

Mission: Iconic Reefs and National Coral Reef Monitoring Program Benthic Analysis

Summary Report for 2022 and 2024

Introduction

Mission: Iconic Reefs (M:IR) is a multi-institutional initiative designed to restore ecological function and biodiversity across key reef sites in the Florida Keys. Led by NOAA in collaboration with federal, state, institutional, and non-profit partners, M:IR targets nearly three million square feet of reef at seven key coral reefs in the Florida Keys National Marine Sanctuary (FKNMS): Carysfort (North and South), Cheeca Rocks, Eastern Dry Rocks, Horseshoe Reef, Looe Key, Newfound Harbor, and Sombrero Reef. Across these reefs, M:IR aims to restore coral cover to at least 25% – an initiative unparalleled in scope and scale that will require hundreds of thousands of coral restoration outplants and over a decade of phased intervention.

These Iconic Reefs were selected for restoration due to their diversity in reef types, levels of anthropogenic disturbances, initial coral cover, and geographic distribution. Restoration progress at these reefs is informed by ongoing monitoring of coral reef benthic communities and coral populations. Such monitoring is essential to evaluating whether current restoration practices are effective in establishing and maintaining coral cover, as restoration 'success' encompasses a range of ecological and management metrics rather than a single measurement (e.g., coral cover) (Goergen et al., 2020). In addition to monitoring within the M:IR reefs, it is also important to assess the surrounding reefs in the Florida Keys to interpret restoration progress. The National Coral Reef Monitoring Program (NCRMP), which conducts standardized reef assessments across the Florida Keys, provides a solid framework for comparison. To align with this program, the M:IR team applied NCRMP survey methodology within its Iconic Reefs in 2022 and 2024 to complement NCRMP surveys in the outer FKNMS. These surveys focused on shallow (<30 m), hard-bottom reef habitats, using a stratified-random, one-stage design within 50 m × 50 m grid cells to ensure representative sampling across depth and rugosity strata (Ault et al., 2021). The survey design ensures that survey sites are allocated by cross-shelf zone, rugosity type, and depth strata, with sites distributed around the Florida Keys from nearshore to offshore to a maximum depth of 30 m. The

NCRMP sample grid was spatially joined with the seven distinct M:IR zones (Figure 1). Survey sites were proportionally allocated within NCRMP strata to maintain consistent representation across habitats.



Figure 1: Map of the Florida Keys showing the sites of Mission: Iconic Reefs

Corals and benthic communities were monitored using two different NCRMP surveys: the Benthic Community Assessment survey and the Coral Demographics survey (NOAA CRCP 2022a, 2022b, 2024a, 2024b). The Benthic Community Assessment survey includes: 1) benthic cover (%) estimates along a 15-m transect with a line point intercept method, 2) presence/absence of Endangered Species Act (ESA)-listed coral species (NOAA National Marine Fisheries Service, 2014), 3) abundance of key macroinvertebrates, and 4) reef rugosity measurements within a 15 m x 2 m belt-transect area (NOAA CRCP 2022a, 2024b). At the same site, coral demographics were surveyed within a 10 m x 1 m belt-transect area (NOAA CRCP 2022b, 2024b). NCRMP coral demographic survey data were combined with complementarily allocated survey data from Florida Fish and Wildlife Conservation Commission's Disturbance Response Monitoring ([DRM](#)). In all coral demographics surveys, all live coral colonies 4 cm were counted, identified to species, measured to the nearest centimeter, and estimates were made of the proportion per colony of any present mortality (recent or old), disease (absent, present: slow, fast), and/or bleaching (none, total, partial, paling). Only live coral colonies were included in the survey; dead colonies with 100% mortality were not surveyed (e.g., colonies killed by coral disease). Juvenile corals (< 4 cm) were reported for species richness only and were not included in counts, size measurements, or estimates of condition

(NOAA CRCP 2022b); in 2024, juveniles of select coral species were counted (NOAA CRCP 2024b). In 2024, NCRMP benthic surveys also included large area imaging (LAI) collected at most survey sites; analyses of these LAI data are in progress and not presented here.

To allow for direct comparisons of benthic communities inside the M:IR restoration areas with control, non-restored areas across the Florida Keys reefs, the NCRMP dataset was restricted to strata types and depth zones (0-12 m) found within M:IR sites. Statistical comparisons were conducted using a two-tailed t-test between M:IR and NCRMP estimates for each survey year (2022 or 2024) and between years for M:IR and NCRMP. This report focuses on coral populations and benthic community metrics; a separate [report](#) can be found for fish population assessments (Blondeau et al., 2025).

NCRMP analyses scripts for corals and benthic communities are open source and available at [NCRMP Benthic R package](#) (Groves et al., 2025).

Summary of Benthic Surveys

In 2022, a total of 584 surveys occurred (Table 1) across 403 sites (Viehman et al., 2023). In 2024, 771 surveys occurred across 542 sites (Grove et al., in prep).

Table 1. Number of demographic (Demo) and benthic community assessment (BCA) surveys completed by M:IR, NCRMP, and DRM in 2022 and 2024.

Year	M:IR		NCRMP		DRM
	Demo	BCA	Demo	BCA	Demo
2022	90	89	95	92	218
2024	100	100	129	129	313
Total	379		445		531

Figure 2: Summary Table

Benthic Composition

Table 1: Table 2. Number of Benthic Community Assesement (BCA) sites sampled inside and outside M:IR areas in each stratum.

Study Area	Strata Name	Strat Description	2022 Sample N
Inside (M:IR)	CFK01	Inshore reef, all relief types and depths	8
Inside (M:IR)	CFK02	Mid-channel patch reef, all relief types and depths	12

Study Area	Strata Name	Strat Description	2022 Sample N
Inside (M:IR)	CFK03	Offshore patch reef, all relief types and depths	7
Inside (M:IR)	CFK04	Forereef, low relief, shallow (0-6 m)	--
Inside (M:IR)	CFK05	Forereef, high relief, shallow (0-6 m)	24
Inside (M:IR)	CFK06	Forereef, low relief, mid-shallow (6-12 m)	4
Inside (M:IR)	CFK07	Forereef, high relief, mid-shallow (6-12 m)	32
Outside (NCRMP)	CFK01	Inshore reef, all relief types and depths	10
Outside (NCRMP)	CFK02	Mid-channel patch reef, all relief types and depths	21
Outside (NCRMP)	CFK03	Offshore patch reef, all relief types and depths	9
Outside (NCRMP)	CFK04	Forereef, low relief, shallow (0-6 m)	--
Outside (NCRMP)	CFK05	Forereef, high relief, shallow (0-6 m)	7
Outside (NCRMP)	CFK06	Forereef, low relief, mid-shallow (6-12 m)	9
Outside (NCRMP)	CFK07	Forereef, high relief, mid-shallow (6-12 m)	10

Coral Demography

Table 2: Table 3. The number of coral demographic sites sampled inside and outside M:IR areas in each stratum (includes DRM data).

Study Area	Strata Name	Strat Description	2022 Sample Number	2024 Sample Number
Inside (M:IR)	CFK01	Inshore reef, all relief types and depths	12	10
Inside (M:IR)	CFK02	Mid-channel patch reef, all relief types and depths	16	12
Inside (M:IR)	CFK03	Offshore patch reef, all relief types and depths	7	11
Inside (M:IR)	CFK04	Forereef, low relief, shallow (0-6 m)	--	4
Inside (M:IR)	CFK05	Forereef, high relief, shallow (0-6 m)	25	38

Study Area	Strata Name	Strat Description	2022 Sample Number	2024 Sample Number
Inside (M:IR)	CFK06	Forereef, low relief, mid-shallow (6-12 m)	4	12
Inside (M:IR)	CFK07	Forereef, high relief, mid-shallow (6-12 m)	34	34
Outside (NCRMP + DRM)	CFK01	Inshore reef, all relief types and depths	27	24
Outside (NCRMP + DRM)	CFK02	Mid-channel patch reef, all relief types and depths	79	109
Outside (NCRMP + DRM)	CFK03	Offshore patch reef, all relief types and depths	37	42
Outside (NCRMP + DRM)	CFK04	Forereef, low relief, shallow (0-6 m)	4	31
Outside (NCRMP + DRM)	CFK05	Forereef, high relief, shallow (0-6 m)	21	45
Outside (NCRMP + DRM)	CFK06	Forereef, low relief, mid-shallow (6-12 m)	19	33
Outside (NCRMP + DRM)	CFK07	Forereef, high relief, mid-shallow (6-12 m)	60	61

Benthic Community Composition

Temporal trends in benthic cover of functional groups such as coral and macroalgae cover provide information on changes to the benthic community composition

over time.

Hard Coral

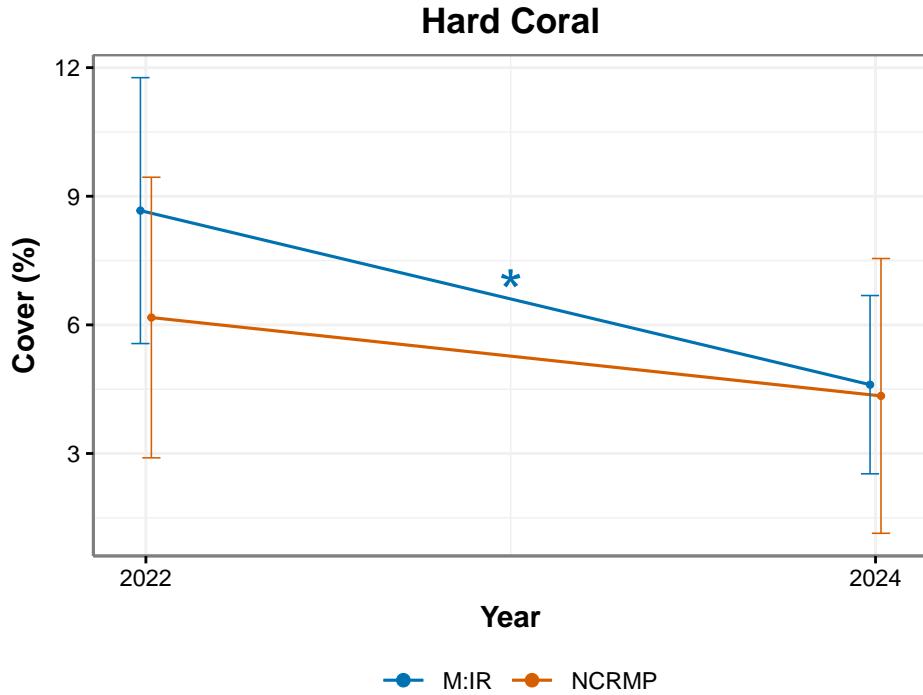


Figure 3: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

Macroalgae

Octocoral

Sponge

Turf Algae

Crustose Coralline Algae (CCA)

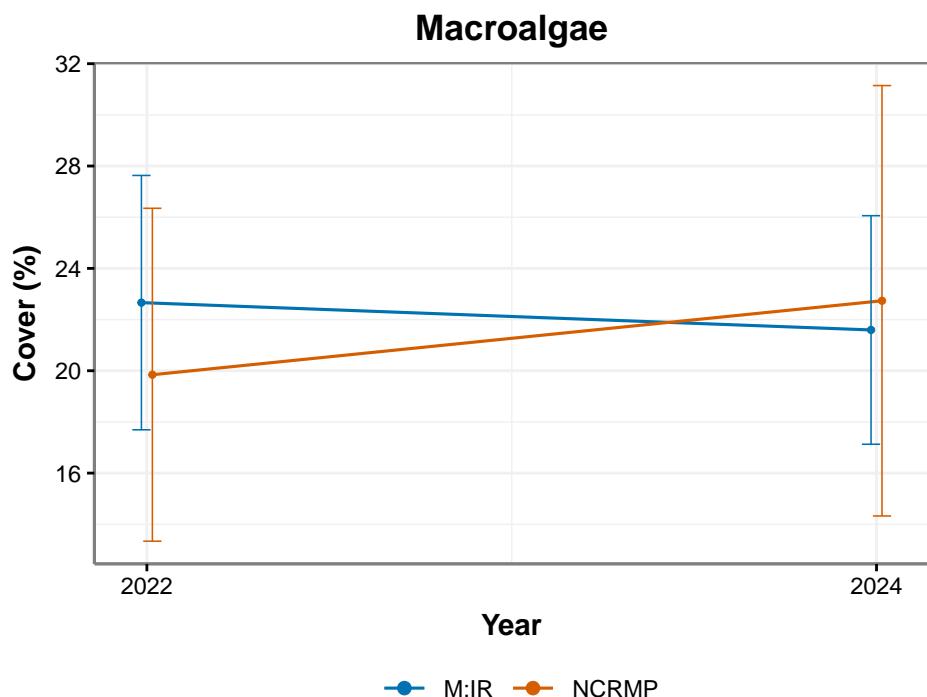


Figure 4: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

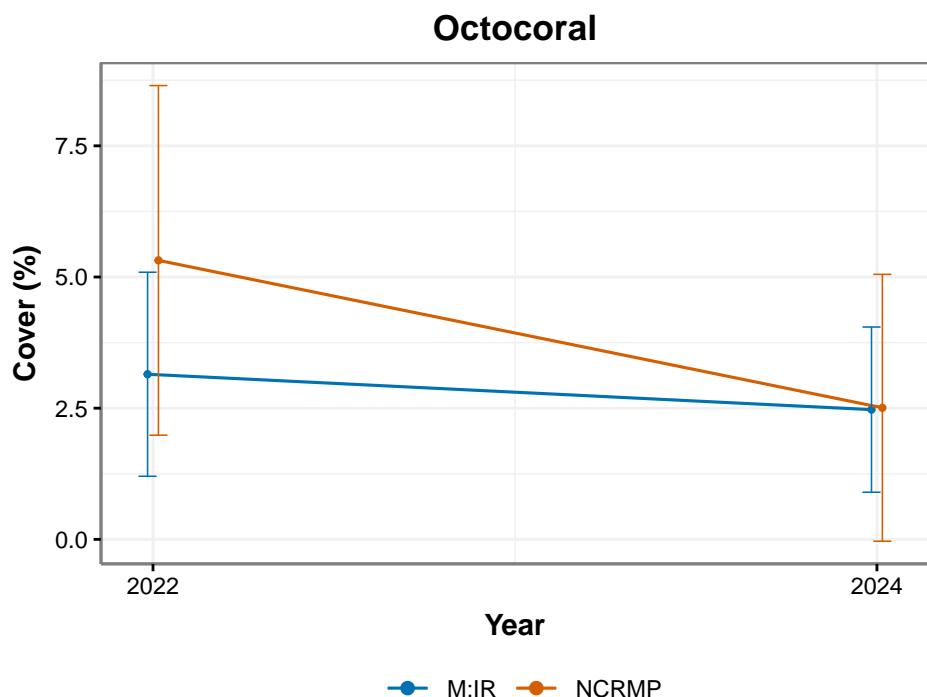


Figure 5: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

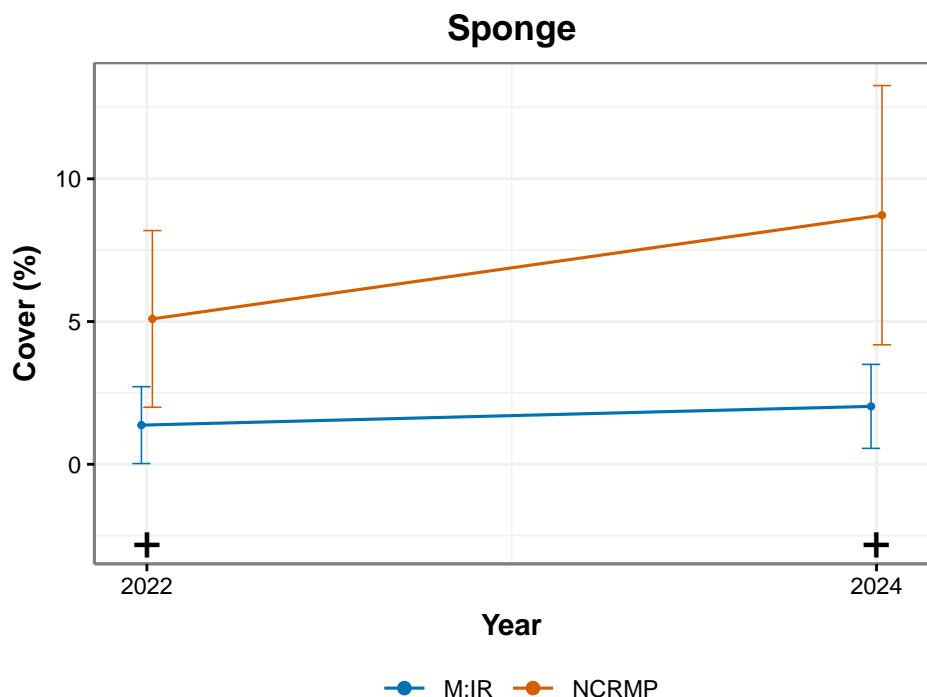


Figure 6: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

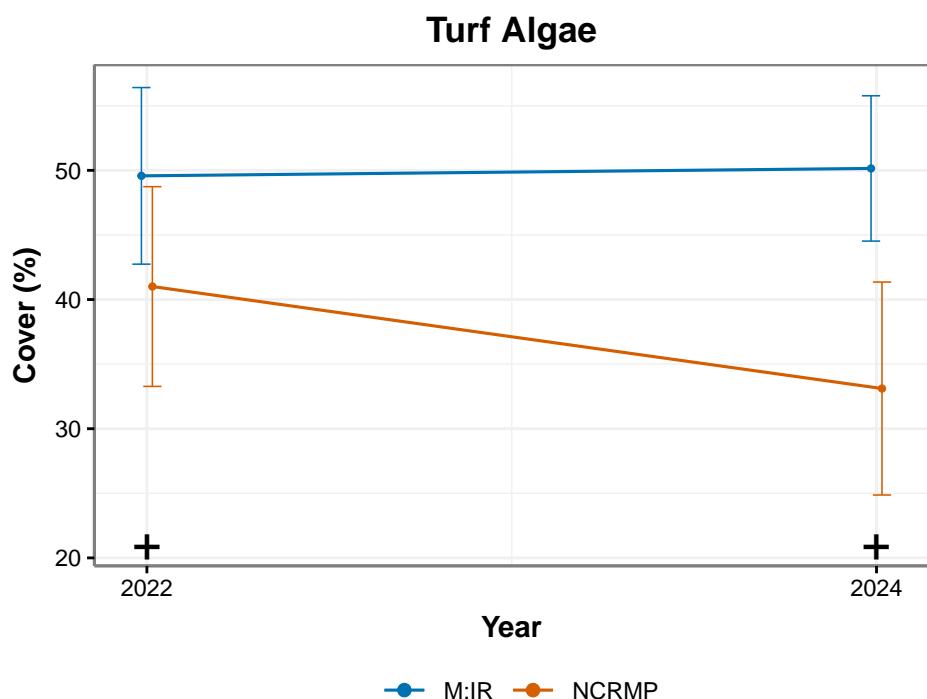


Figure 7: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

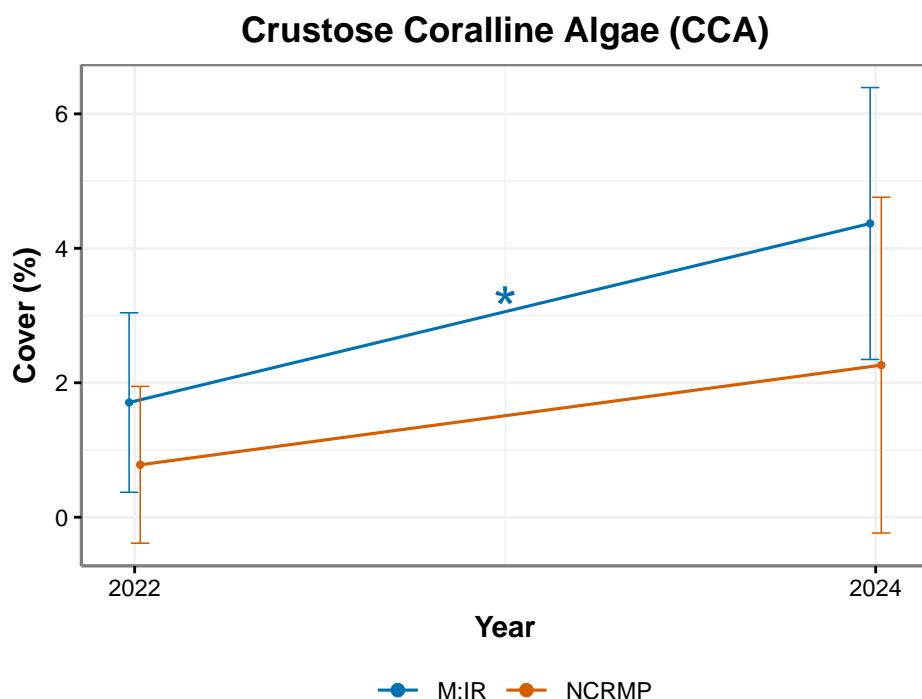


Figure 8: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

Ramicrusta

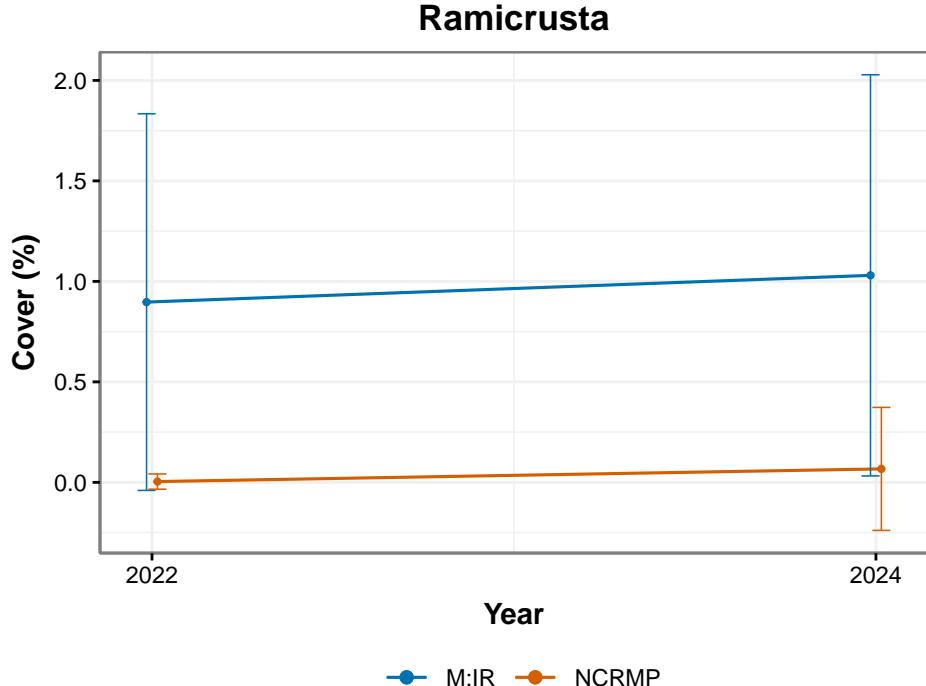


Figure 9: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category 'Other' comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

Other

Coral Demography

Although several metrics reported here encompass all observed coral species, ten focal species are highlighted as particularly important to M:IR's goal: *Acropora palmata*, *Acropora cervicornis*, *Colpophyllia natans*, *Dendrogyra cylindrus*, *Dichocoenia stokesii*, *Diploria labyrinthiformis*, *Meandrina meandrites*, *Montastraea cavernosa*, *Pseudodiploria clivosa*, and *Pseudodiploria strigosa*. These species have experienced drastic population declines and are targeted for restoration at the M:IR sites (!Citation!). Specifically, most were severely affected by White Band Disease (*Acropora* spp.) or Stony Coral Tissue Loss Disease (SCTLD).

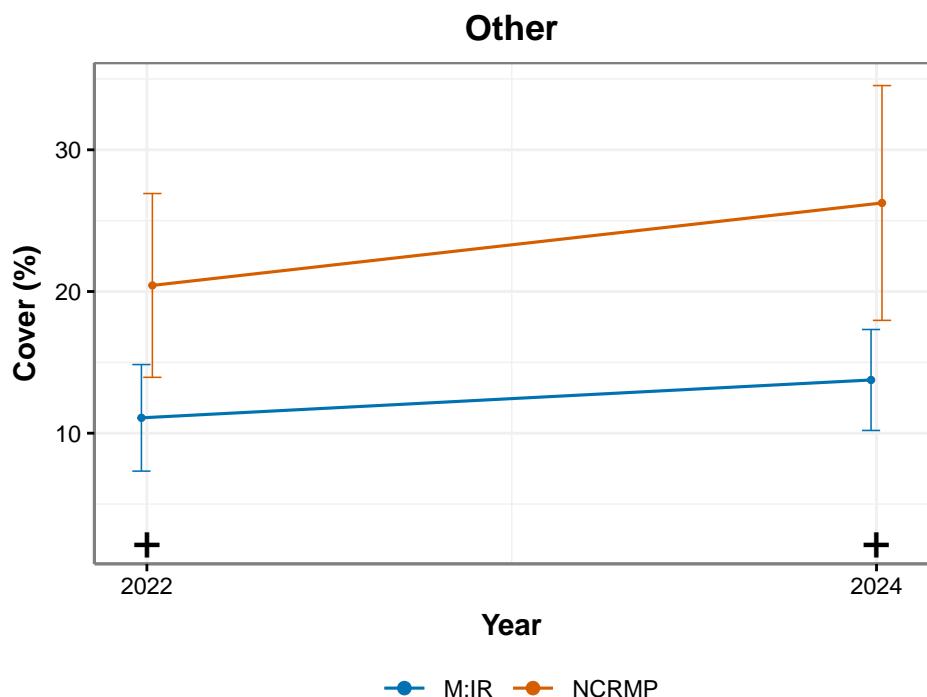


Figure 10: Figure 2. Cover estimates for main benthic groups inside and outside M:IR areas for 2022 and 2024. A black (+) indicates a significant difference between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance difference between years for the given group (i.e., M:IR or NCRMP). The category ‘Other’ comprises Cyanobacteria, Palythoa, Millepora, Seagrass, Bare Substrate, and other miscellaneous organisms.

The following table summarizes the number of observations across all stratum and survey years of each focal species and identifies the most abundant species encountered.

Table 3: Table 4. Number of colonies observed for focal M:IR species and the most commonly encountered non-focal species in 2022 and 2024.

Species	Colonies in 2022	Colonies in 2024
<i>Siderastrea siderea</i>	3,868	5,618
<i>Porites astreoides</i>	2,657	2,132
<i>Stephanocoenia intersepta</i>	1,345	1,534
<i>Agaricia agaricites</i>	884	237
<i>Porites porites</i>	776	558
* <i>Montastraea cavernosa</i>	437	645
<i>Orbicella faveolata</i>	266	237
<i>Orbicella annularis</i>	211	156
<i>Siderastrea radians</i>	182	328
<i>Porites furcata</i>	160	77
<i>Porites divaricata</i>	118	100
* <i>Dichocoenia stokesii</i>	106	137
* <i>Colpophyllia natans</i>	103	76
<i>Solenastrea bournoni</i>	79	113
* <i>Acropora cervicornis</i>	74	13
* <i>Diploria labyrinthiformis</i>	50	65
* <i>Pseudodiploria strigosa</i>	50	46
<i>Eusmilia fastigiata</i>	45	75
* <i>Pseudodiploria clivosa</i>	23	31
* <i>Acropora palmata</i>	14	NA
* <i>Meandrina meandrites</i>	5	11
* indicates M:IR focal species		

Focal Species

The stratified random surveys are designed to optimize sampling efficiency and provide high precision estimates of coral population metrics at relatively low sample sizes (Smith et al., 2011). The effectiveness of restoration can be quantified by comparison of these metrics between M:IR sites and similar habitats outside these restoration areas.

The following figures for these metrics are grouped by each focal species. Significant statistical differences using a two-tailed t-test are indicated for differences

between survey years (2022 vs. 2024) and between areas (M:IR vs. NCRMP) for density, old mortality, and mean colony size.

Acropora cervicornis

Acropora palmata

Colpophyllia natans

Dichocoenia stokesii

Diploria labyrinthiformis

Meandrina meandrites

Pseudodiploria clivosa

Pseudodiploria strigosa

Montastraea cavernosa

Coral Density

Old Mortality

Coral Size

Bleaching Estimates

** warning these estimates are not correct **

Disease Estimates

** warning these estimates are not correct **

Point of Contact

NCRMP Atlantic Benthic Team Lead: Shay Viehman (shay.viehman@noaa.gov)

Acropora cervicornis

Colony density, mortality, size, and size class distribution (2022 vs. 2024)

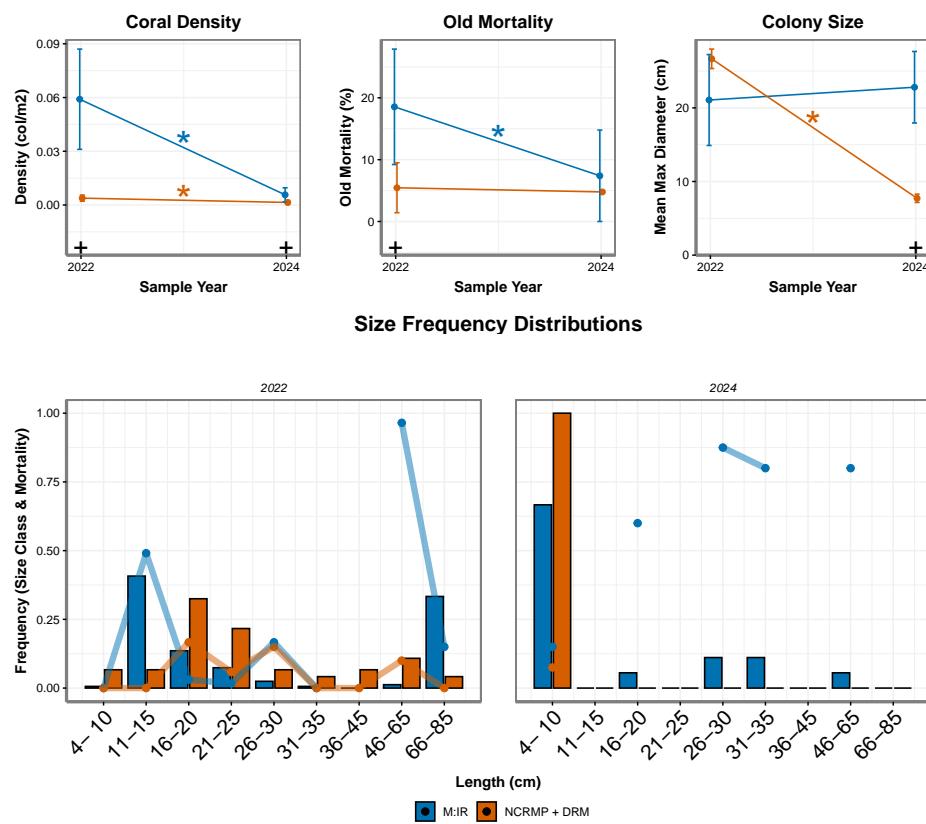
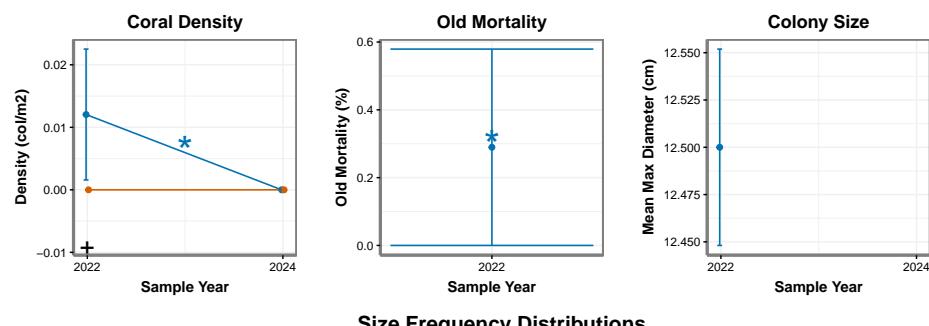


Figure 11: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Acropora palmata
 Colony density, mortality, size, and size class distribution (2022 vs. 2024)



Size Frequency Distributions

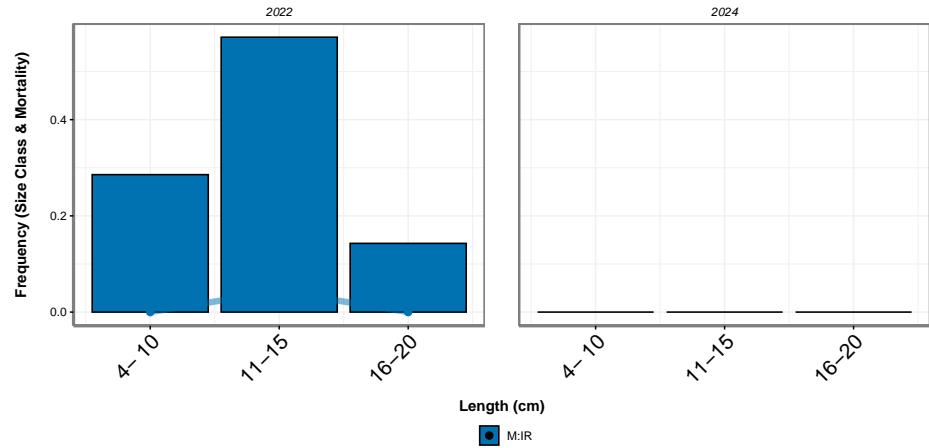
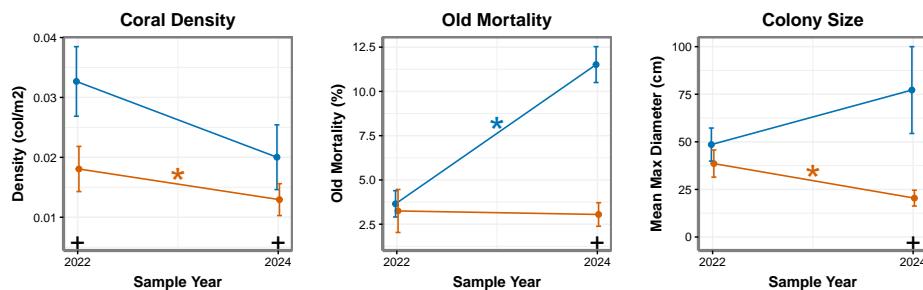


Figure 12: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (MIR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Colpophyllia natans

Colony density, mortality, size, and size class distribution (2022 vs. 2024)



Size Frequency Distributions

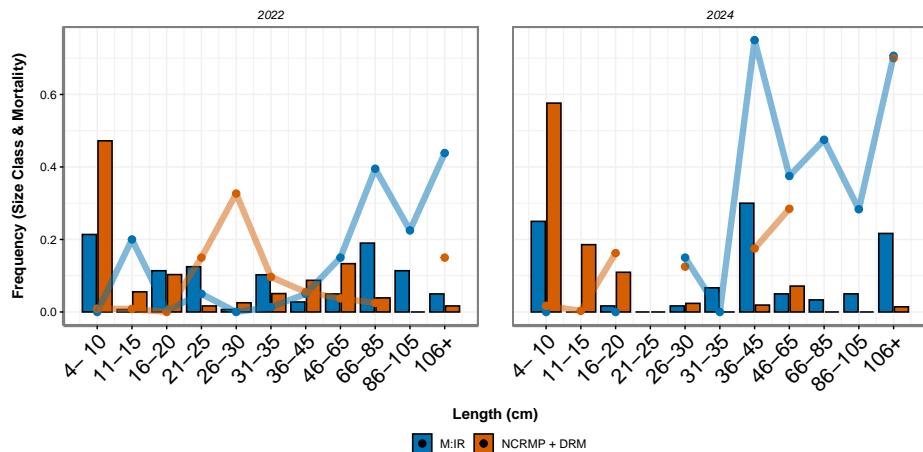


Figure 13: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Dichocoenia stokesii

Colony density, mortality, size, and size class distribution (2022 vs. 2024)

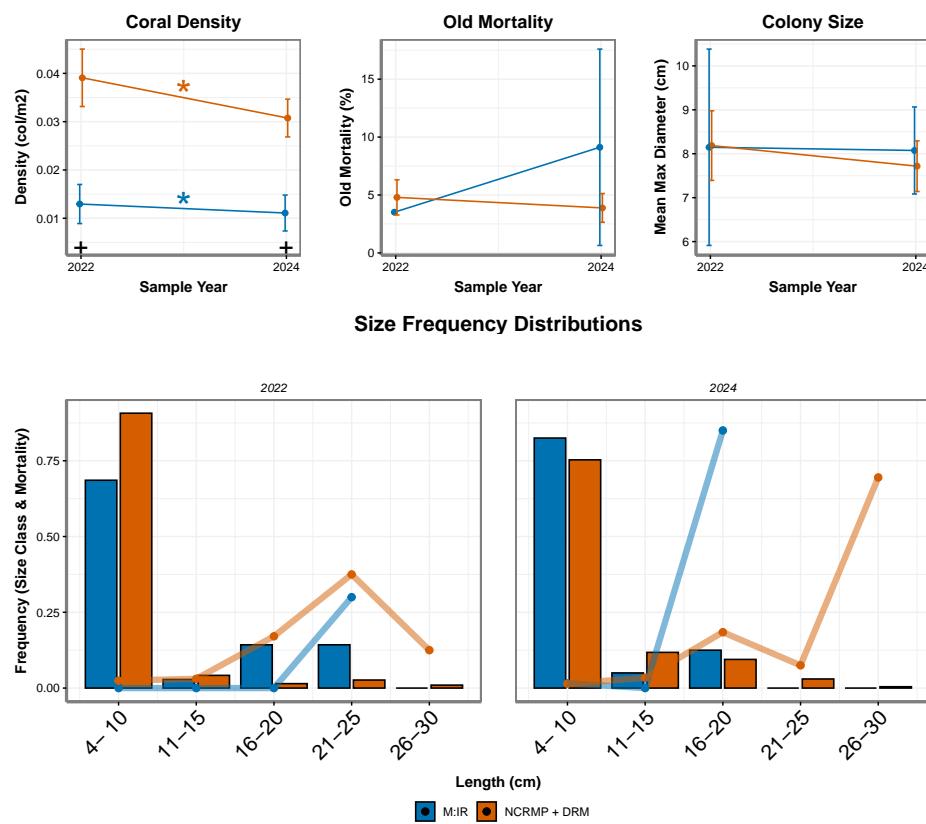


Figure 14: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Diploria labyrinthiformis

Colony density, mortality, size, and size class distribution (2022 vs. 2024)

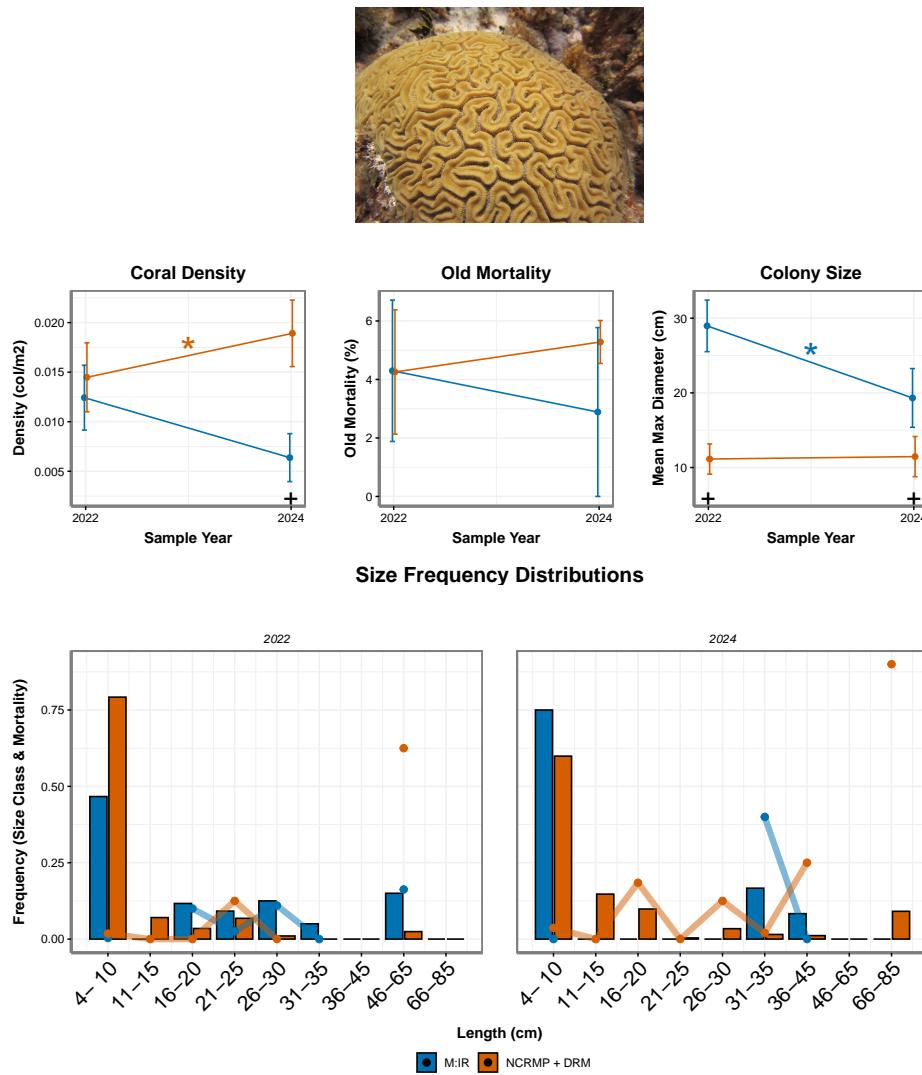
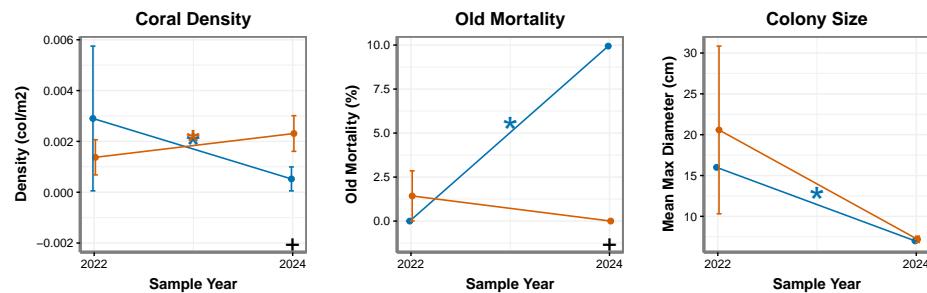


Figure 15: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Meandrina meandrites

Colony density, mortality, size, and size class distribution (2022 vs. 2024)



Size Frequency Distributions

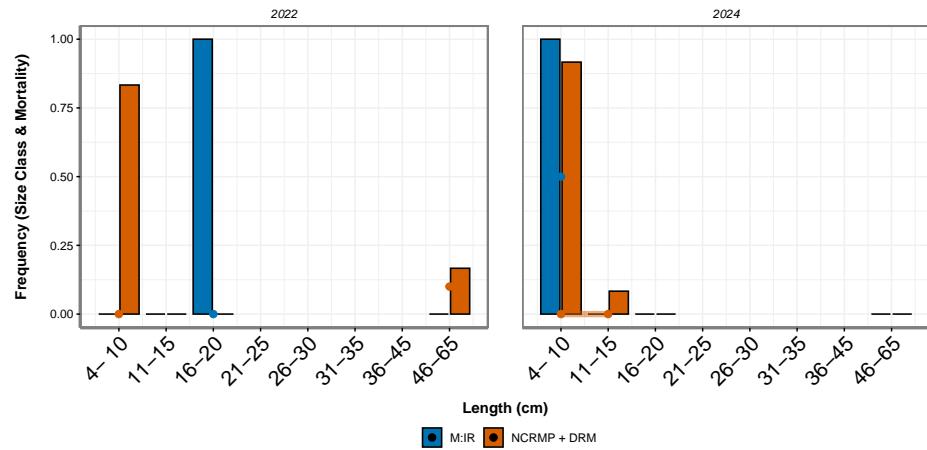
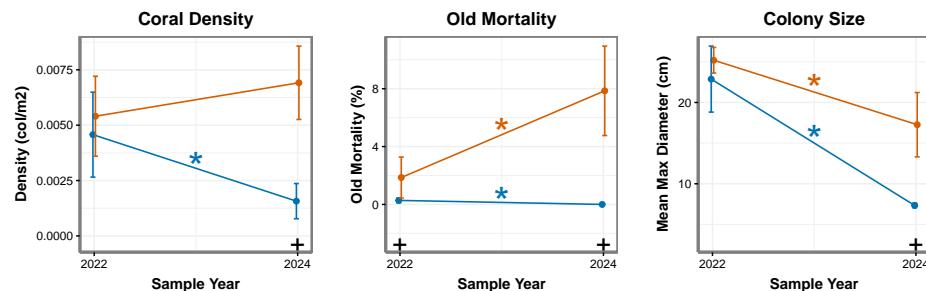


Figure 16: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Pseudodiploria clivosa

Colony density, mortality, size, and size class distribution (2022 vs. 2024)



Size Frequency Distributions

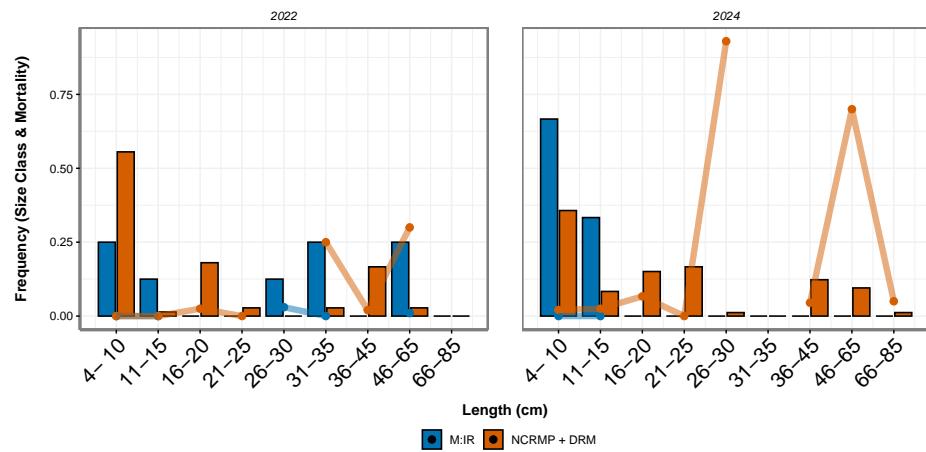


Figure 17: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Pseudodiploria strigosa

Colony density, mortality, size, and size class distribution (2022 vs. 2024)

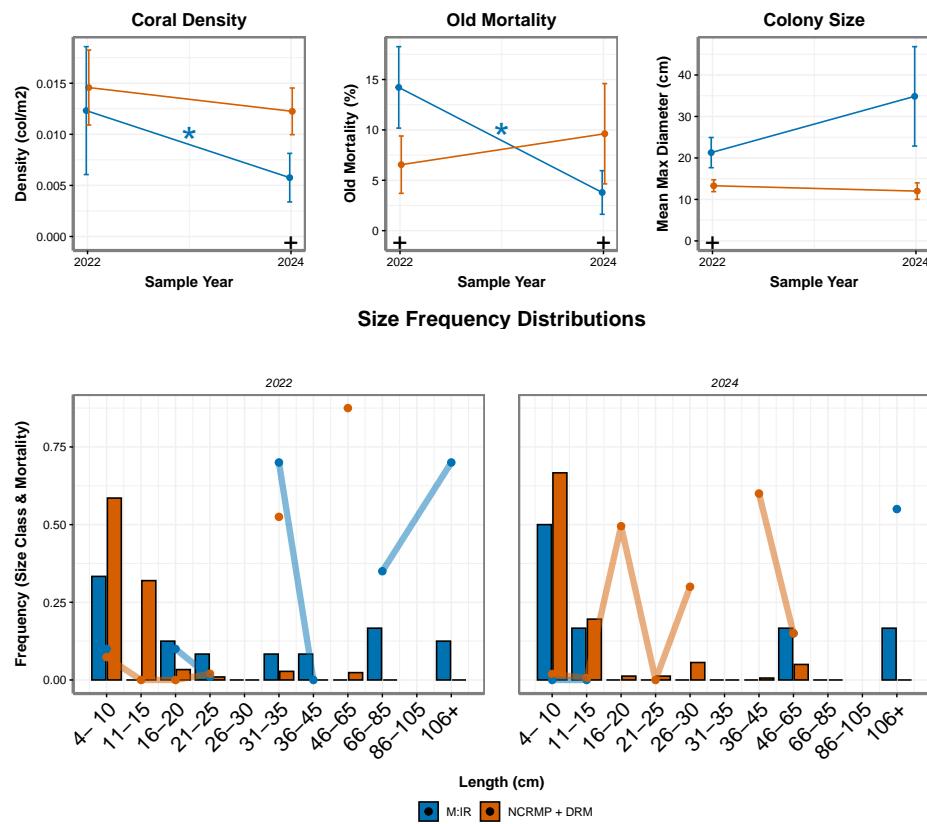


Figure 18: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

Montastraea cavernosa

Colony density, mortality, size, and size class distribution (2022 vs. 2024)

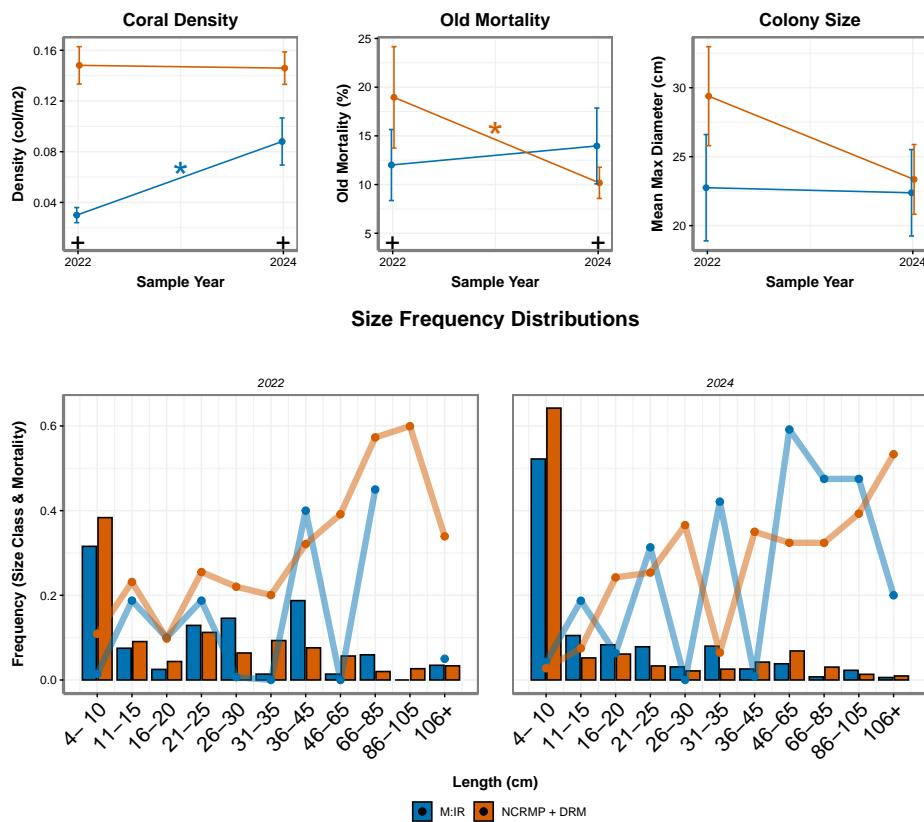


Figure 19: Figure 3. Coral density, old mortality, colony size, and size frequency distribution for focal M:IR species across sample years (2022 and 2024) and survey types (M:IR and NCRMP + DRM). A black (+) indicates a significant difference in cover estimates between groups in that survey year (i.e., 2022 or 2024). A colored (*) indicates significance between years for the given group (i.e., M:IR or NCRMP).

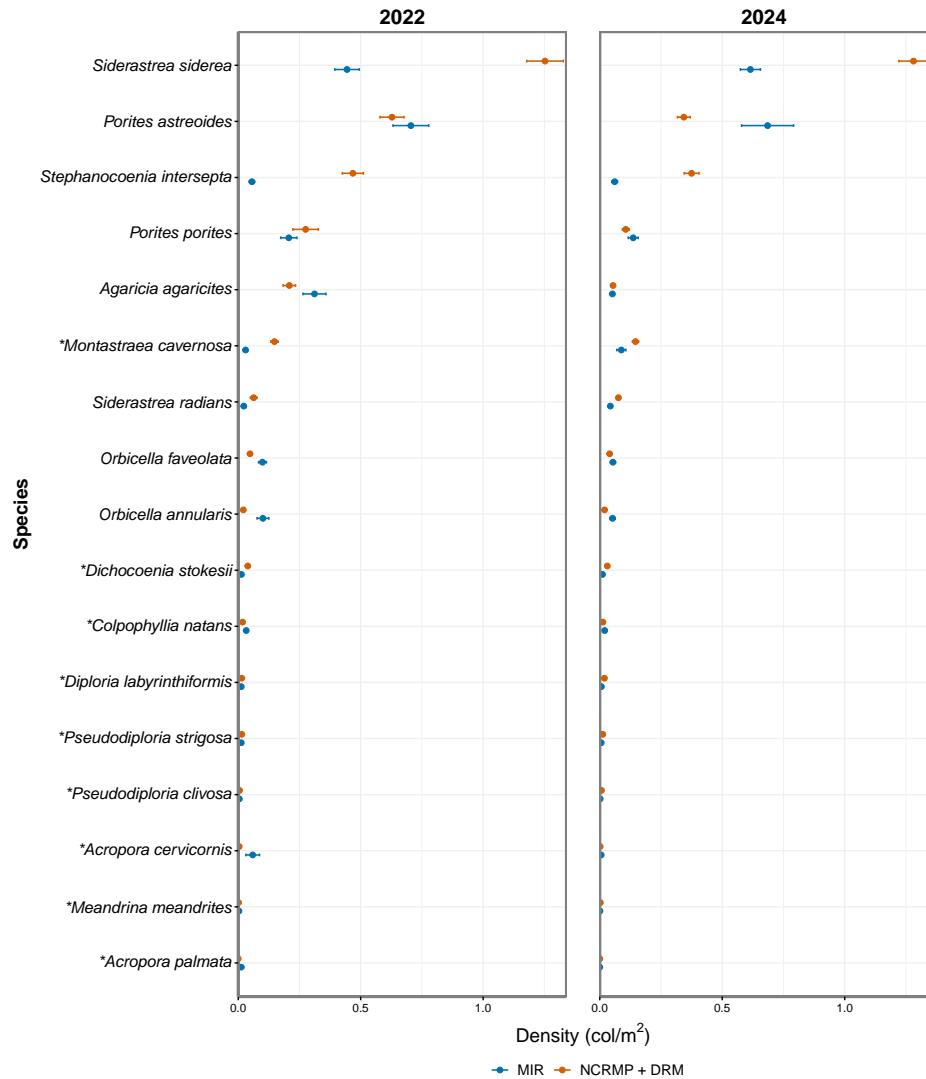


Figure 20: Figure 4. Species-specific coral density (colones/m²) outside (NCRMP and DRM) and inside M:IR areas in 2022 and 2024. Focal M:IR species are denoted with a (*).

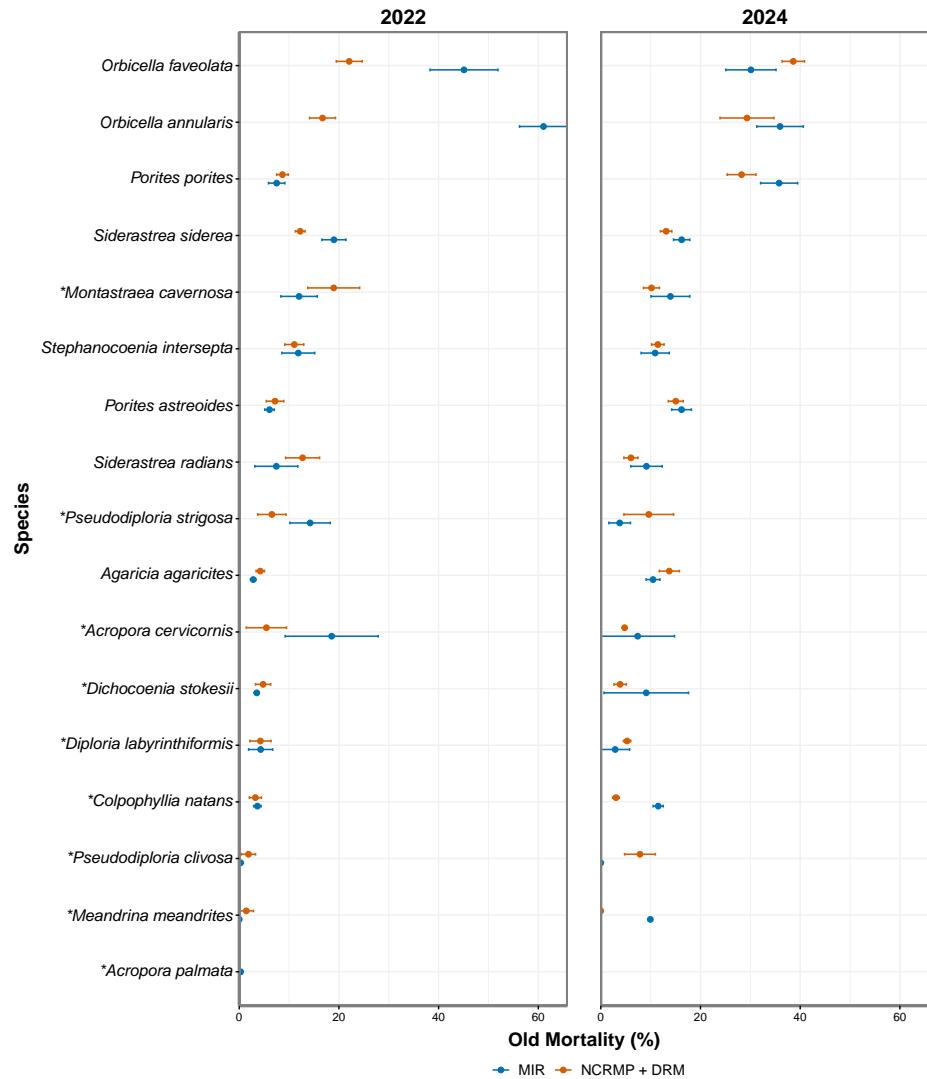


Figure 21: Figure 5. Percent Old Mortality (\pm SEM) by coral species outside (NCRMP and DRM) and inside M:IR areas in 2022 and 2024. Focal M:IR species are denoted with a (*).

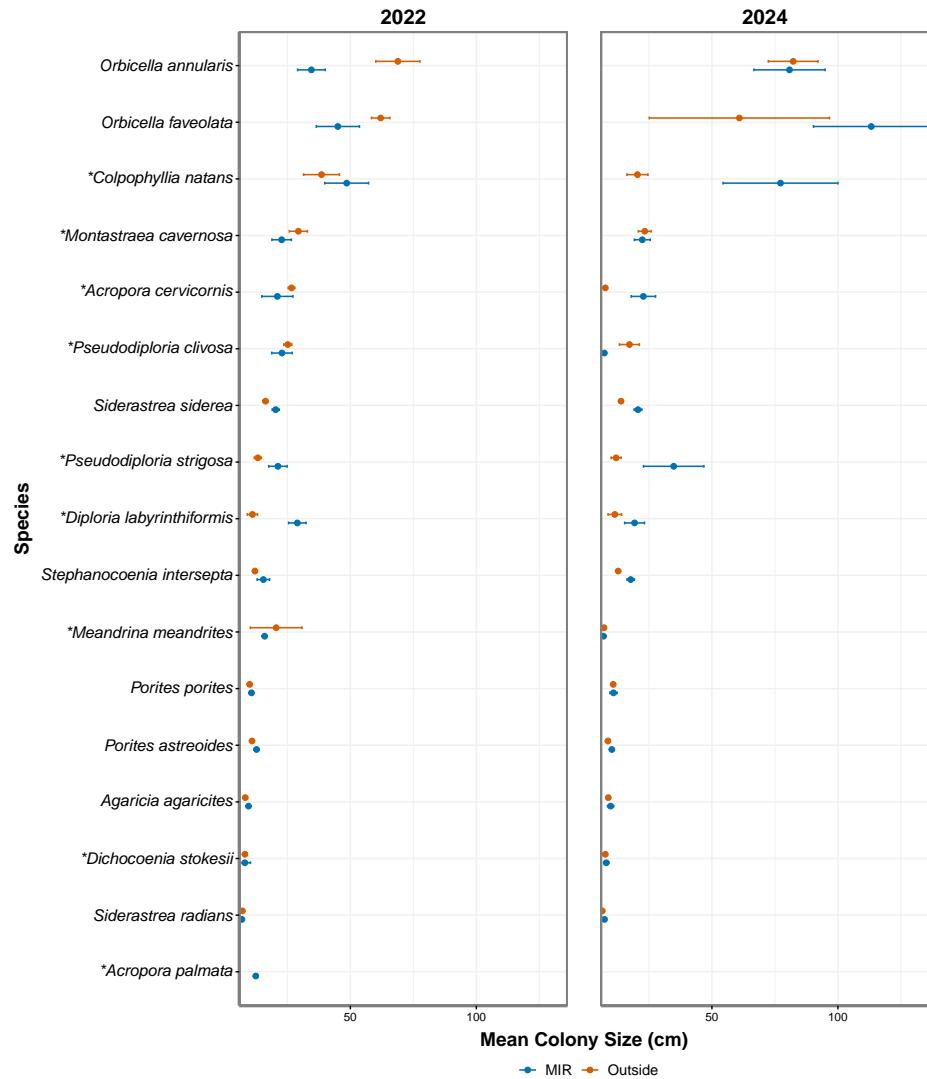


Figure 22: Figure 6. Maximum diameter (cm) \pm SEM by coral species outside (NCRMP and DRM) and inside M:IR areas in 2022 and 2024. Focal M:IR species are denoted with a (*).

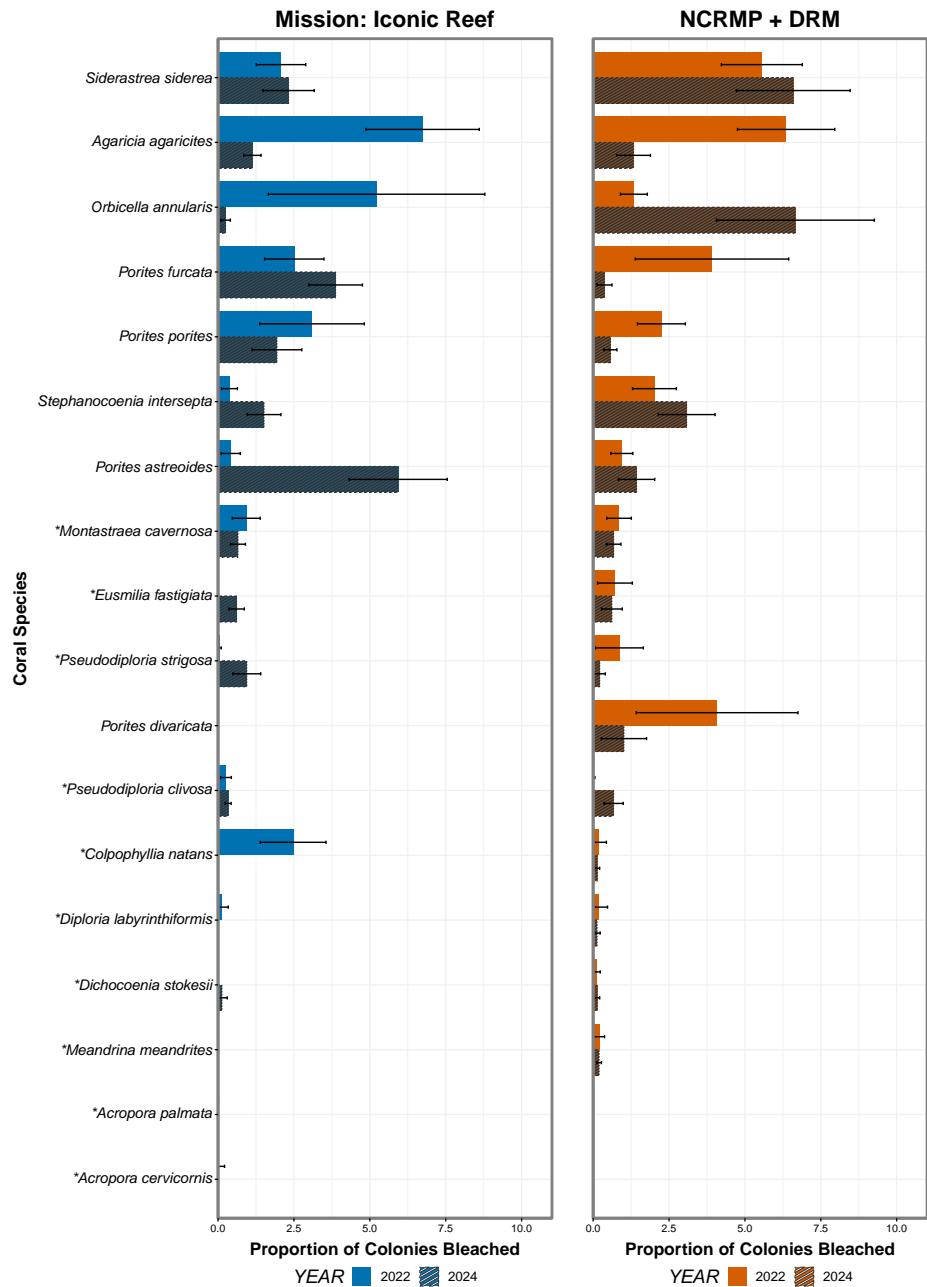


Figure 23: Figure 7. Species-specific bleaching frequency observed outside (NCRMP + DRM) and inside M:IR areas. Focal M:IR species are denoted with a (*).

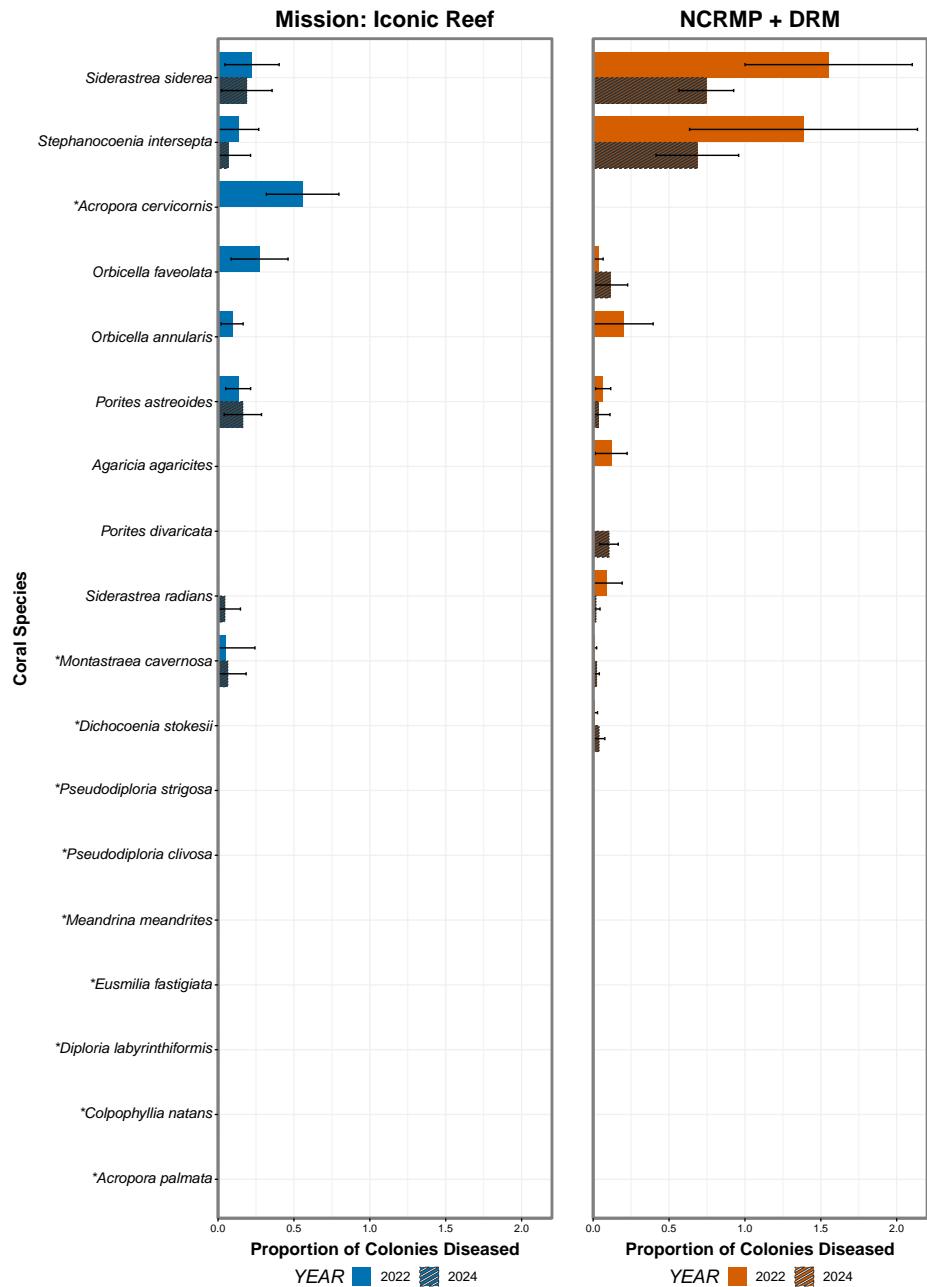


Figure 24: Figure 8. Species-specific disease frequency observed outside (NCRMP + DRM) and inside M:IR areas. Focal M:IR species are denoted with a (*).

References

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