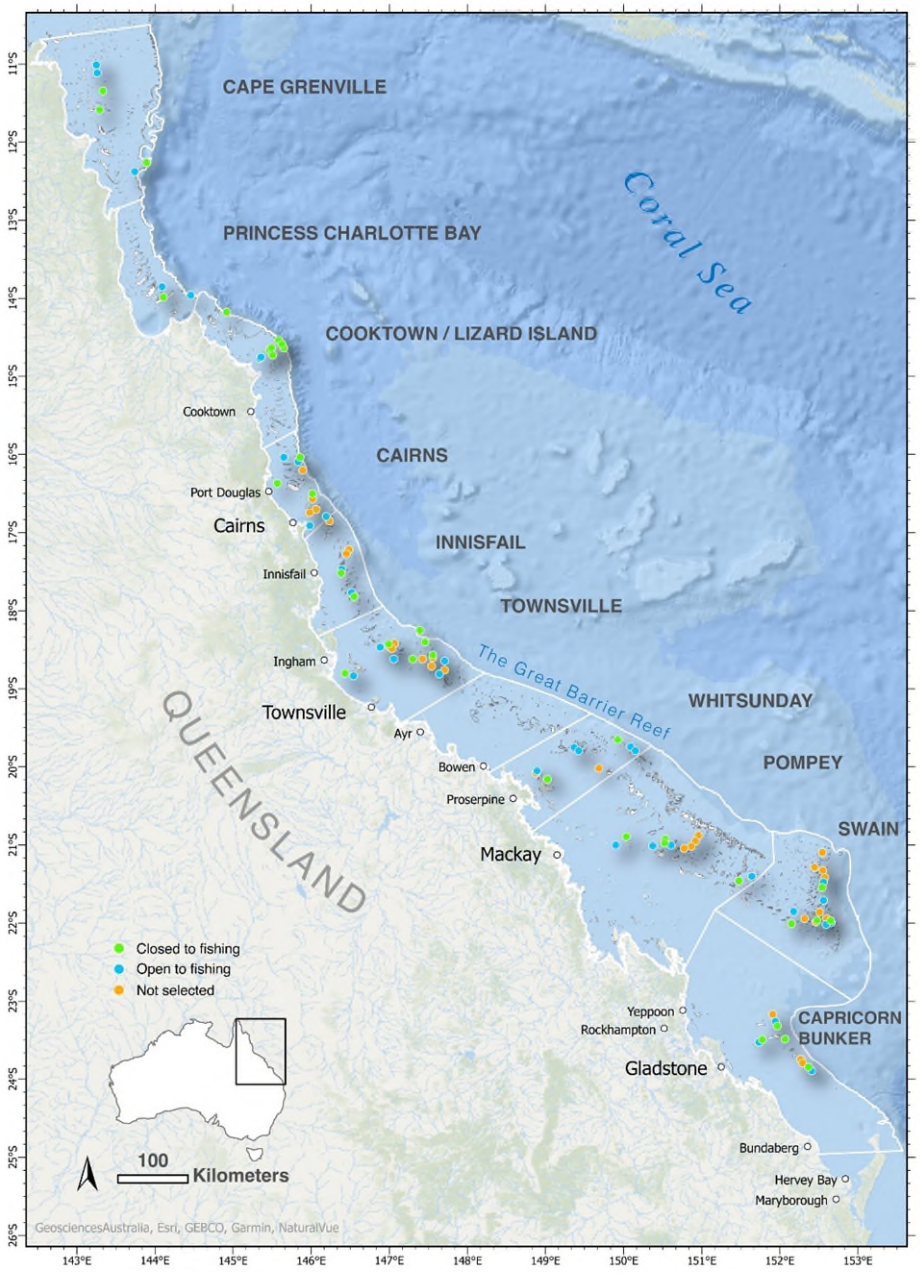

Figure 2. Changes to reef selections for sampling using fixed site surveys from 2022. Reefs retained are represented by their zoning of blue dots (open to fishing), green dots (closed to fishing), while discarded reefs are denoted by the orange dots.

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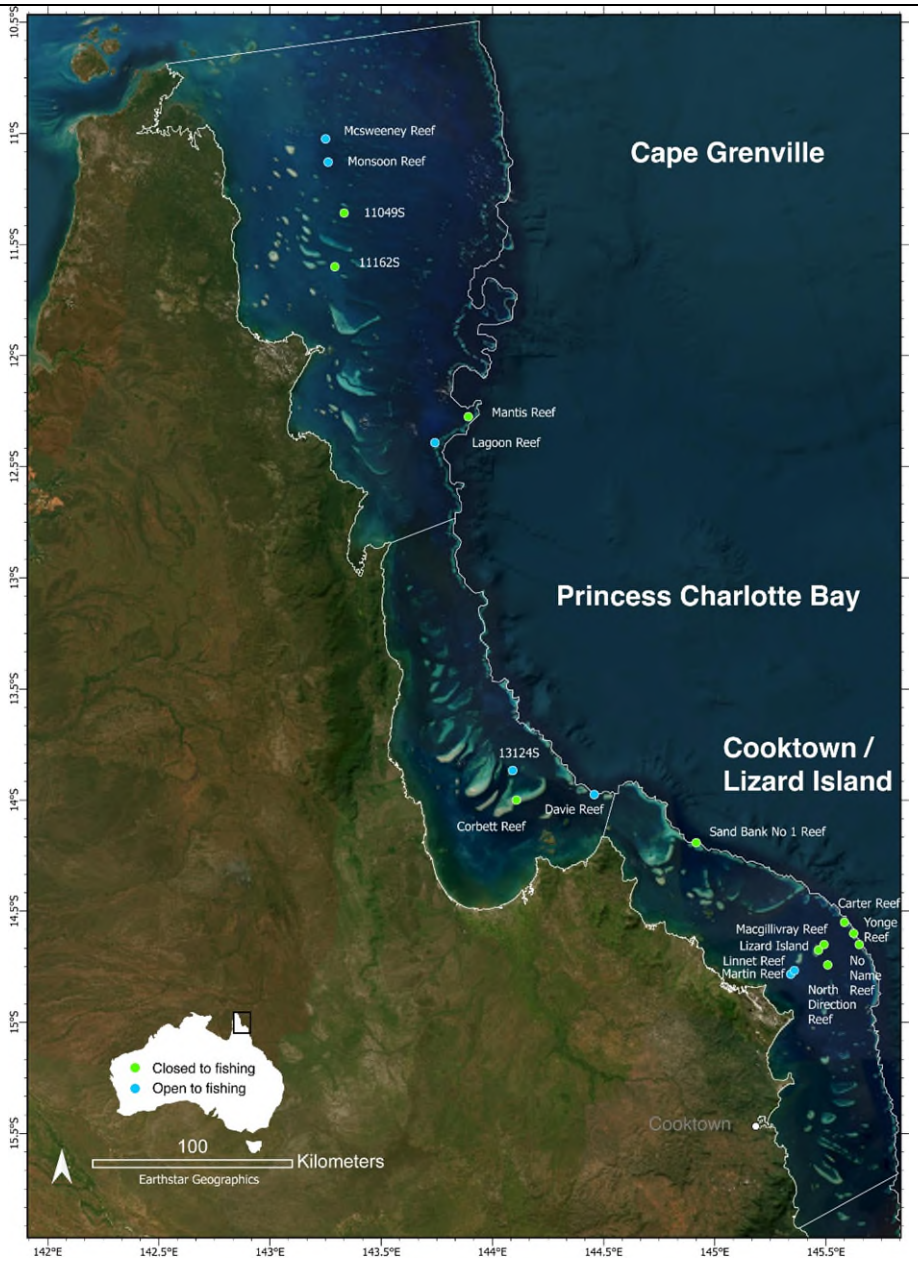
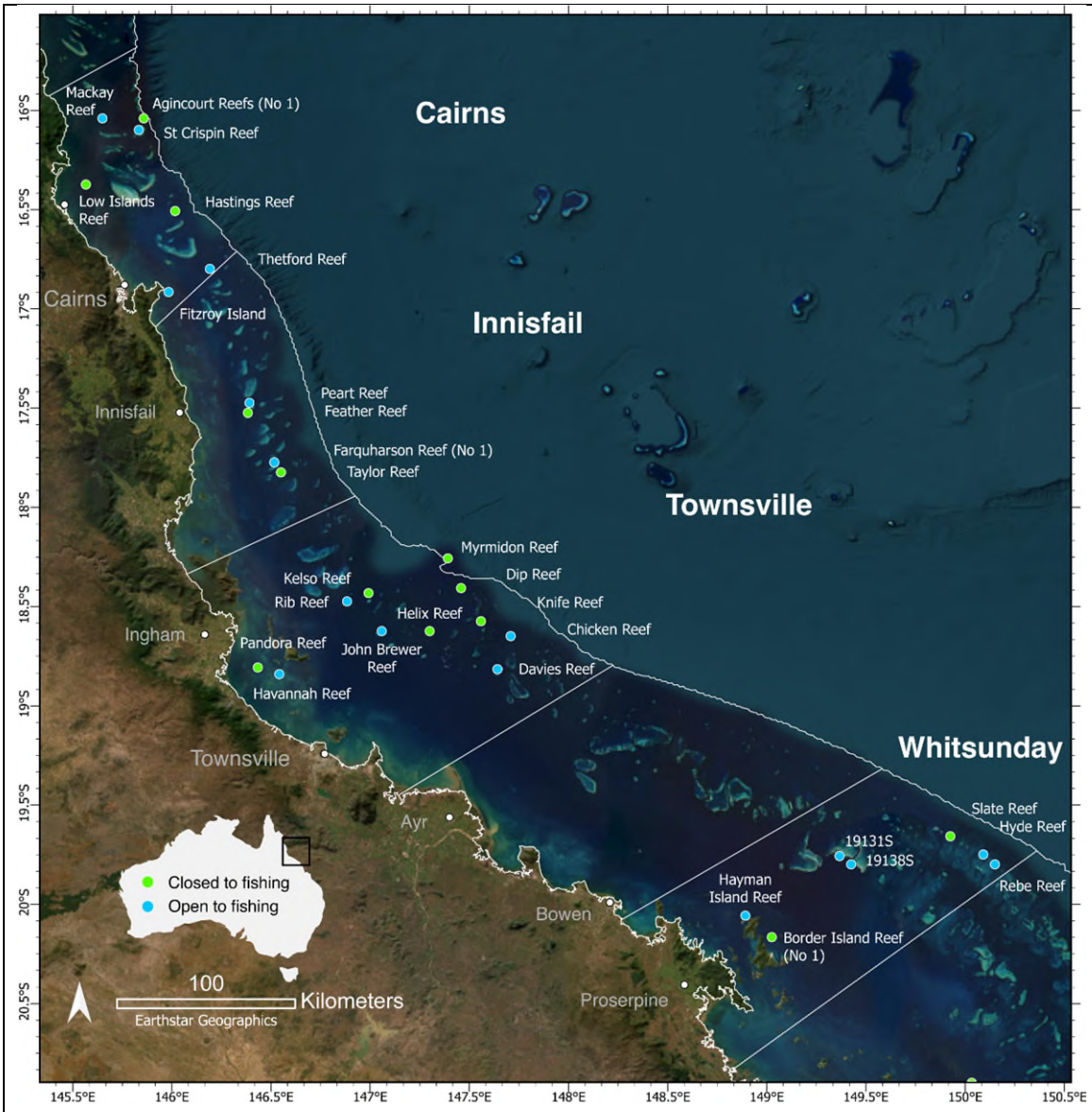
6 APPENDICES

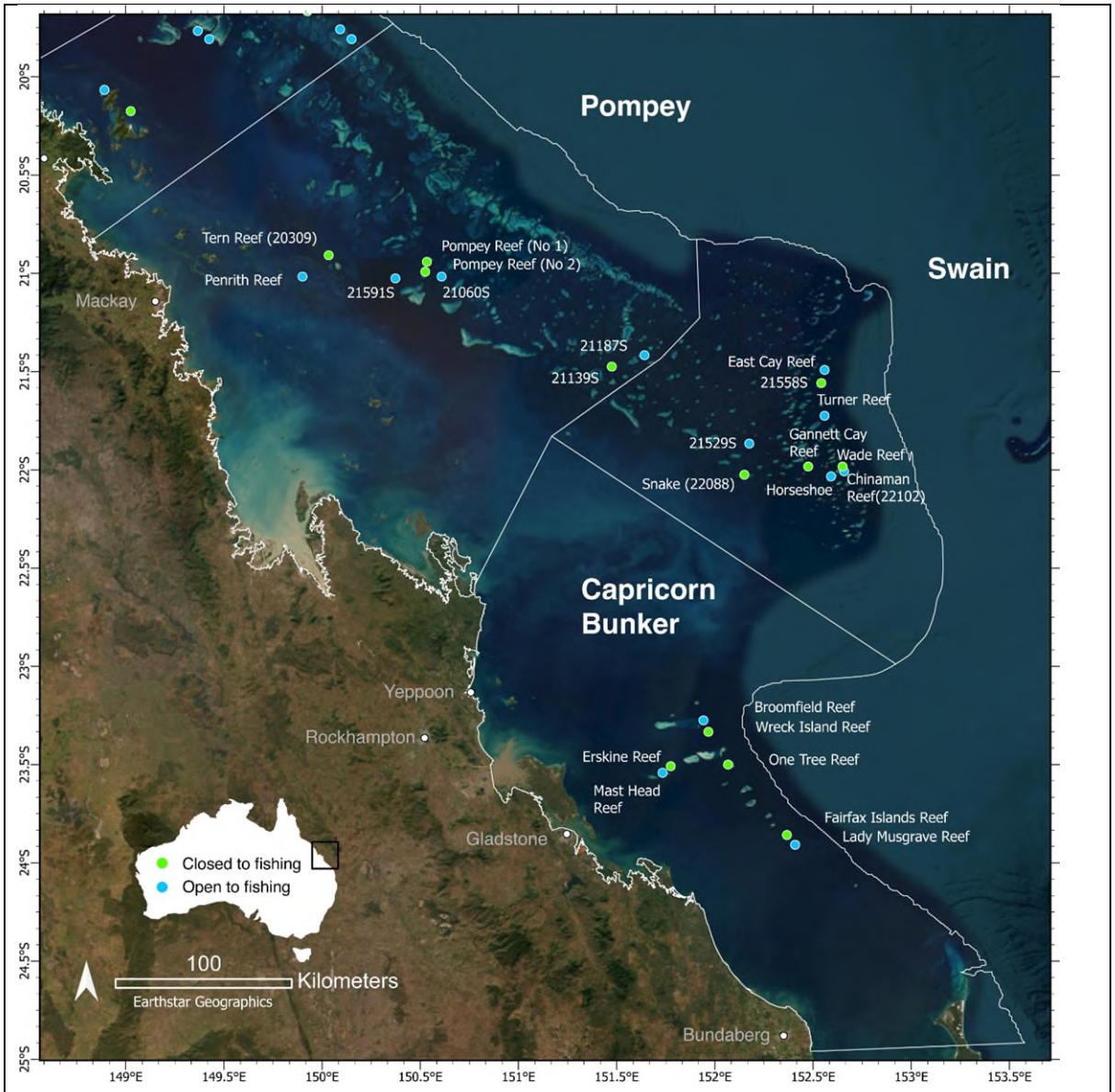
6.1 The LTMP reporting regions (Northern, Central and Southern), displaying reefs selected for annual sampling from 2022 and their status with respect to fishing zonation. Each region displays several AIMS sectors. The LTMP reporting regions are used in the LTMP Annual Summary Report of Coral Reef Condition for the GBR.



Northern Region



Central Region



Southern Region

Note: Open or closed to fishing includes multiple zones and is specific to the site location on each reef.

6.2 Spatial distribution of LTMP reefs selected for annual sampling from 2022 by AIMS sector, shelf and reef bioregion.

AIMS sector	Shelf	Reef Bioregion	Number of survey reefs
Cape Grenville	Mid	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	4
Cape Grenville	Outer	RA2 Outer Barrier Reefs	2
Princess-Charlotte Bay	Mid	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	2
Princess-Charlotte Bay	Outer	RA2 Outer Barrier Reefs	2
Cooktown-Lizard	Inner	RF1 Northern Open Lagoon Reefs	2
Cooktown-Lizard	Mid	RG1 Sheltered Mid Shelf Reefs	3
Cooktown-Lizard	Outer	RA2 Outer Barrier Reefs	3
Cairns	Inner	RF1 Northern Open Lagoon Reefs	2
Cairns	Mid	RG1 Sheltered Mid Shelf Reefs	1
Cairns	Mid	RG2 Exposed Mid Shelf Reefs	2
Cairns	Outer	RA2 Outer Barrier Reefs	2
Innisfail	Mid	RG2 Exposed Mid Shelf Reefs	4
Townsville	Inner	RE3 Coastal Central Reefs	1
Townsville	Inner	RHC High Continental Island Reefs	1
Townsville	Mid	RG2 Exposed Mid Shelf Reefs	5
Townsville	Outer	RA3 Outer Shelf Reefs	2
Townsville	Outer	RG2 Exposed Mid Shelf Reefs	2
Whitsunday	Inner	RHC High Continental Island Reefs	2
Whitsunday	Mid	RHW Strong Tidal Mid Shelf Reefs (West)	2
Whitsunday	Outer	RA4 Strong Tidal Outer Shelf Reefs	3
Pompey	Mid	RE5 High Tidal Fringing Reefs	1
Pompey	Mid	RHE Strong Tidal Mid Shelf Reefs (East)	2
Pompey	Mid	RK Strong Tidal Inner Mid Shelf Reefs	5
Swain	Mid	RHE Strong Tidal Mid Shelf Reefs (East)	2
Swain	Mid	RSW-M Swains Mid Reefs	4
Swain	Outer	RSW-O Swains Outer Reefs	3
Capricorn-Bunker	Outer	RCB1 Capricorn Bunker Outer Reefs	5
Capricorn-Bunker	Outer	RCB2 Capricorn Bunker Mid Shelf Reefs	2

6.3 Reef selection and reefs paired for zoning comparisons.

Full reef id	AIMS reef name	Reef Bioregion	New Pair	AIMS sector	Shelf	LTMP Reporting region	Zoning
11016S	McSweeney Reef	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	1	CG	M	Northern	Open
11029S	Monsoon Reef	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	2	CG	M	Northern	Open
11049S	Reef 11-049	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	1	CG	M	Northern	Closed
11162S	Reef 11-162	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	2	CG	M	Northern	Closed
12056S	Mantis Reef	RA2 Outer Barrier Reefs	3	CG	O	Northern	Closed
12061S	Lagoon Reef	RA2 Outer Barrier Reefs	3	CG	O	Northern	Open
13124S	Reef 13-124	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	4	PC	M	Northern	Open
13130S	Davie Reef	RA2 Outer Barrier Reefs	5	PC	O	Northern	Open
14016S	Corbett Reef	RC2 Far Northern Protected Mid Shelf Reefs and Shoals	4	PC	M	Northern	Closed
14045S	Sand bank No.1	RA2 Outer Barrier Reefs	5	PC	O	Northern	Closed
14114S	Macgillivray Reef	RG1 Sheltered Mid Shelf Reefs		CL	M	Northern	Closed
14116S	Lizard Isles	RG1 Sheltered Mid Shelf Reefs		CL	M	Northern	Open
14123S	Martin	RF1 Northern Open Lagoon Reefs		CL	I	Northern	Open
14126S	Linnet Reef	RF1 Northern Open Lagoon Reefs		CL	I	Northern	Open
14137S	Carter Reef	RA2 Outer Barrier Reefs		CL	O	Northern	Closed
14138S	Yonge Reef	RA2 Outer Barrier Reefs		CL	O	Northern	Closed
14139S	No Name Reef	RA2 Outer Barrier Reefs		CL	O	Northern	Closed
14143S	North Direction Island	RG1 Sheltered Mid Shelf Reefs		CL	M	Northern	Closed

15099C	Agincourt Reef No.1	RA2 Outer Barrier Reefs	6	CA	O	Central	Closed
16015S	Mackay Reef	RG1 Sheltered Mid Shelf Reefs		CA	M	Central	Open
16019S	St. Crispin Reef	RA2 Outer Barrier Reefs	6	CA	O	Central	Open
16028S	Low Isles	RF1 Northern Open Lagoon Reefs		CA	I	Central	Closed
16054S	Fitzroy Island	RF1 Northern Open Lagoon Reefs		CA	I	Central	Open
16057S	Hastings Reef	RG2 Exposed Mid Shelf Reefs	7	CA	M	Central	Closed
16068S	Thetford Reef	RG2 Exposed Mid Shelf Reefs	7	CA	M	Central	Open
17024S	Peart Reef	RG2 Exposed Mid Shelf Reefs	8	IN	M	Central	Open
17034S	Feather Reef	RG2 Exposed Mid Shelf Reefs	8	IN	M	Central	Closed
17063A	Farquarson Reef	RG2 Exposed Mid Shelf Reefs	9	IN	M	Central	Open
17064S	Taylor Reef	RG2 Exposed Mid Shelf Reefs	9	IN	M	Central	Closed
18030S	Kelso Reef	RG2 Exposed Mid Shelf Reefs	10	TO	M	Central	Closed
18032S	Rib Reef	RG2 Exposed Mid Shelf Reefs	11	TO	M	Central	Open
18034S	Myrmidon Reef	RA3 Outer Shelf Reefs		TO	O	Central	Closed
18039S	Dip Reef	RA3 Outer Shelf Reefs		TO	O	Central	Closed
18051S	Pandora Reef	RE3 Coastal Central Reefs		TO	I	Central	Closed
18065S	Havannah Reef	RHC High Continental Island Reefs		TO	I	Central	Open
18075S	John Brewer Reef	RG2 Exposed Mid Shelf Reefs		TO	M	Central	Open
18076S	Helix Reef	RG2 Exposed Mid Shelf Reefs	11	TO	M	Central	Closed
18081S	Knife Reef	RG2 Exposed Mid Shelf Reefs	12	TO	O	Central	Closed
18086S	Chicken Reef	RG2 Exposed Mid Shelf Reefs	12	TO	O	Central	Open
18096S	Davies Reef	RG2 Exposed Mid Shelf Reefs	10	TO	M	Central	Open
19131S	Reef 19-131	RHW Strong Tidal Mid Shelf Reefs (West)		WH	M	Central	Open

19138S	Reef 19-138	RHW Strong Tidal Mid Shelf Reefs (West)		WH	M	Central	Open
19159S	Slate Reef	RA4 Strong Tidal Outer Shelf Reefs	13	WH	O	Central	Closed
19207S	Hyde Reef	RA4 Strong Tidal Outer Shelf Reefs	13	WH	O	Central	Open
19209S	Rebe Reef	RA4 Strong Tidal Outer Shelf Reefs		WH	O	Central	Open
20014S	Hayman Island	RHC High Continental Island Reefs	14	WH	I	Central	Open
20067A	Border Island	RHC High Continental Island Reefs	14	WH	I	Central	Closed
20309S	Tern Island	RK Strong Tidal Inner Mid Shelf Reefs	15	PO	M	Southern	Closed
20351A	Pompey Reef No.1	RK Strong Tidal Inner Mid Shelf Reefs	16	PO	M	Southern	Closed
20351B	Pompey Reef No.2	RK Strong Tidal Inner Mid Shelf Reefs	17	PO	M	Southern	Closed
21025S	Penrith Island	RE5 High Tidal Fringing Reefs	15	PO	M	Southern	Open
21060S	Reef 21-060	RK Strong Tidal Inner Mid Shelf Reefs	16	PO	M	Southern	Open
21139S	Reef 21-139	RHE Strong Tidal Mid Shelf Reefs (East)	18	PO	M	Southern	Closed
21187S	Reef 21-187	RHE Strong Tidal Mid Shelf Reefs (East)	18	PO	M	Southern	Open
21305S	East Cay	RSW-O Swains Outer Reefs	19	SW	O	Southern	Open
21529S	Reef 21-529	RHE Strong Tidal Mid Shelf Reefs (East)		SW	M	Southern	Closed
21556S	Gannet Cay	RSW-M Swains Mid Reefs		SW	M	Southern	Closed
21558S	Reef 21-558	RSW-O Swains Outer Reefs	19	SW	O	Southern	Closed
21562S	Turner Cay	RSW-O Swains Outer Reefs		SW	O	Southern	Open
21588S	Wade Reef	RSW-M Swains Mid Reefs	20	SW	M	Southern	Closed
21591S	Reef 21-591	RK Strong Tidal Inner Mid Shelf Reefs	17	PO	M	Southern	Open
22088S	Snake Reef	RHE Strong Tidal Mid Shelf Reefs (East)		SW	M	Southern	Open
22102S	Chinaman Reef (22-102)	RSW-M Swains Mid Reefs	20	SW	M	Southern	Open

22104S	Horseshoe Reef	RSW-M Swains Mid Reefs		SW	M	Southern	Open
23048S	Broomfield Reef	RCB1 Capricorn Bunker Outer Reefs	21	CB	O	Southern	Open
23051S	Wreck Island	RCB1 Capricorn Bunker Outer Reefs	21	CB	O	Southern	Closed
23055S	One Tree Island	RCB1 Capricorn Bunker Outer Reefs		CB	O	Southern	Closed
23068S	Erskine Island	RCB2 Capricorn Bunker Mid Shelf Reefs	22	CB	O	Southern	Closed
23069S	Masthead Island	RCB2 Capricorn Bunker Mid Shelf Reefs	22	CB	O	Southern	Open
23081S	Fairfax Island	RCB1 Capricorn Bunker Outer Reefs	23	CB	O	Southern	Closed
23082S	Lady Musgrave Island	RCB1 Capricorn Bunker Outer Reefs	23	CB	O	Southern	Open