



INSTITUTE FOR
MARINE RESEARCH
DAUIN PHILIPPINES



OUTLOOK REPORT 2024

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For additional copies of this report, please phone IMR on (+63) 917 103 4536 or write to us at info@institutemarineresearch.org

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Institute for Marine Research

KM 12.5, Bulak

Municipality of Dauin

6217, Philippines

Full report written by:

Espen Oswald, Chelsea Waters, Corey Cathcart and Daniel Lipton



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Table of Contents

Message from the Directors	03
Materials and Methods	05
Benthic Assays	06
Dauin's Coastal Reef Survey Sites	06
SCUBA Search: Reef Impacts & Coral Mortality	07
Diver-Operated Stereo Video System (DO-SVS)	07
3-Dimensional Reef Modelling	09
Dauin Long-Term Monitoring Project	11
IMR in Numbers	12
Fish Community & Trends	13
Long-Term Trends Across Dauin	15
Spatial Patterns in Biomass	17
Long-Term Trends and External Stressors	18
Total Fish Biomass Trends (2020 – 2023)	20
Benthic Community Trends (2019 – 2024)	22
Long-Term Trends Across Dauin	23
Spatial Patterns in Benthic Cover	25
External Stressors and Potential Impacts	27
Conclusion and Future Considerations	28
Reef Impacts (2019 – 2024)	29
Crown-of-Thorns Starfish (Acanthaster spp.)	30
Coral Bleaching	33
Porites Ulcerative White Spot Disease	35
Site 9 – Case Study	37
Management Actions	39
Future Research	41

Message from the Directors

As we reflect on 2024, we are proud to share the Institute for Marine Research's continued growth in advancing marine science, fostering community engagement, and championing conservation leadership. This year has highlighted the power of collaboration, innovation, and resilience in the face of mounting environmental challenges.

At IMR, we remain committed to the highest scientific standards, guided by our core principle of evidence-based conservation. In 2024, we launched several new reef monitoring projects, allowing us to hone in on specific stressors that affect our local reefs. These initiatives include our enhanced impact surveys which looked closer at coral predators like *Drupella* spp. and *Acanthaster* spp., as well as coral disease. We also started several projects looking into the recruitment of corals in the area. This is in preparation for the future spawning work we shall conduct along the coast. These projects include our Macroalgal Removal Study (MARS) and our permanent natural recruitment plots.

In terms of international collaborations, we are proud to have hosted some talented and dedicated researchers from institutions such as Stockholm University, Heinrich Heine University Düsseldorf and Gothenburg University. Their research helped expand our understanding of our coral reef ecosystem, their capacity for recovery, and enhance our ability to protect them.

Nationally IMR has continued its mission to encourage fine scale conservation in the Philippines. This resulted in us becoming involved in a PEW Research project run by the esteemed Dr. Rene Abessamis. We were also invited to participate in the DRT dive show in Manila where we outlined our views and strategies for using digital monitoring to enhance citizen science and encourage a move away from outdated methodologies. IMR has also expanded our partnership with our sister organizations Liquid Dive Dumaguete and Atmosphere Resorts & Spa by starting our Functional Restoration and Growth Studies (FRAGS), allowing guests of the resorts to participate in coral restoration activities.

One of our proudest accomplishments this year was the launch of the Reef Rangers Initiative—an exciting program dedicated towards empowering girls (12 – 17 years) from the Bata ng Calabnugan orphanage in Dumaguete to become future leaders in marine conservation. Through a comprehensive curriculum that combines environmental education, hands-on marine ecology training, and professional dive certifications (from PADI Open Water to Divemaster), these young women are gaining the confidence, skills, and scientific literacy needed to thrive both in the water and professionally within their communities. Our first cohort of six incredible girls have already begun their journey, and we are inspired by their progress. We extend our deepest thanks to everyone who donated and supported this program, helping us turn a dream into a reality.

Looking ahead to 2025, we are excited to build on this momentum. We are preparing to establish a dedicated coral research site in partnership with Atmosphere Resorts & Spa, which will significantly enhance our long-term monitoring and restoration capabilities. We will also deepen our commitment to education and outreach through a new after-school marine program with ONE International School here in Dauin. Additionally, we are supporting new community-based training programs to equip local residents with research skills and increase grassroots involvement in marine conservation.

Thank you for believing in our mission. Together, we are building a more hopeful and sustainable future for our oceans.

With gratitude,

Rafael Manrique
Director, Institute for Marine Research
Chelsea Waters
Director, Institute for Marine Research

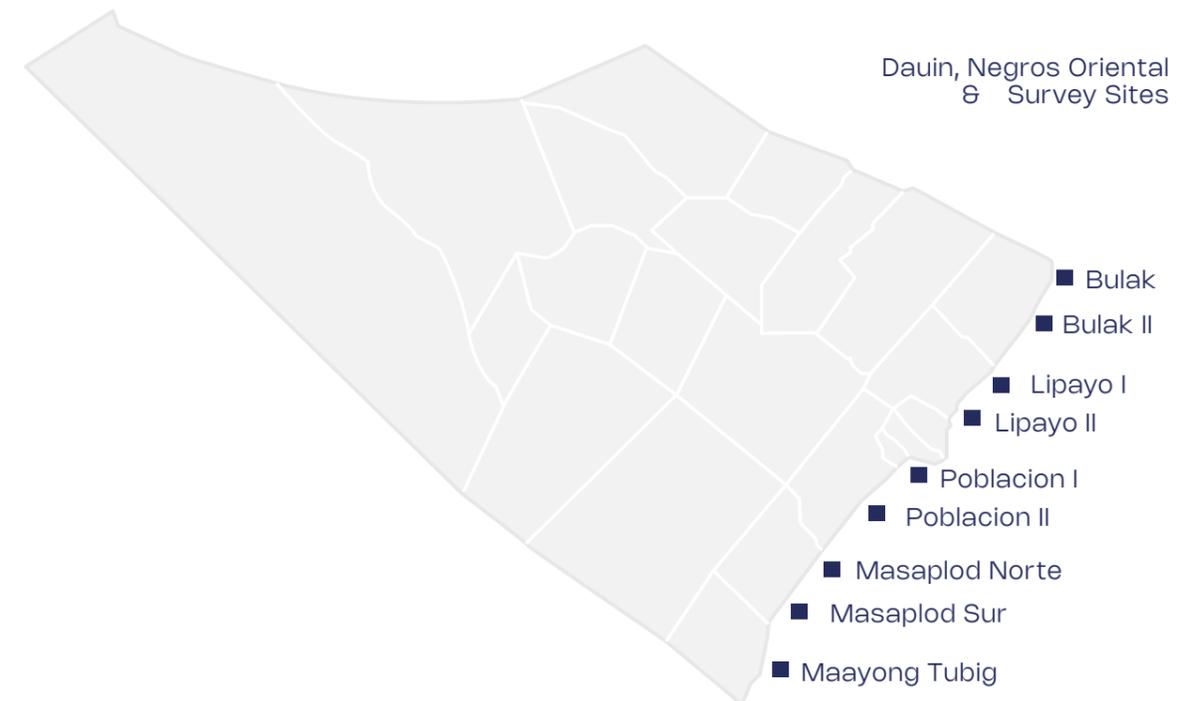


Materials and Methods



Dauin's Coastal Reef Survey Sites

Dauin is a fourth-class municipality in the province of Negros Oriental, Philippines. The municipality stretches across nine kilometers of coastline, bordered in the north by Bacong and in the south by Zamboanguita. **The Dauin coastline was split into three research zones (North, Central, and South), each zone measuring 3 km in length.** Nineteen core sites at eleven locations were selected for monitoring. **These sites span the variation in coral reef composition, benthic and fish communities across the municipality and account for the zoning history of its associated no-take marine protected areas.** Each of the 19 core sites has one 50m transect that runs parallel to the reef crest, between depth ranges of 1–6m and 7–12m. **Surveys are conducted bi-annually to account for seasonal variability,** with dry season surveys running from February to July and wet season surveys running from August to January.



Benthic Assays

Surveys of sessile benthic organisms were conducted following the Australian Institute of Marine Science (AIMS) LTMP methodology. Images were taken along the transect line using a GoPro camera held approximately 0.5m above the substrate. One image was taken per 1m interval, totaling fifty images per 50m transect.

Benthic assay analysis was conducted using ReefCloud software (reefcloud.ai), which overlays underwater images with a matrix of 30 randomly distributed points to facilitate benthic cover classification. The software incorporates machine learning algorithms trained on expert-annotated datasets to automatically identify benthic categories (e.g., coral, algae, sand) at each point, significantly reducing manual processing time while maintaining high levels of accuracy.

Points were identified based on a predetermined codec, which contains all Indo-Pacific Scleractinian coral genera, octocorals, hydroids, bivalves, other hexacorals (anemones, corallimorphs, and zoanthids), sponge growth forms, "other live" (ascidian, crown-of-thorns starfish, cyanobacteria, etc.), algae, seagrass, dead coral, and abiotic factors. The data from individual frames can be combined to produce inter- and intra-transect and site comparisons via automatically generated Excel spreadsheets. For each category of benthic organism, the mean values for percent cover at each site are used to analyze seasonal and temporal trends in cover of benthic organisms at each site, zone, and throughout the municipality as a whole.

SCUBA Search: Reef Impacts & Coral Mortality

The SCUBA search was designed to provide a more detailed picture of the causes and relative scale of coral mortality, and was conducted following a modified version of the AIMS LTMP methodology. SCUBA searches were conducted along a 50m transect, with a 2m belt (1m on either side of the transect line; 100m 2).

Observers recorded the presence of key stressors, including marine debris (general and fishing trash), *Acanthaster* spp. (Crown of Thorns Starfish; CoTS), *Drupella* spp. (corallivorous snail), coral bleaching, physical damage (direct destruction), and coral disease.

Photographs of impacted colonies were taken using an Olympus TG-6 camera, with a ruler included in the frame to provide scale. The affected areas of coral were subsequently measured using ImageJ software.



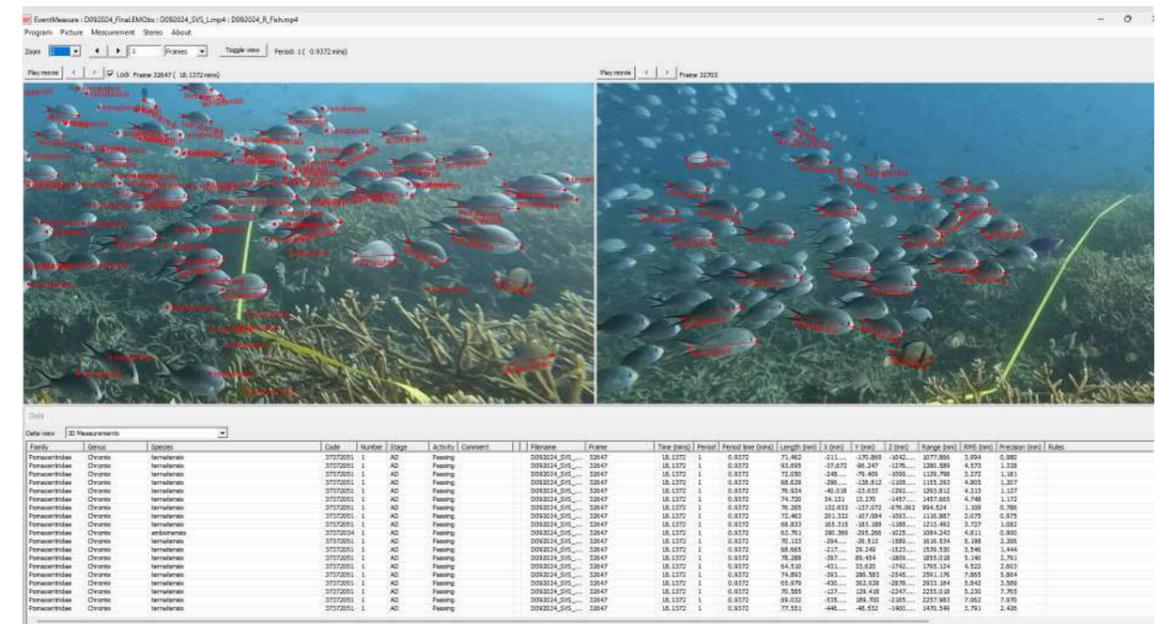
Diver-Operated Stereo Video System (DO-SVS)

Transects were conducted using a Diver-Operated Stereo Video System (DO-SVS; SeaGIS, Melbourne, Australia), comprised of two GoPro 10 Black cameras. To minimize potential disturbance to the fish community, cameras were set to record and synchronized prior to entry, and the SVS operator was at the front of the survey team. At the start of the 50m transect, the cameras were oriented parallel to the substrate, angled approximately 20° downward, and kept approximately 0.5m above the substrate. The SVS operator moved at a steady pace (adjusting for currents), filming the reefscape along the 50m transect; transects take approximately 4 minutes (30 seconds).



EventMeasure V5.25 (SeaGIS, Melbourne, Australia) was used to synchronize SVS footage, calibrate camera measurements, and measure fish encountered along the transect. EventMeasure resolves center points of each individual fish encountered into distances on a three-dimensional coordinate system. This allowed the exclusion of fish outside 2.5m on either side of and 5m in front of the camera system; side distance restrictions maintain a consistent survey belt along the transect, and front distance restrictions prevent variations in visibility (e.g., turbidity, light intensity) from influencing data. Each fish encountered within the transect belt was identified to species level. For fish visible in both cameras, measurements were possible; for those only seen in the left-hand side video, a point identifying the fish to species level was recorded. Fish biomass was estimated using the equation: $W = aL^b$ where W is weight (g), L is fish length (cm), and a and b are species-specific allometric constants obtained from FishBase.

The genus name was used when allometric constants for a specific species were not available. For points where length measurements were not possible, the mean length for the species recorded across all depths and survey sites was used. This was done first within a year then across the entire dataset if needed to account for temporal changes in mean fish length. Length at first maturity of all fish species (where available) was obtained from FishBase.



Fish species were classified into functional groups: grazers/detritivores, scrapers/small excavators, browsers, detritivores, obligate corallivores, planktivores, invertivores, and piscivores/scavengers. The invertivores/sessile group was included with the invertivores. Trophic groups were allocated following the FishBase 'Food Items' table, using the Food I-III hierarchical classification of food items consumed by a species, based on diet composition of >20% of recorded items accessed through FishBase. The proportional biomass of each functional group was also calculated at each site. Fish species were also categorized into IUCN Red List Categories and their commercial value according to FishBase.

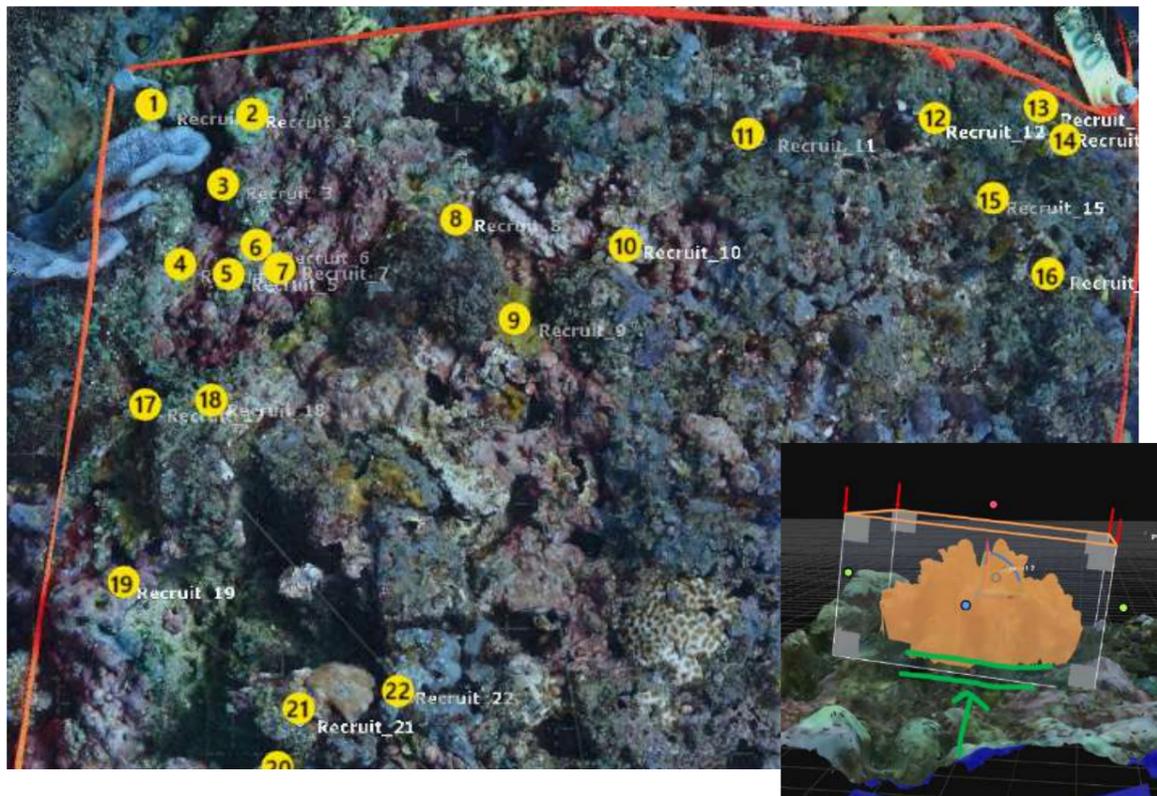
Statistical analysis methods varied by dataset. For total fish populations (for Dauin as a whole and separated by survey location), log-transformed abundance and biomass data and untransformed species richness (n) data were used in ANOVAs and GLMMs to compare across survey years, sites, and seasons.

3-Dimensional Reef Modelling

A 3D camera rig consisting of two GoPro Hero 5 Black cameras placed 0.9m apart on a one-metre long aluminium pole was used to obtain video footage of the survey transect. The cameras were set to wide-angle, resolution of 1080 pixels, and 60 frames per second. The principles for this method of stereo-video measurement are described in Harvey and Shortis (1995). The cameras were faced directly down at the substratum at the beginning of the 50m transect, with the rig approximately 2m above the substrate. A lawnmower pattern was followed at a steady pace, covering 1m either side of the transect line along the 50m transect. The operator aimed for at least 60% overlap of the path to ensure images could be aligned; preliminary testing indicates this method decreases alignment errors over single passes or higher image intervals.

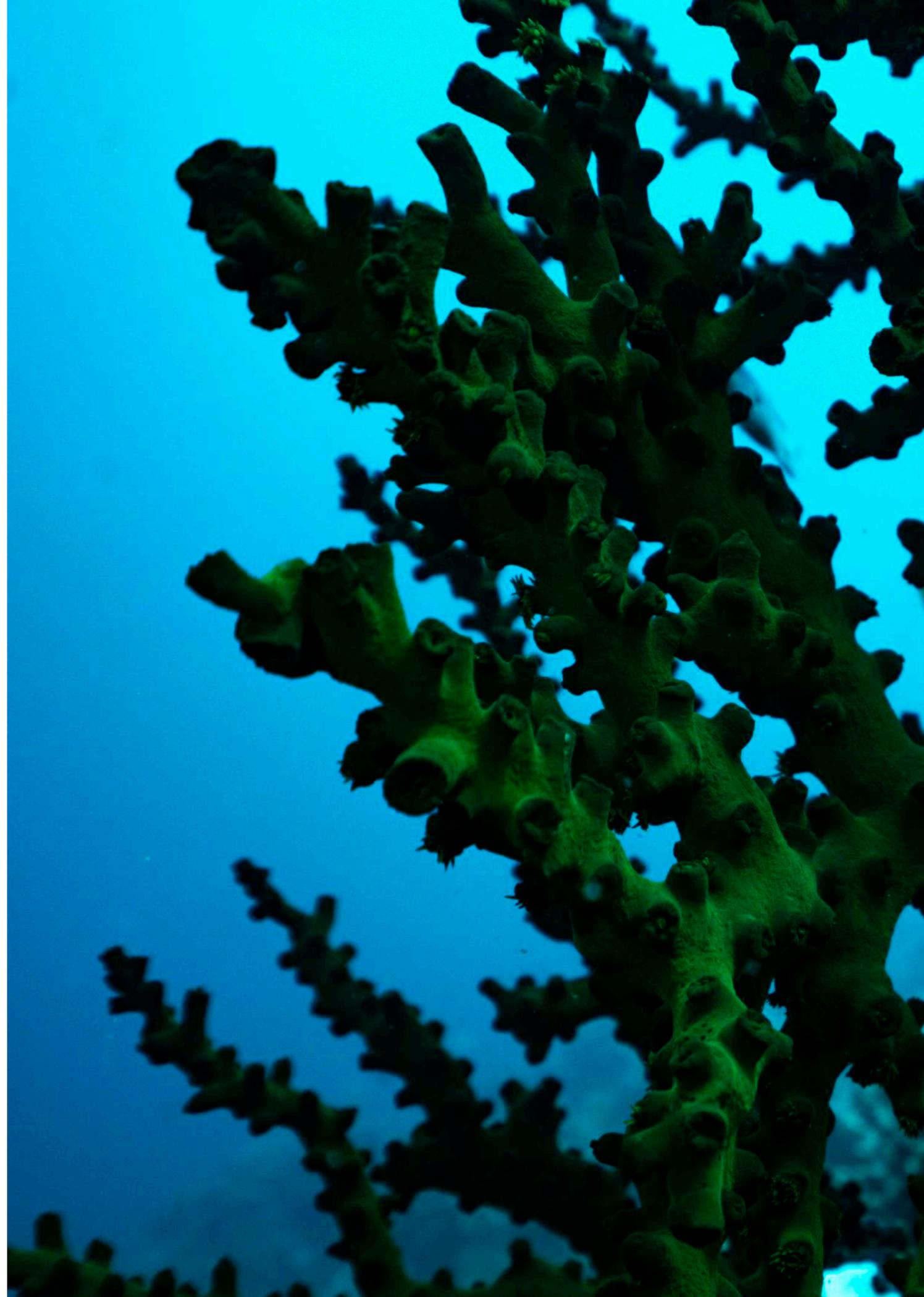
Stills were extracted at a rate of one per 30 frames from both camera videos, which were used to generate a 3D model (Agisoft Metashape Standard 9), using Structure from Motion (SfM) software and photogrammetry principles. Images were aligned with a high accuracy, generic preselection, key point limit of 40,000, tie point limit of 1000, and with an adaptive camera model fitting.

The alignment was optimised to fit k4, and a dense cloud was created with medium quality, mild depth filtering, with point colours calculated..



Metadata

Before every survey dive, air temperature (°C), wind speed (kts), tidal state (low/high, rising/falling), sea state (calm/slight/moderate/rough), and boat activity (number of fishing and diving boats present) were recorded. This can be used in conjunction with any other data collected when needed.



Dauin Long-Term Monitoring Project

IMR in Numbers

2023 – 2024

>1200
Min of Trash
Collecting



+200
Dive Against
Debris
Conducted



35672
Fish Counted of
Dauin's Reefs



Fish Community & Trends

19
Sites
Surveyed in
Dauin

5
Sites had
Low
Biomass

4
Sites had
Moderate
Biomass

2
Only Sites
with High
Biomass

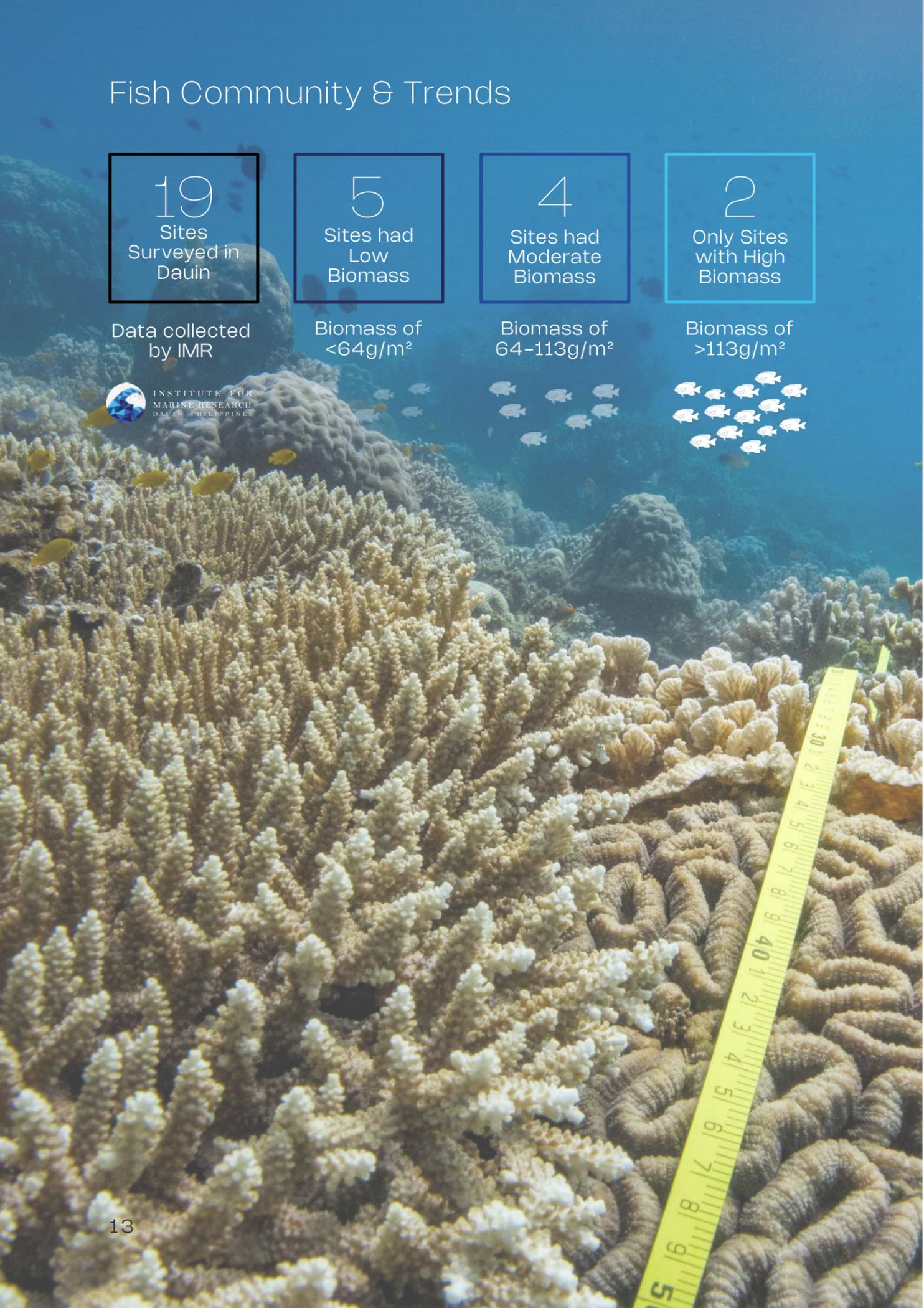
Data collected by IMR



Biomass of <math><64\text{g/m}^2</math>

Biomass of $64\text{--}113\text{g/m}^2$

Biomass of $>113\text{g/m}^2$



Mean Fish Biomass per Location (2023)

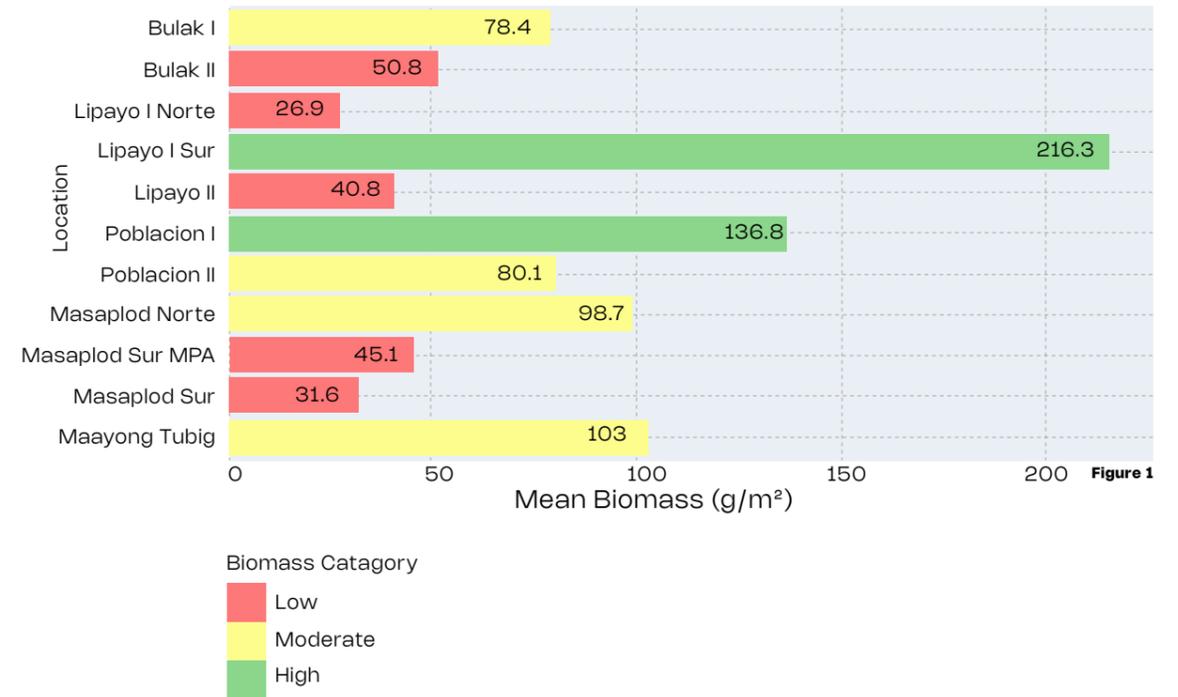


Figure 1 Mean fish biomass (g/m²) across sites, categorized as high (green), moderate (yellow), or low (red). Lipayo I Sur and Masaplod Norte exhibit the highest biomass, while sites such as Lipayo I Norte, Masaplod Sur, and Bulak II show the lowest. The moderate biomass category includes sites such as Poblacion I and Maayong Tubig. These spatial patterns highlight site-specific differences in fish biomass distribution.



45%

of all reefs surveyed recorded a low fish biomass

18%

The total fish abundance decline, recorded from 2020–2023.

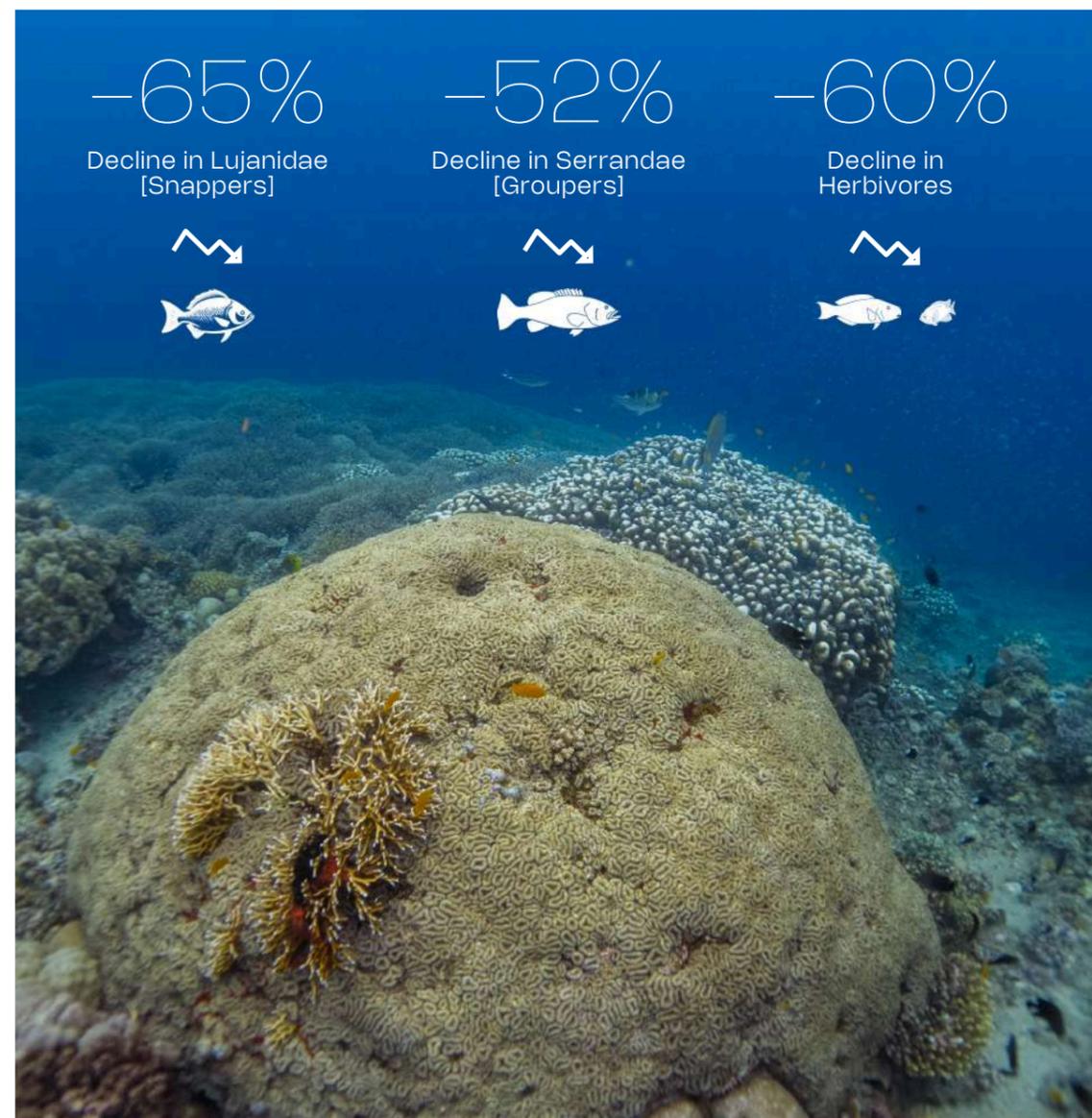
71.5%

of total trash found on the reef related to fishing.

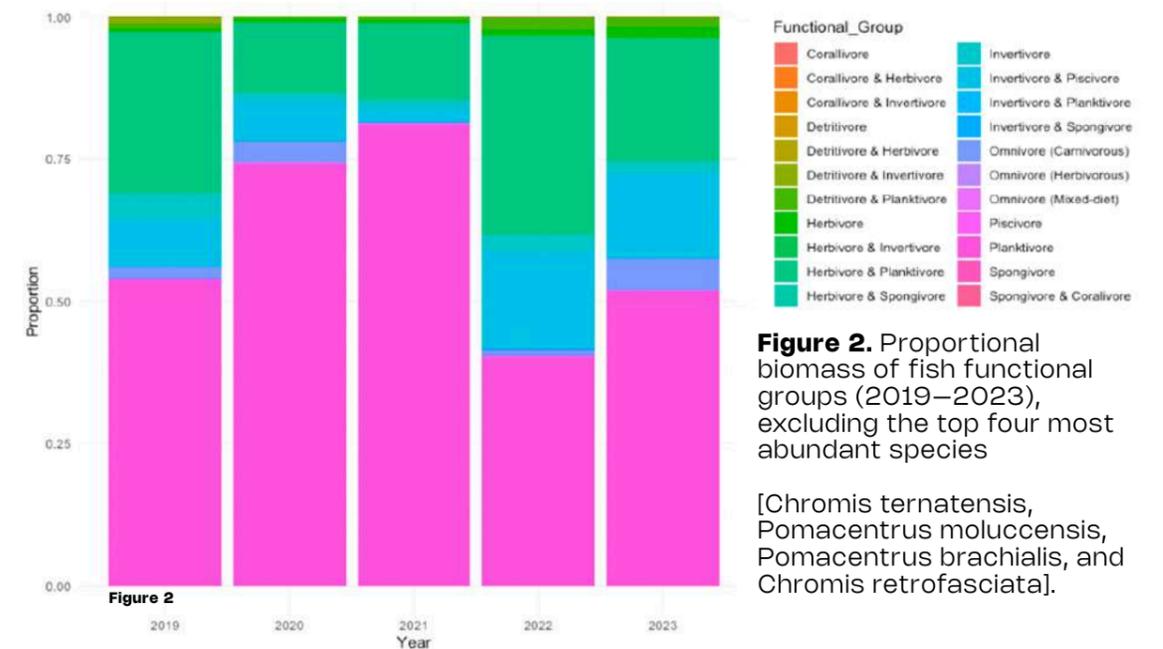
Long-Term Trends Across Dauin

Fish abundance, biomass, and species richness **declined from 2019 to 2023**, coinciding with an increase in fishing trash during COVID-19. A model analysis indicated a significant lag effect of fishing trash on biomass (Estimate = -2.295, p = 0.043). Fishing trash was 71.5% of total trash found on the reef. However, signs of recovery were observed between 2022 and 2023.

- ◆ Total fish abundance declined by 18% (2020–2023).
- ◆ Shallower sites (5m) experienced a **12% greater decline than deeper sites** (10m).
- ◆ **Predatory fish biomass declined sharply between 2019 and 2021:**
 - ◆ Lutjanidae [Snappers] (-65%) Serranidae [Groupers] (-52%) Herbivores declined by 60%, particularly at sites with decreased coral cover.



Proportional Functional Group Biomass Over Time (Excluding Top 4 Species)



Planktivores (pink) consistently dominate biomass, though their proportion fluctuates. **Herbivorous fish (green) remain a key component**, while invertivores and piscivores (blue) show variability. This suggests relative stability in functional group representation despite overall biomass declines. **Fish community composition remained relatively stable due to strong site dependence**, despite overall declines in abundance and biomass.



Spatial Patterns in Biomass

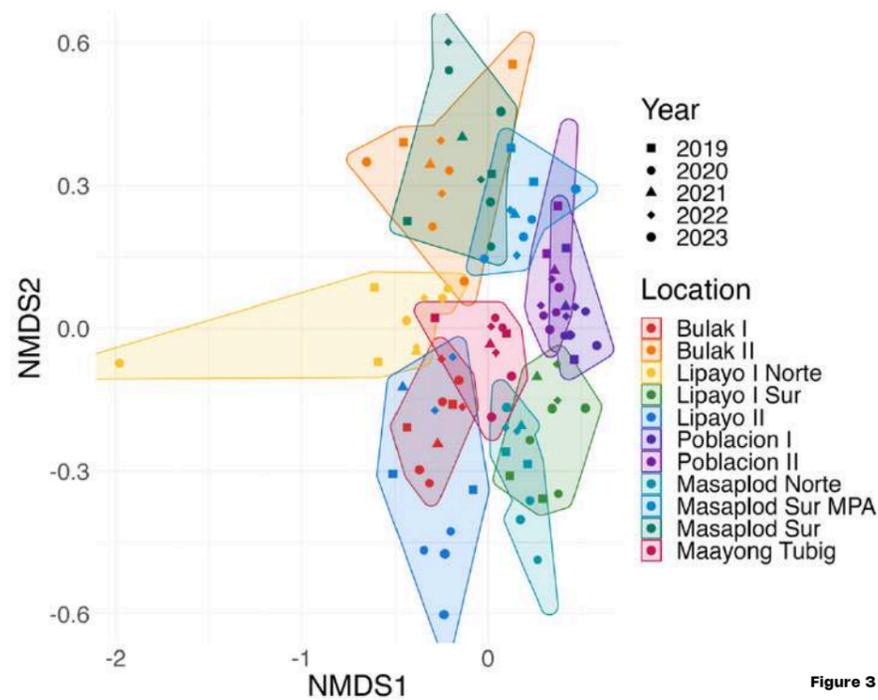


Figure 3

Figure 3. Non-metric multidimensional scaling (NMDS) ordination of fish community composition across sites. Each point represents a surveyed fish community, colored by site and shaped by year. Convex hulls illustrate community similarity and dispersion. NMDS axes represent relative differences based on species composition and abundance.

Long-Term Trends and External Stressors

- ◆ Fish biomass and abundance were relatively stable (2019–2021) before declining in 2022, coinciding with increased fishing pressure and habitat degradation.
- ◆ Partial recovery occurred from 2022 to 2023, particularly in MPAs.
- ◆ Fishing pressure and habitat degradation were likely key drivers of biomass loss.
- ◆ **Sites with declining coral cover and increasing algal cover experienced more extreme fish losses, including herbivores, which are crucial for reef resilience.**

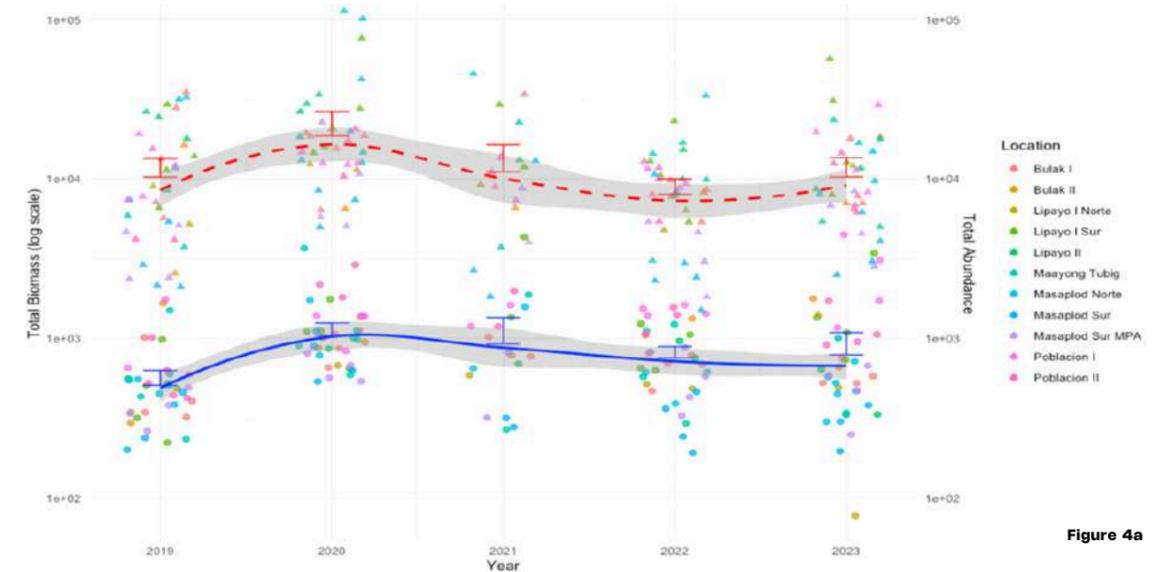


Figure 4a & 4b. Trends in fish community metrics and fishing trash over time: (a) Total fish abundance (blue) and biomass (red) (2019–2023) with fitted trend lines. (b) Species richness trends, initially increasing before a slight decline.

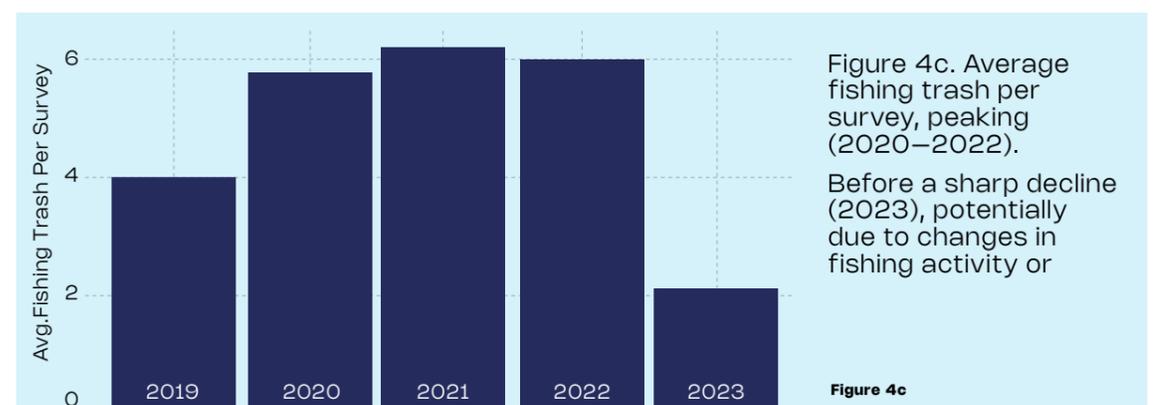
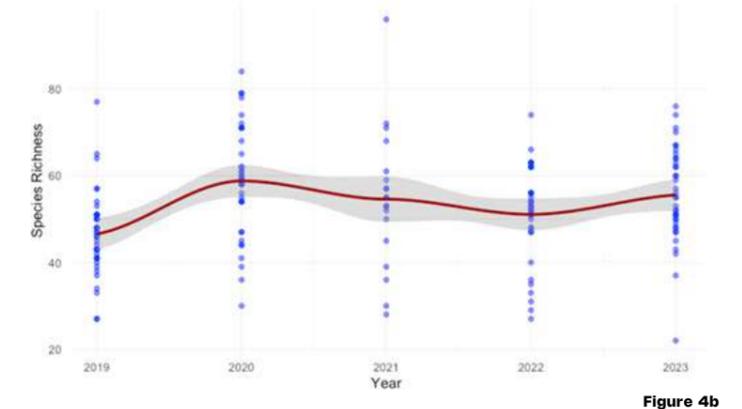
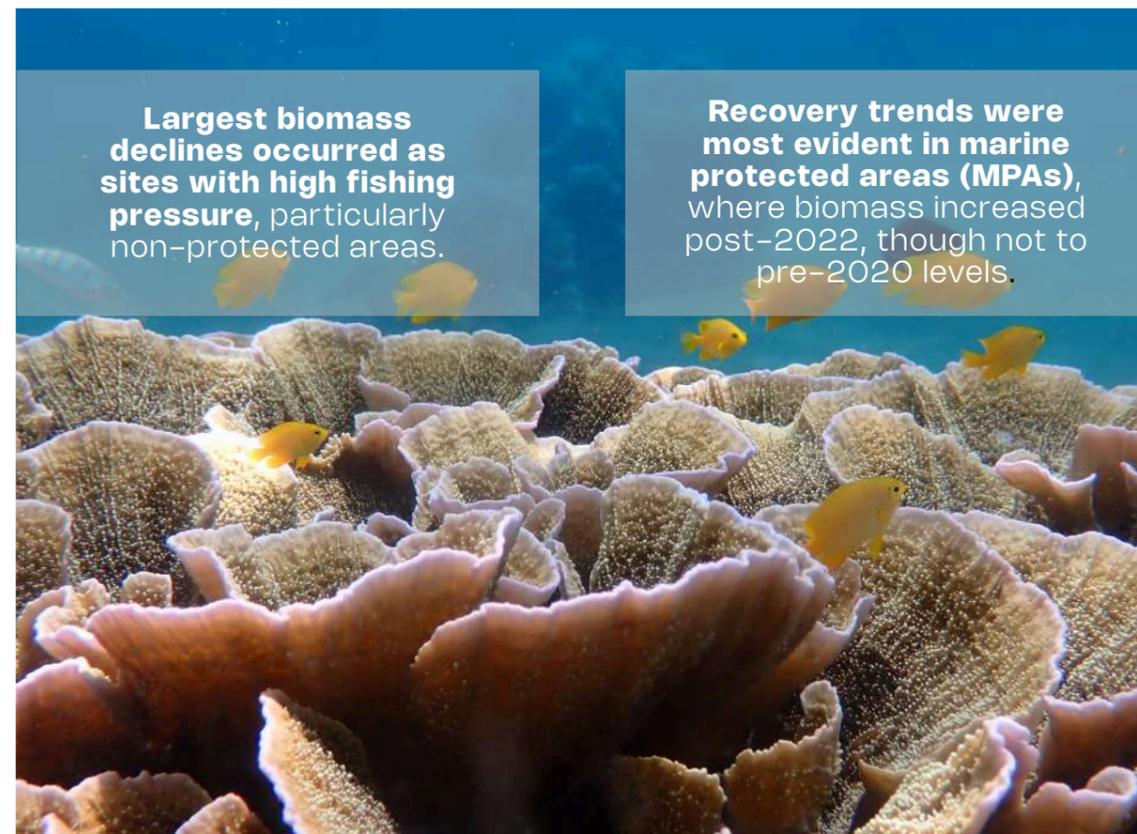


Figure 4c. Average fishing trash per survey, peaking (2020–2022). Before a sharp decline (2023), potentially due to changes in fishing activity or



Site Specific Observations

- ◆ Sites with sustained coral cover had a **35.35% increase in fish biomass (2019–2023)**.



- ◆ Biomass at sustained coral sites was **84.05% higher than at sites with coral loss**.

- ◆ Sites with coral decline experienced a **48.7% biomass decrease**.



- ◆ A rise in algal-associated fish was observed at macroalgal-dominant sites.

Total Fish Biomass Trends (2020 – 2023)

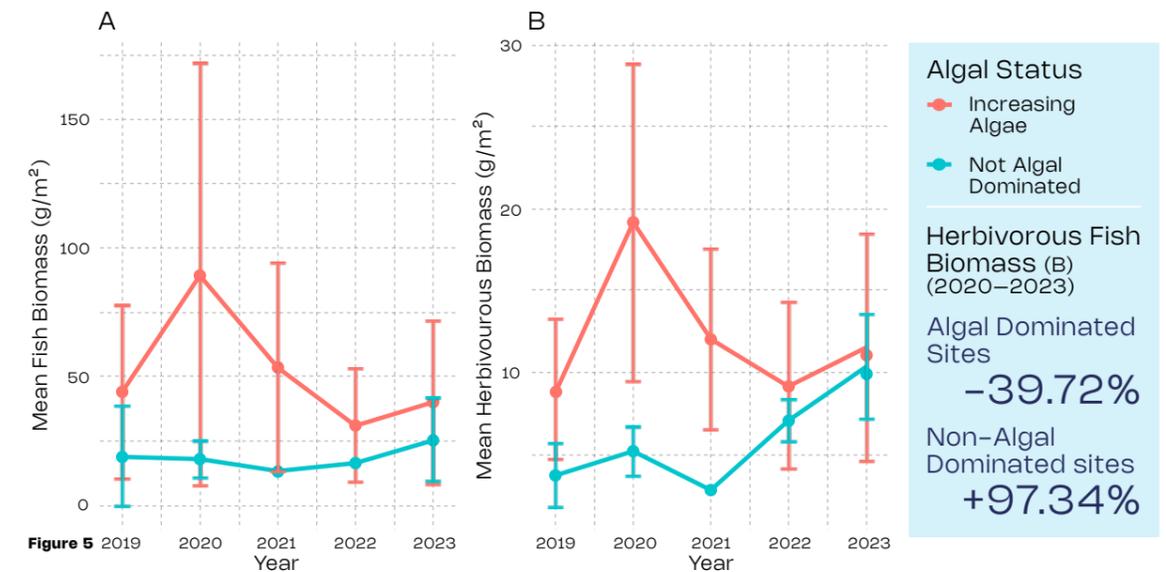


Figure 5. Fish biomass trends in relation to algal dominance: **(A)** Mean total fish biomass (g/m²) across years for sites classified as "Increasing Algae" or "Not Algal Dominated." **(B)** Mean herbivorous fish biomass (g/m²) for the same classifications, highlighting potential differences in herbivore responses to algal increases.

Key Summary

- ◆ Fish abundance, biomass, and species richness declined (2019–2023), **correlating with increased fishing trash during COVID-19**.
- ◆ **Community composition remained stable despite biomass declines**, due to strong site dependence.
- ◆ A delayed negative impact of fishing trash on biomass was observed.
- ◆ **Sites with coral loss and increasing algal cover suffered the most extreme fish declines**, including among herbivores.
- ◆ Signs of recovery appeared post-2022, **particularly in MPAs**.

Among the 19 sites surveyed

- 2 Only Two Sites recorded hard coral cover in the Good Coral Communities range (31–50%).
- 4 Sites recorded hard coral cover in the Fair Coral Communities range (11–30%).
- 5 Sites recorded hard coral cover in the Poor Coral Communities range (0–10%).

Benthic Community Trends (2019 – 2024)

Current State of Dauin Reefs

Benthic community composition varied significantly across all sites surveyed from 2019 to 2024. **Hard coral cover declined by 15.5%.**

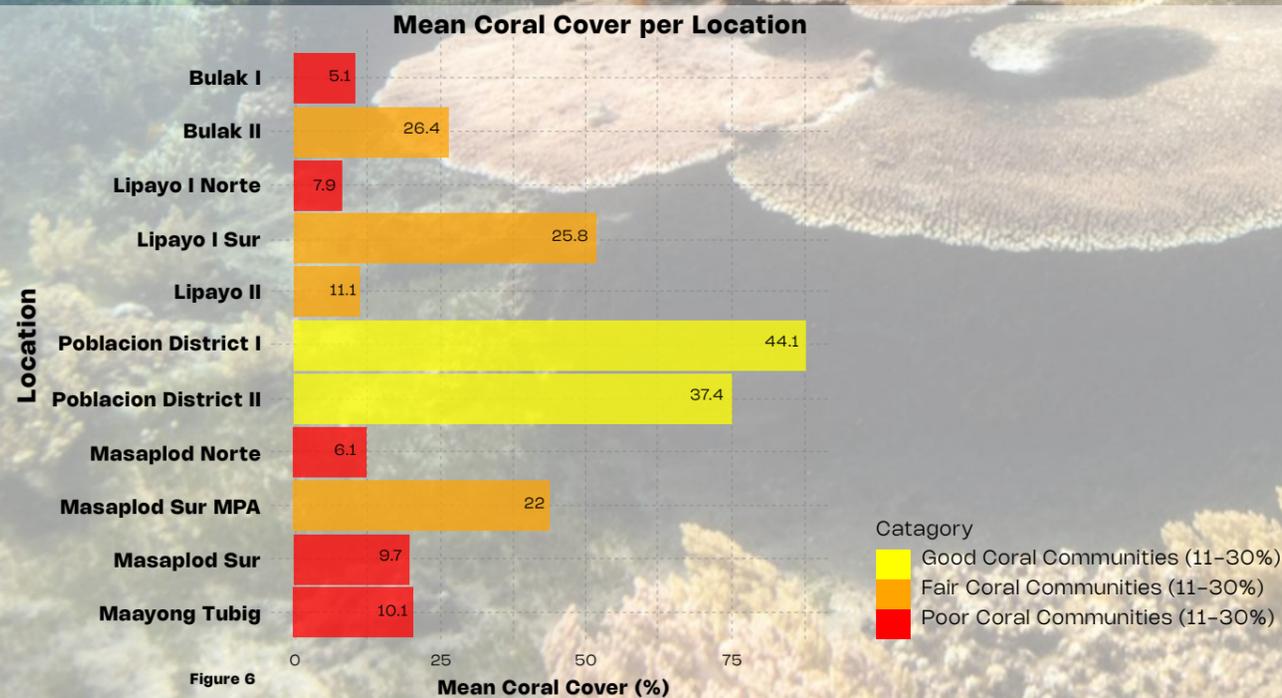
This decline has been driven by multiple stressors, including **thermal stress, disease outbreaks, and significant crown-of-thorns starfish (COTS) predation** (covered in a later section).

Where hard corals have declined, **turf algae and macroalgae have been the dominant replacement benthos**, with notable increases in ascidians and other encrusting organisms. Octocorals and CCA have also expanded substantially, signaling broader shifts in benthic structure.

Among the 19 sites surveyed:

- ◆ 0 sites recorded hard coral cover in the Excellent Coral Communities range (76–100%).
- ◆ 0 sites recorded hard coral cover in the Very Good Coral Communities range (51–75%).
- ◆ 2 sites recorded hard coral cover in the Good Coral Communities range (31–50%).
- ◆ 4 sites recorded hard coral cover in the Fair Coral Communities range (11–30%).
- ◆ 5 sites recorded hard coral cover in the Poor Coral Communities range (0–10%).

Figure 6. Mean coral cover (%) across sites, categorized into three coral community conditions: poor (0–10%, red), fair (11–30%, orange), and good (31–50%, yellow). Poblacion District I and II exhibit the highest coral cover, while several sites, including Bulak I, Lipayo I Norte, and Masaplod Norte, fall into the poor category with <10% coral cover.



Long-Term Trends Across Dauin

Long-term monitoring reveals major shifts in substrate composition driven primarily by coral loss, algal encroachment, and an increase in other benthic groups.

Coral cover declined significantly at 11 of 19 sites from 2019 to 2024.

Rubble cover decreased by 54%, due to colonization by encrusting organisms and sediment shifts.

Macroalgae increased by 37%, particularly at sites with reduced herbivore populations.

Turf algae increased at all sites, with an overall **rise of 218%**, indicating an ongoing phase shift in benthic composition. However, in the past year, **some sites have seen a replacement of turf algae by bare substrate as herbivore populations begin to rebound.**

Octocorals expanded by 268%, signaling a shift toward alternative reef structures in areas of prolonged coral loss.

Sponges and ascidians increased at several degraded sites, often competing with corals for available space.



Trends in Benthic Categories Over Time

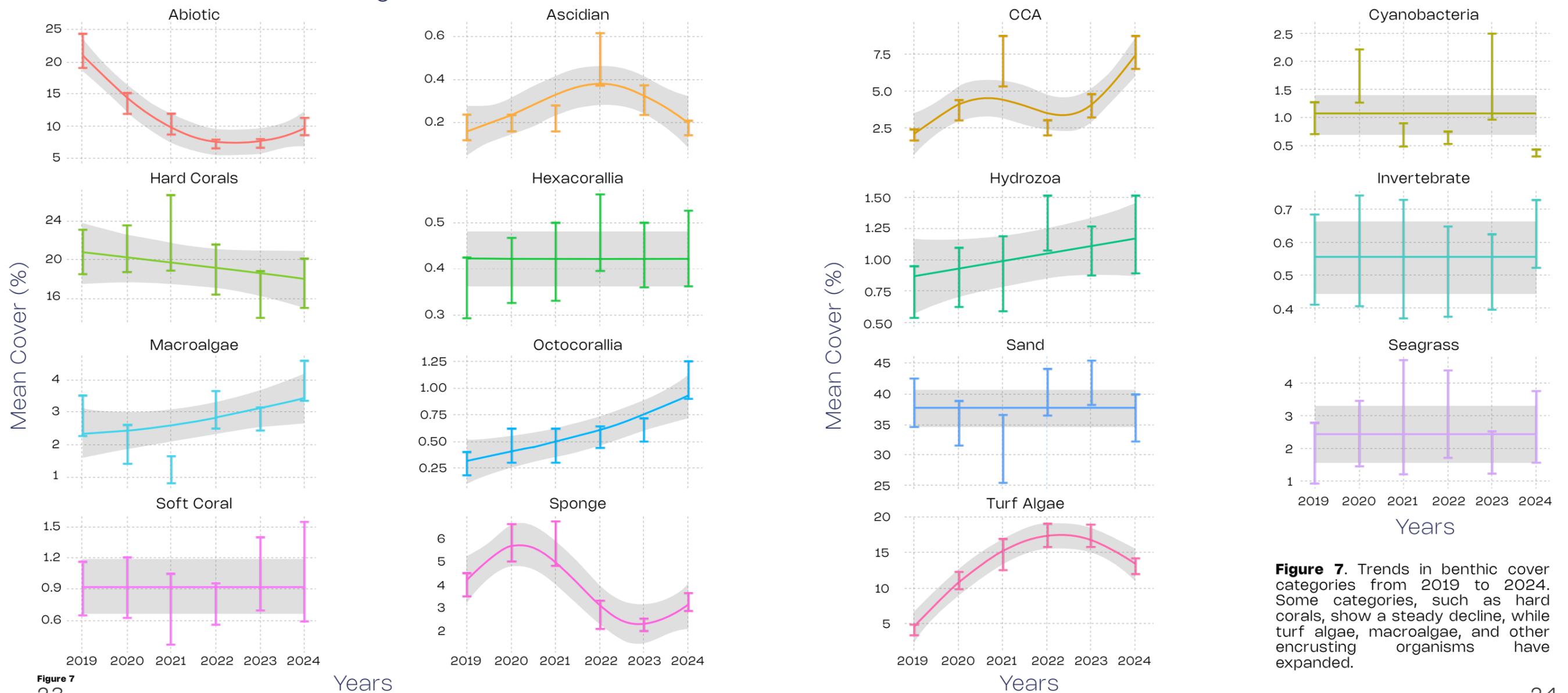


Figure 7. Trends in benthic cover categories from 2019 to 2024. Some categories, such as hard corals, show a steady decline, while turf algae, macroalgae, and other encrusting organisms have expanded.

Spatial Patterns in Benthic Cover

- ◆ **Sites with long-term protection and lower disturbance levels retained higher coral cover.**
- ◆ Sites experiencing chronic stressors, including **high fishing pressure and sedimentation, exhibited more pronounced coral loss and algal shifts.**
- ◆ **Macroalgae cover increased at five sites**, particularly in areas with declining coral cover and limited herbivore presence.
- ◆ Rubble and unconsolidated substrate decreased at most sites, indicating that previously loose substrate is either being buried or colonized by benthic organisms.

Non-metric multidimensional scaling of Benthic Communities

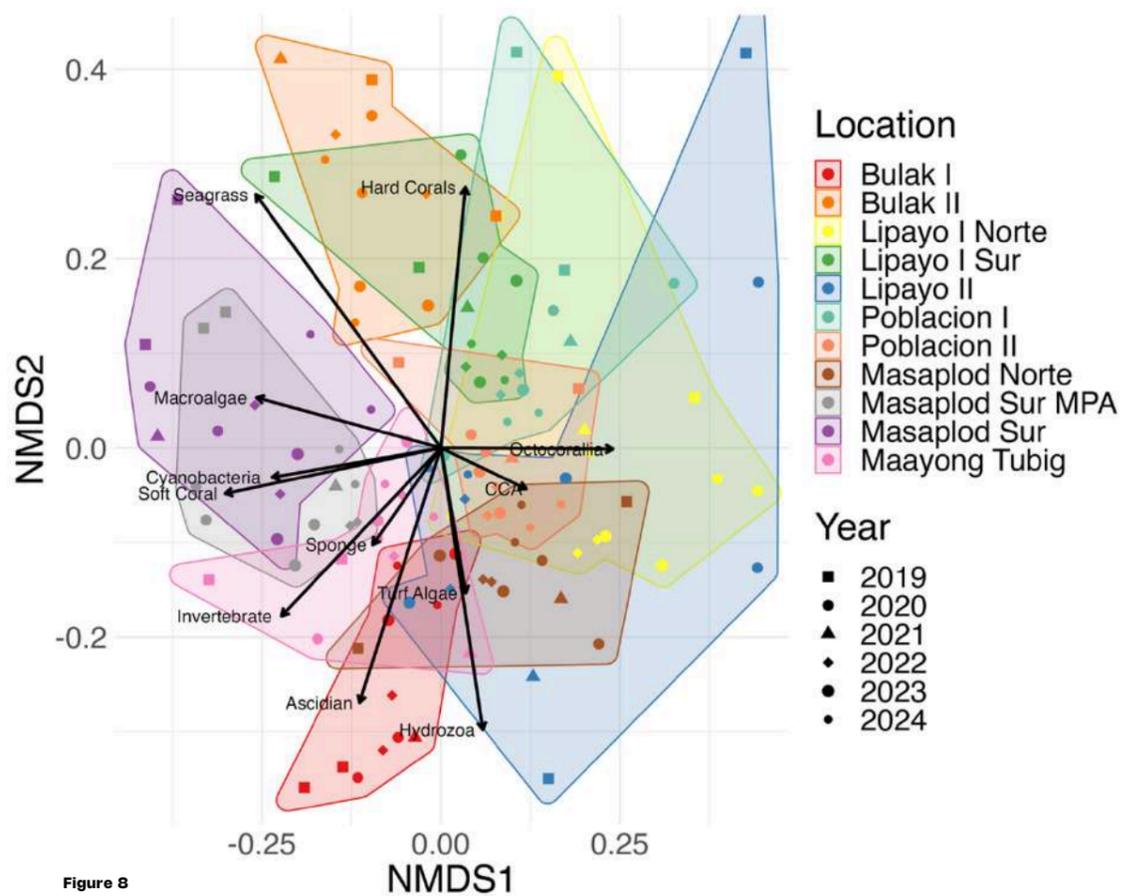


Figure 8. Non-metric multidimensional scaling (NMDS) plot showing benthic community structure across different sites during dry and wet seasons. Each point represents a sample, colored by site, with circles indicating the dry season and triangles indicating the wet season. Convex hulls enclose points from the same site, illustrating community composition variability.

Site-Specific Observations

- ◆ Sites with sustained coral cover exhibited greater reef resilience, maintaining more diverse benthic compositions.
- ◆ Sites experiencing coral loss showed increasing dominance of turf algae and macroalgae.
- ◆ Sponges and encrusting organisms expanded at several degraded sites, suggesting opportunistic colonization.

Changes in Key Benthic Categories (1019- 2024)

- ◆ **Hard Coral Cover: -15.5%**
- ◆ **Crustose Coralline Algae (CCA): +289%**
- ◆ **Macroalgae Cover: +37%**
- ◆ **Sponges: -20%**
- ◆ **Turf Algae Cover: +218%**
- ◆ **Cyanobacteria: -64%**
- ◆ **Octocorals: +268%**

Trends in Benthic Categories Over Time – (Decreasing Coral Sites Only)

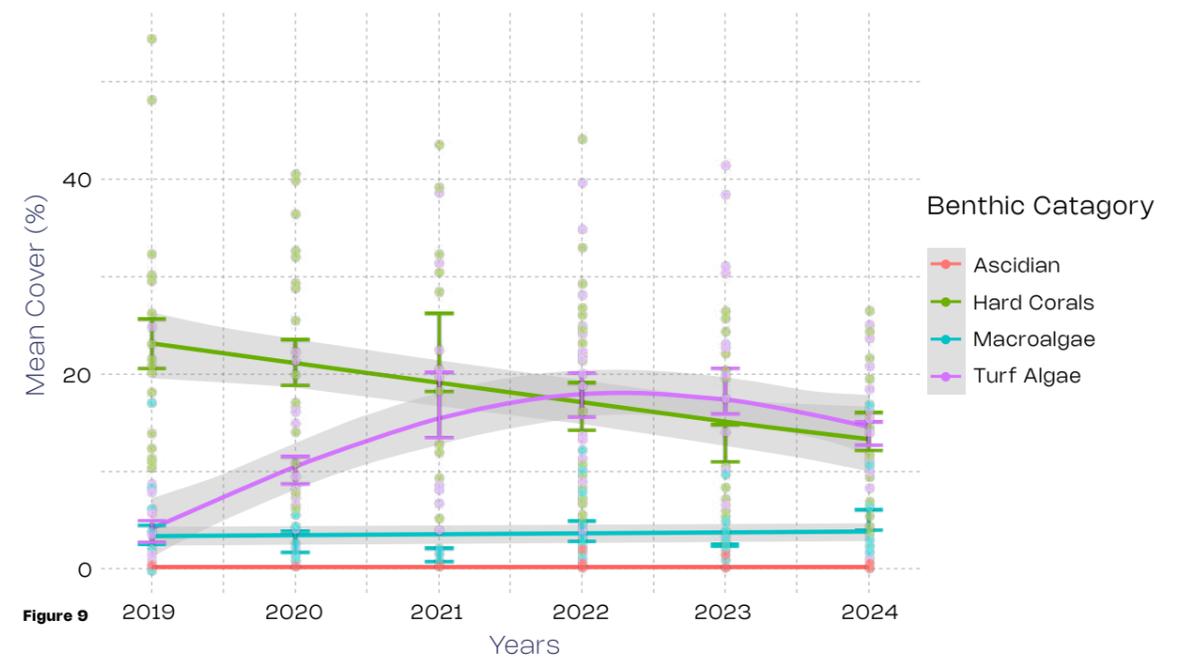


Figure 9. Trends in key benthic categories over time at sites where hard coral cover declined from 2019 to 2024. Hard corals (green) show a clear downward trend, while turf algae (purple) increases over time, suggesting a shift from coral-dominated to algal-dominated benthic communities. Macroalgae (blue) remains relatively low but slightly increases, while ascidians (red) show a stable but notable presence.

External Stressors and Potential Impacts

- ◆ Coral decline has been driven by a **combination of typhoon, disease outbreaks, and significant COTS predation**.
- ◆ Sites with **higher fishing pressure and reduced herbivore biomass** exhibit more pronounced macroalgal overgrowth.
- ◆ **Sedimentation and nutrient input from coastal activities** contribute to increased turf algae and cyanobacteria growth.

Conclusion and Future Considerations

- ◆ Surveys indicate that coral cover is declining overall, though it remains stable at some sites.
- ◆ Turf algae and macroalgae continue to increase where coral loss has occurred, raising concerns about long-term reef resilience.
- ◆ A decline in rubble and abiotic cover suggests stabilization, but shifts toward encrusting organisms and soft corals indicate a broader ecological transition.
- ◆ Continued monitoring is necessary to assess ongoing changes and potential recovery trajectories.

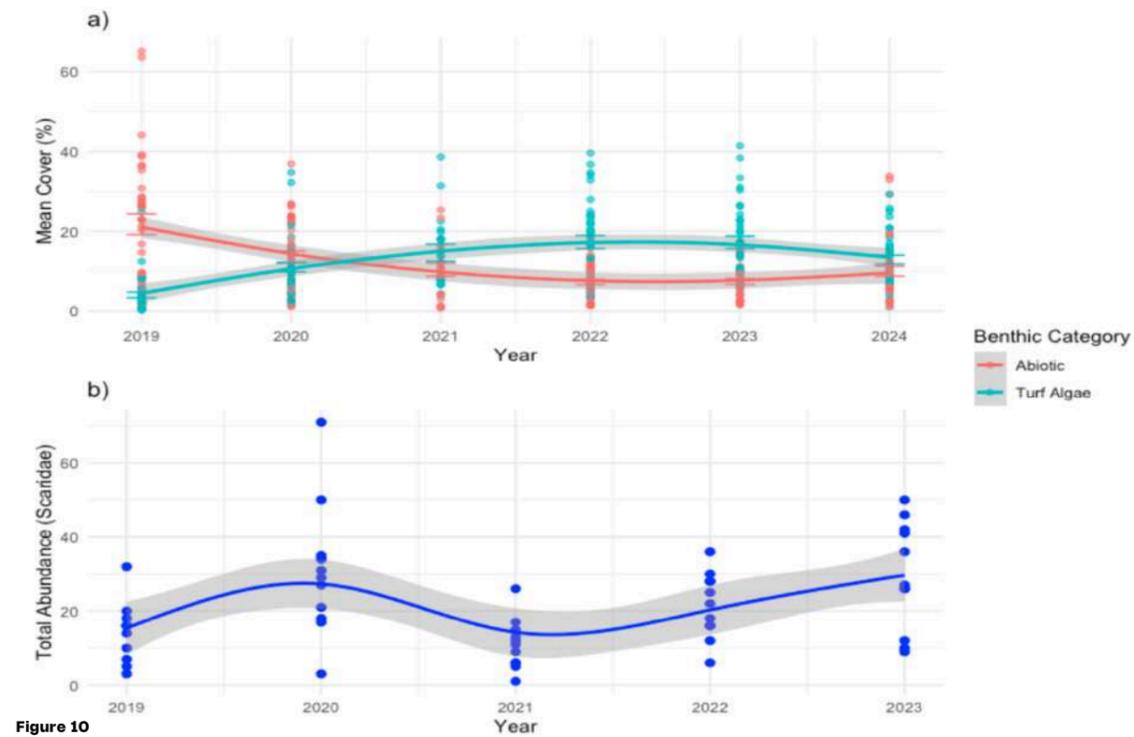


Figure 10. Trends in benthic cover and parrotfish abundance over time. (A) Mean cover of turf algae and abiotic substrate from 2019 to 2024, showing fluctuations in these benthic categories. (B) Total abundance of parrotfish (Scaridae) over the same period, with a smoothing trend indicating temporal patterns.

Depth Variation

Deeper (10m) sites generally retained higher coral cover than shallower (5m) sites.

Sites with stable coral cover corresponded with high fish herbivore biomass.

Sites with declining coral cover showed increases in macroalgae and reduced herbivore presence. Activities contribute to increased turf algae and cyanobacteria growth.

Reef Impacts (2019 - 2024)



Crown-of-Thorns Starfish (Acanthaster spp.)

- ◆ Crown-of-Thorns Starfish (COTs) **outbreaks are a complex ecological issue, are considered to be the third biggest threat to coral reefs in the Philippines.** The specific definition of an outbreak can vary slightly depending on the region, reef type, and study.
- ◆ **IMR classifies an outbreak as >1 COTs per 100 m² (0.1/m²).**
- ◆ The following data was collated from a **7-month monitoring period** (May – November) in 2024 **within 4 Marine Protected Areas** (Lipayo I Sur, Maayong Tubig, Masaplod Sur and Poblacion). As a result, all sites are experiencing targeted, and ongoing culling efforts.

COTs Prevalence (May – November 2024)

Maayong Tubig:

Across 4 of the 5 months surveyed, COTS numbers exceeded ~100 individuals per hectare. In June, however, over 200 individuals were estimated per hectare (Figure 11).

Masaplod Sur:

Across 3 of the 5 months surveyed, estimated numbers exceeding ~100 individuals per hectare. The other two surveys conducted (August & September) display an estimated number of 50+ individuals per hectare.

Poblacion:

COTs numbers increase in November, with ~500 estimated individuals/hectare recorded.

Comparatively, this is a big increase in numbers seen from previous survey months at Poblacion. In May, estimated numbers were close to 200 individuals/hectare, August saw an estimate of approx. 70 and September averaged out just short of 200 estimated individuals/hectare

Estimated COTs Populations at Sites (Monitoring from May – Nov. 2024)



Maayong Tubig : **200> COTs Per Hectare**

Masaplod Sur : **200> COTs Per Hectare**

Poblacion : **500> COTs Per Hectare**

*IMR Classifies an outbreak as 1> COT per Hectare

Estimated COTs Populations per Site (May – November 2024)

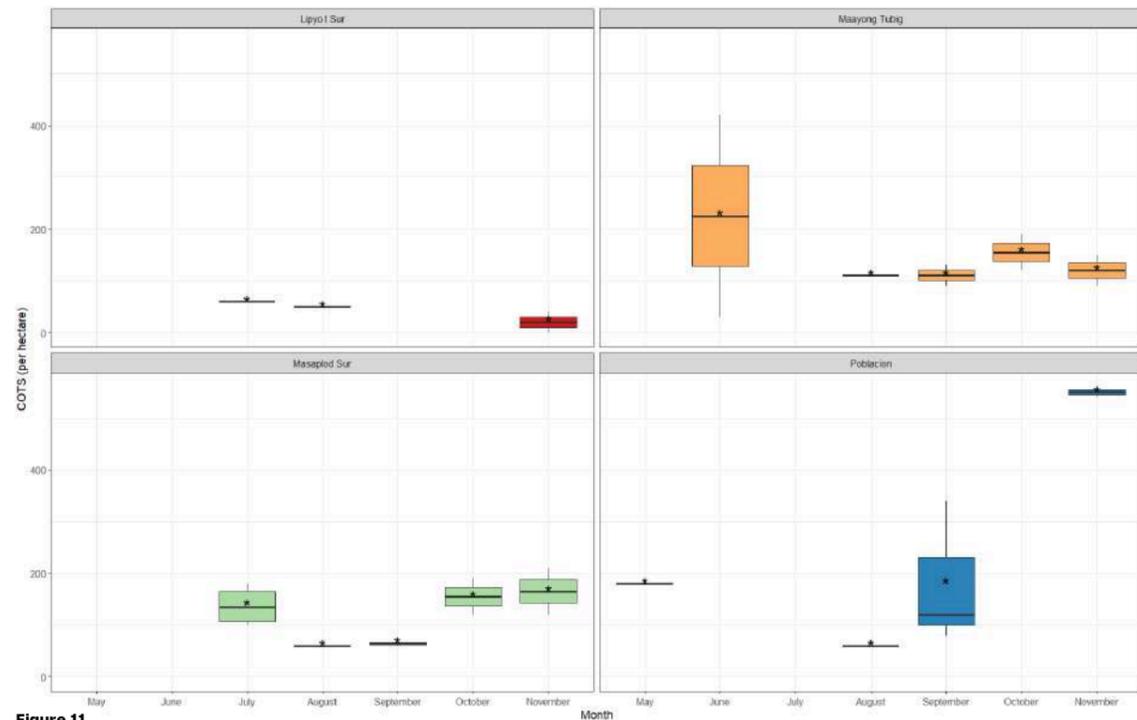


Figure 11

Figure 11. Estimated number of COTS per hectare across a 7-month monitoring period (May to November 2024) at 4 Marine Protected Areas along the Dauin inshore reef (Lipayo I Sur, Maayong Tubig, Masaplod Sur, Poblacion).

Site-Specific Culling Efforts (May – November 2024)

- ◆ During our 7-month monitoring period, there was no single survey month where we were able to cull 100% or near 100% of individuals seen within our survey paths (Figure x).
- ◆ The most successful culling efforts were seen in August at Maayong Tubig, where 75% of surveyed individuals were culled.
- ◆ In comparison, other surveys recorded near or below 50% COTS culled.
- ◆ Barriers to culling efforts are present, however the following areas are being addressed to optimize culling efforts:
 1. Identifying optimal culling timeframes, where COTS are more active and exposed
 2. Obtain longer needles to target COTS deep with Acropora spp. branches

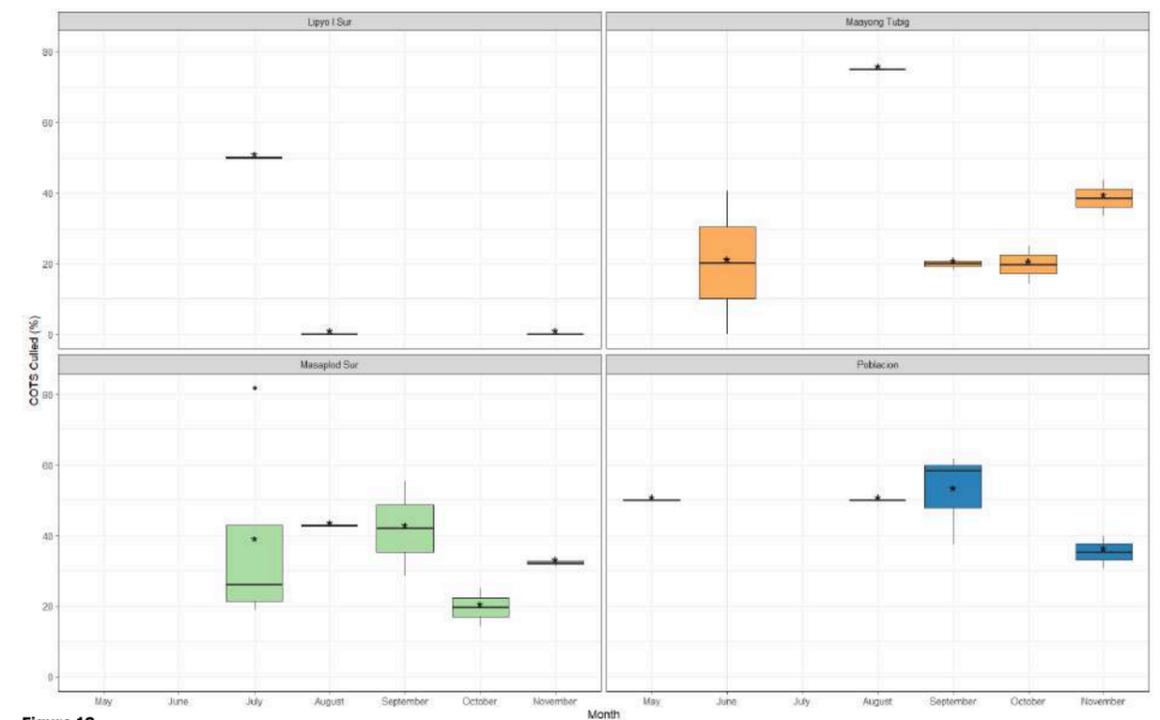
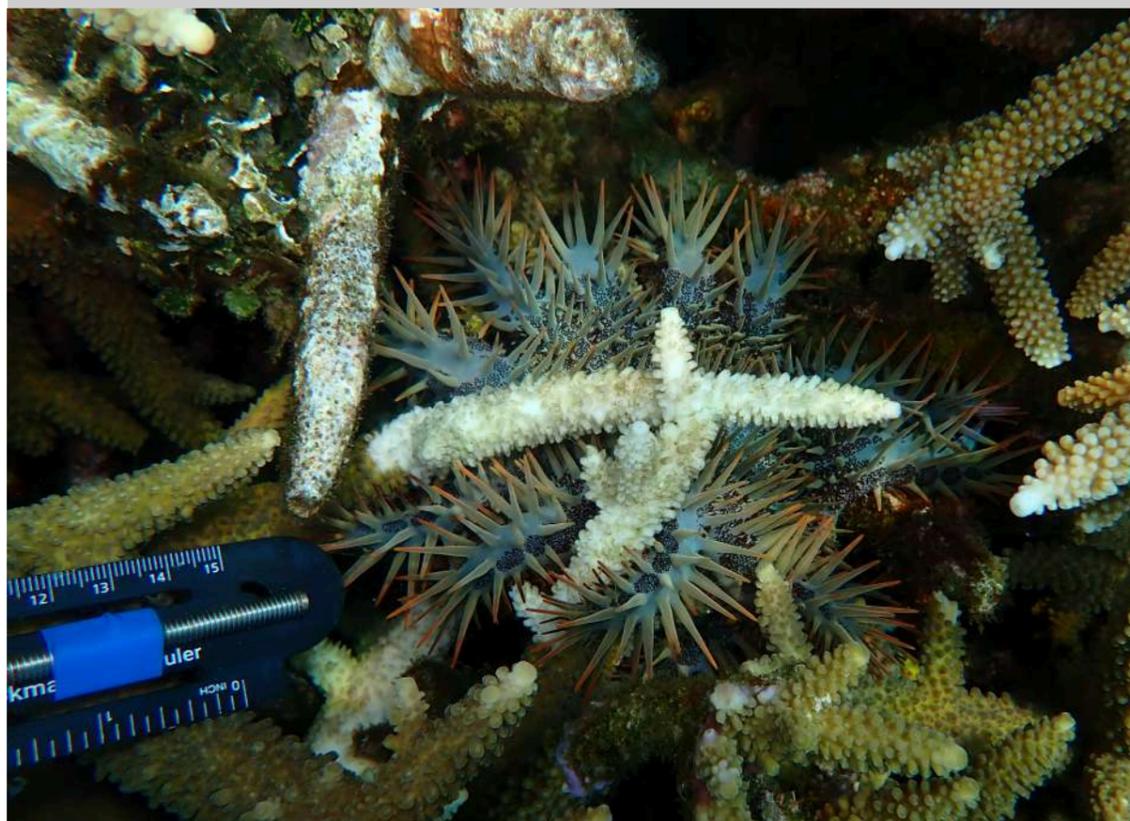


Figure 12

Figure 12. Proportion (%) of COTS per 100m² culled across a 7-month monitoring period (May to November 2024) at 4 Marine Protected Areas along the Dauin inshore reef (Lipayo I Sur, Maayong Tubig, Masaplod Sur, Poblacion). This proportion represents the COTS that



Coral Bleaching

- ◆ **Coral bleaching has remained consistently low across a 6-year monitoring period (2019 – 2024), with 17 – 108 affected colonies/1,900m² recorded per survey season. Genus and size-specific susceptibility to coral bleaching has been identified.**
- ◆ **Wet season of 2022** saw the highest spike in bleaching records (**108 colonies/ 1,900m²**), with most recent surveys (**dry season 2024**) classifying **only 27 colonies per 1,900m² as 'bleached'** (Figure 13).
- ◆ Priority areas of bleaching surveillance include Maayong tubig, Masaplod Norte, and Poblacion II.
- ◆ **No mass coral bleaching events have been recorded across a 6-year monitoring period in Dauin**, despite persistent mass bleaching episodes recorded throughout the Philippines.

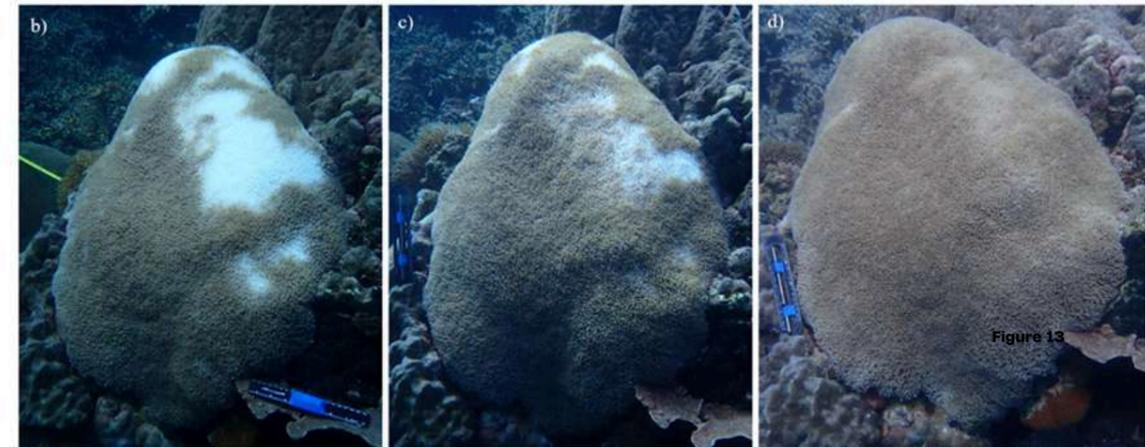
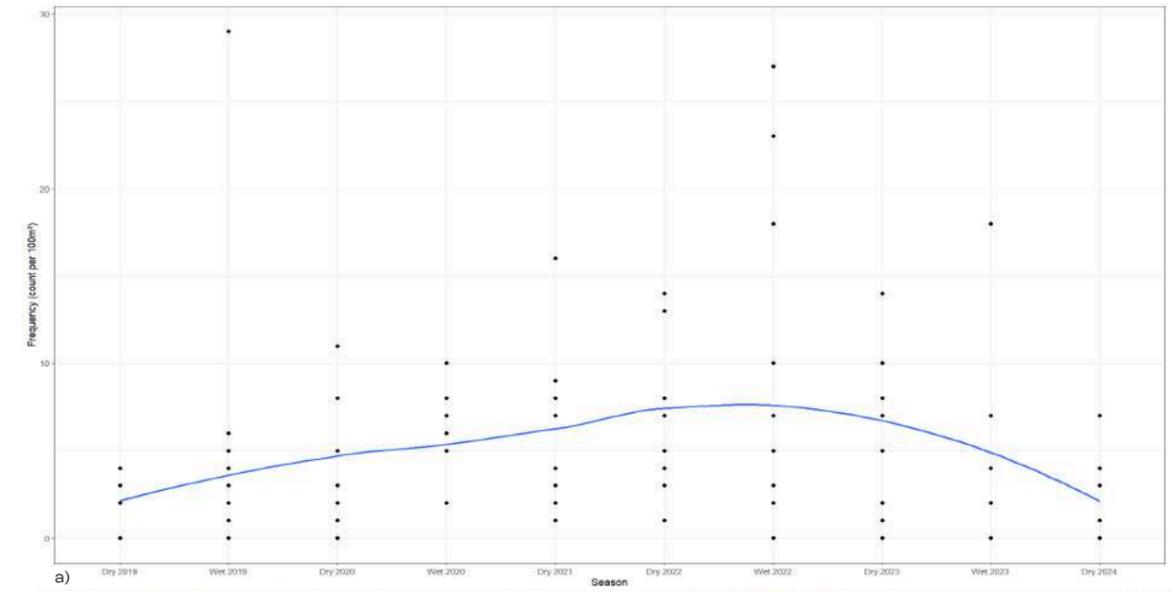
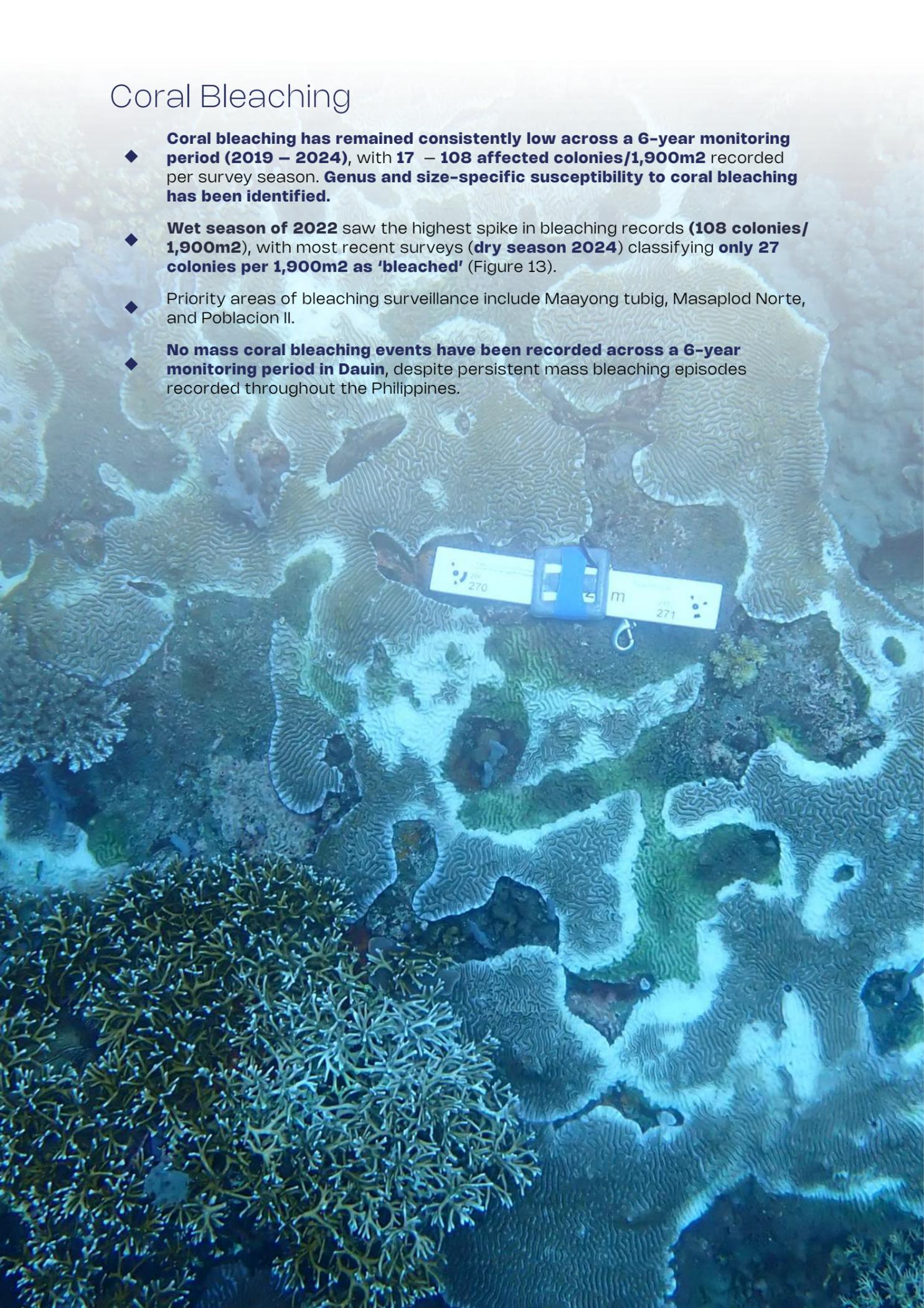


Figure 13. (a) Bleaching frequency across the Dauin inshore reef between 2019 – 2024, (b) partial bleaching of *Physogyra lichtensteini*, (c) partial recovery occurring after 3-months, and (d) full recovery occurring after 5-months.



Figure 14. (a) Partial bleaching of *Dipstastrea* spp., (b) partial recovery occurring after 1-month, and (c) full recovery occurring after 2-months.

Porites Ulcerative White Spot Disease

- ◆ **Porites Ulcerative White Spot (PUWS) is a bacterial disease affecting the dominant reef-building coral *Porites* spp** (Figures 15 and 16).
- ◆ This disease was first observed in the Philippines back in 1996 (Raymundo et al. 2003) and has been **identified through the Dauin long-term reef monitoring project since its inception in 2019.**
- ◆ **In 2019, PUWS was observed at 3 out of 19 survey sites (DLTRMP), expanding into 12 out of 19 survey sites in 2024.**
- ◆ On-going research, both from **our Dauin Long-Term Reef Monitoring Project (DLTRMP)** and from **IMR Independent Researchers** are **continuously monitoring infected colonies over space and time.** These studies aim to quantify the i) prevalence, ii) progression, and iii) ecological impacts of PUWS.

Porites Colony Infected with PUWS

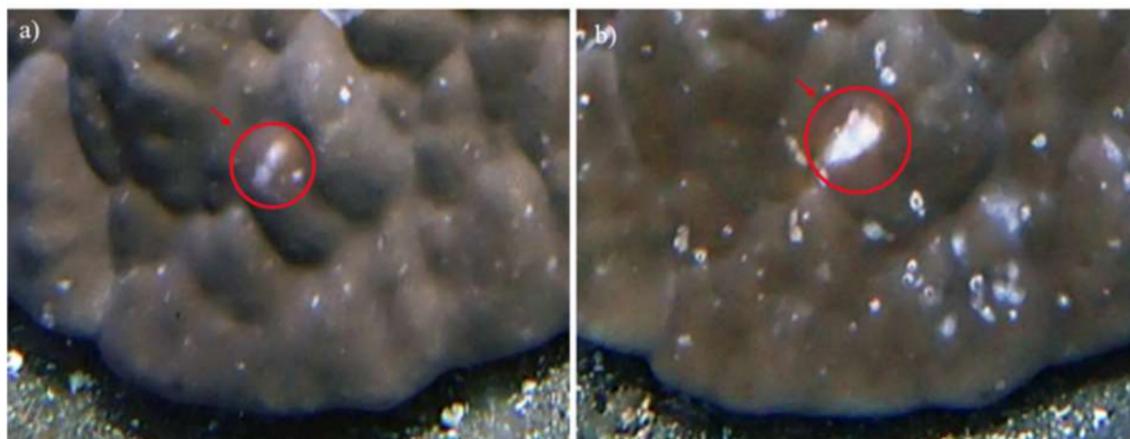


Figure 15

Figure 15. (a) Two PUWS lesions (circled in red) on *Porites* spp., (b) slow progression of the PUWS lesions coalescing into one following a 3-month monitoring period.

Classification of PUWS

PUWS is described and identified as **"discrete, bleached, round foci, 3 to 5 mm in diameter,** that may either regress or progress to full tissue-thickness ulcerations that coalesce, occasionally resulting in colony mortality (Raymundo et al. 2003)" – see Figure 16

***Porites* spp. colonies infected with PUWS has been documented to have a slower onset and progression compared to other Scleractinia-borne diseases.**

Despite the fact that lesions have been recorded for extended periods without significant tissue loss, recovery is rare (Raymundo et al. 2003).



Continuing research of this disease is vital to better understand its prevalence and resulting implications for reef health, especially due to its influence on primary reef-building corals (Kaczmarek 2009).

PUWS Lesion Progression

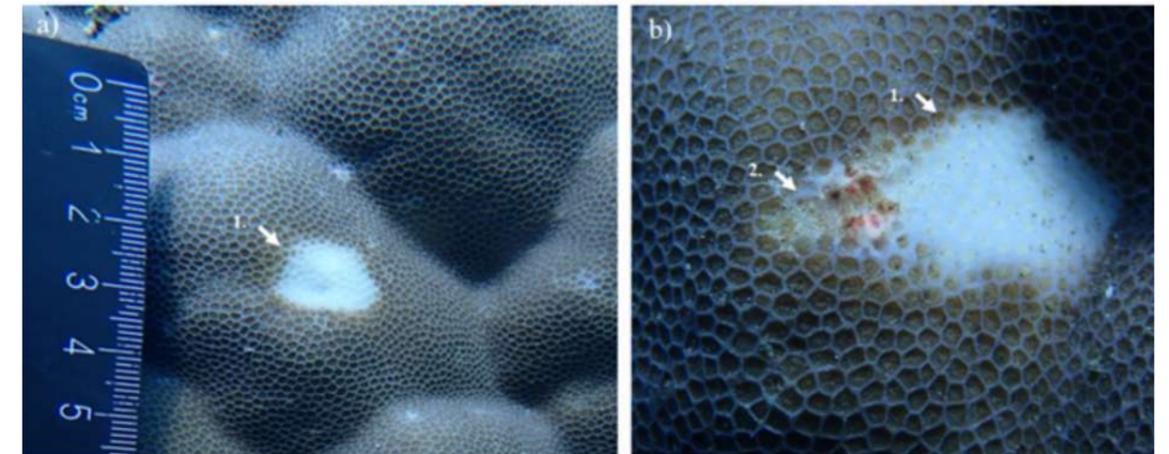


Figure 16

Figure 16. Two-step progression of a PUWS lesion. (a) Stage one of the lesion is characterized by bleaching within the lesion, no sign of any skeletal damage. (b) Stage two of the lesion results in skeletal damage (erosion and tissue loss) within the lesion.

Lipayo Sur – Cae Study

Long-Term Benthic and Fish Trends

Long-term monitoring at the 10m transect of Lipayo I Sur **reveals broader ecological shifts, influenced by declines in coral cover** and shifts in fish community structures.

Key Trends Include:

- Coral Cover Variability**
 Hard coral cover exhibited significant interannual variation, with an **overall decline from 2019 to 2024**. Hard coral cover peaked in 2021 at 43.56% before declining sharply in 2022 and 2023, **reaching a low of 23.03%**. Despite a brief increase in 2024, **the long-term trend suggests ongoing instability in coral populations**. Significant increases in opportunistic benthic organisms specifically **macroalgae, turf algae, and CCA** were observed replacing hard coral cover.
- Herbivore Declines & Algal Expansion**
Declines in key herbivorous fish groups, such as Scaridae (-68.8%) and Pomacentridae (-21.8%), may be linked to increased macroalgae and turf algae encroachment.
- Invertebrate & Predator Declines**
 Populations of invertivores (-25.1%), piscivores (-22.7%), and omnivores (-50.0%) have decreased, indicating **a potential restructuring of trophic interactions on the reef**.
- Significant Declines in Fish Families**
The fish community has undergone significant shifts, with large reductions in Labridae (-43.8%), Lutjanidae (-21.4%), and Holocentridae (-67.1%).

All these **changes suggest cascading effects** where coral decline and habitat degradation have led to **broader ecosystem shifts, impacting fish populations and functional group stability**.

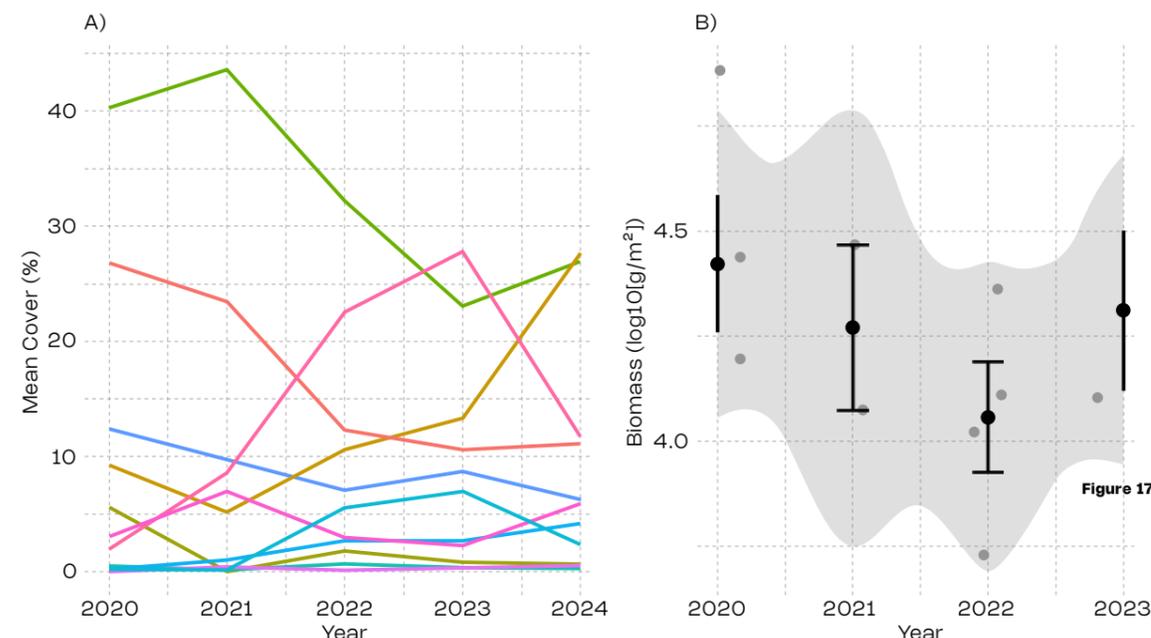


Figure 17. Benthic cover (a) and fish biomass (b) trends at the 10m transect of Lipayo I Sur from 2020 to 2024. (a) Mean percent cover of benthic categories over time, with key groups such as Hard Corals (green), Turf Algae (pink), Macroalgae (light blue), and CCA (orange) showing distinct temporal trends. (b) Fish biomass ($\log_{10} \text{g/m}^2$) over the same period, with a fitted smooth trend (blue line), and error bars indicating variation.

Implications on Reef Resilience

Stemming from COTS and other destructive impacts. 3D complexity lost. The loss of coral cover and associated declines in fish populations indicate a broader phase shift in the Dauin reef ecosystem. Reduced herbivore presence may accelerate algal overgrowth, while predator declines suggest weakened top-down control within the reef food web. These changes highlight the need for continued monitoring and conservation interventions to mitigate stressors and promote reef resilience.





Management Actions

01

Strengthen Local COTS Response Capacity

Equip local dive centres with the necessary tools and training to effectively respond to Crown of Thorns Starfish (COTS) outbreak events. Priority reefs for continuous surveillance and rapid intervention include Poblacion (Districts I and II), Masaplod Sur, and Maayong Tubig.

02

Protect Herbivorous Fish Species

Promote the Dauin-wide protection of key herbivorous fish species (including parrotfish, rabbitfish, unicornfish, and surgeonfish) to support the natural suppression of macroalgal overgrowth.

03

Integrate Water Quality Monitoring into Coastal Management

Utilise spatial water quality data, particularly nutrient load measurements, to inform the management of wastewater outfalls along the Dauin coastline. Particular attention should be given to sites where elevated nutrient levels may be linked to increased COTS and disease prevalence.

04

Build Capacity within Bantay Dagat Units

Strengthen the capacity of Bantay Dagats through targeted training, provision of monitoring and enforcement equipment, and support for community-led conservation initiatives. Empowering these teams will enhance reef protection, promote compliance with fisheries regulations, and improve early detection of reef threats occurring within marine protected area boundaries.

05

Reduce Erosion and Sediment Runoff

Ensure ordinances are in place which challenge the implementation of seawalls and wave breaks, alongside the protection of seagrass meadows to promote stable **coastlines**, trap sediments, and reduce runoff into adjacent reef areas.

Future Research



01

Identify Sources and Drivers of COTS Larvae

Utilize spatial data and oceanographic modelling to determine the origins and ecological factors contributing to increased COTS larvae settling within Dauin's reef system.

02

Trial Restoration Interventions on Degraded Reefs

Test targeted restoration strategies on degraded reef areas (i.e. Masaplod Sur and Maayong Tubig) to assess their effectiveness in enhancing coral post-settlement survival following natural recruitment events.

03

Integrate Coral Recruitment Studies into Long-Term Monitoring

Incorporate coral recruitment assessments into the Dauin Long-Term Reef Monitoring Project to evaluate the natural recovery potential of local reefs after disturbance events.

04

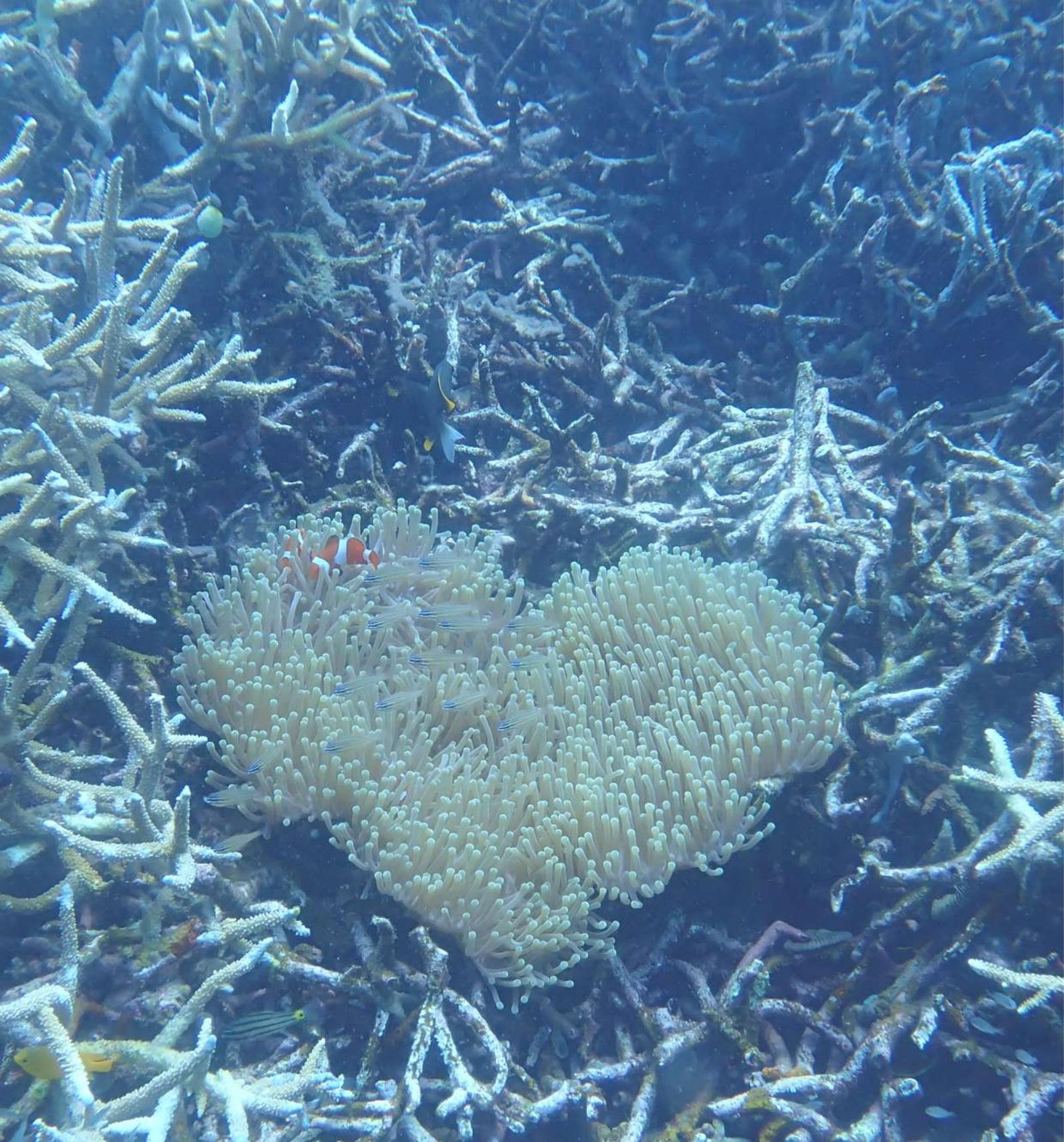
Establish Long-Term Seagrass Monitoring

Implement a long-term monitoring program for seagrass meadows to assess their ecological condition and determine the necessity and feasibility of restoration efforts.

05

Determine Timing of Coral Spawning Events

Conduct studies to identify the timing and synchrony of coral spawning events in Dauin, supporting more effective restoration, management, and conservation planning.



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