

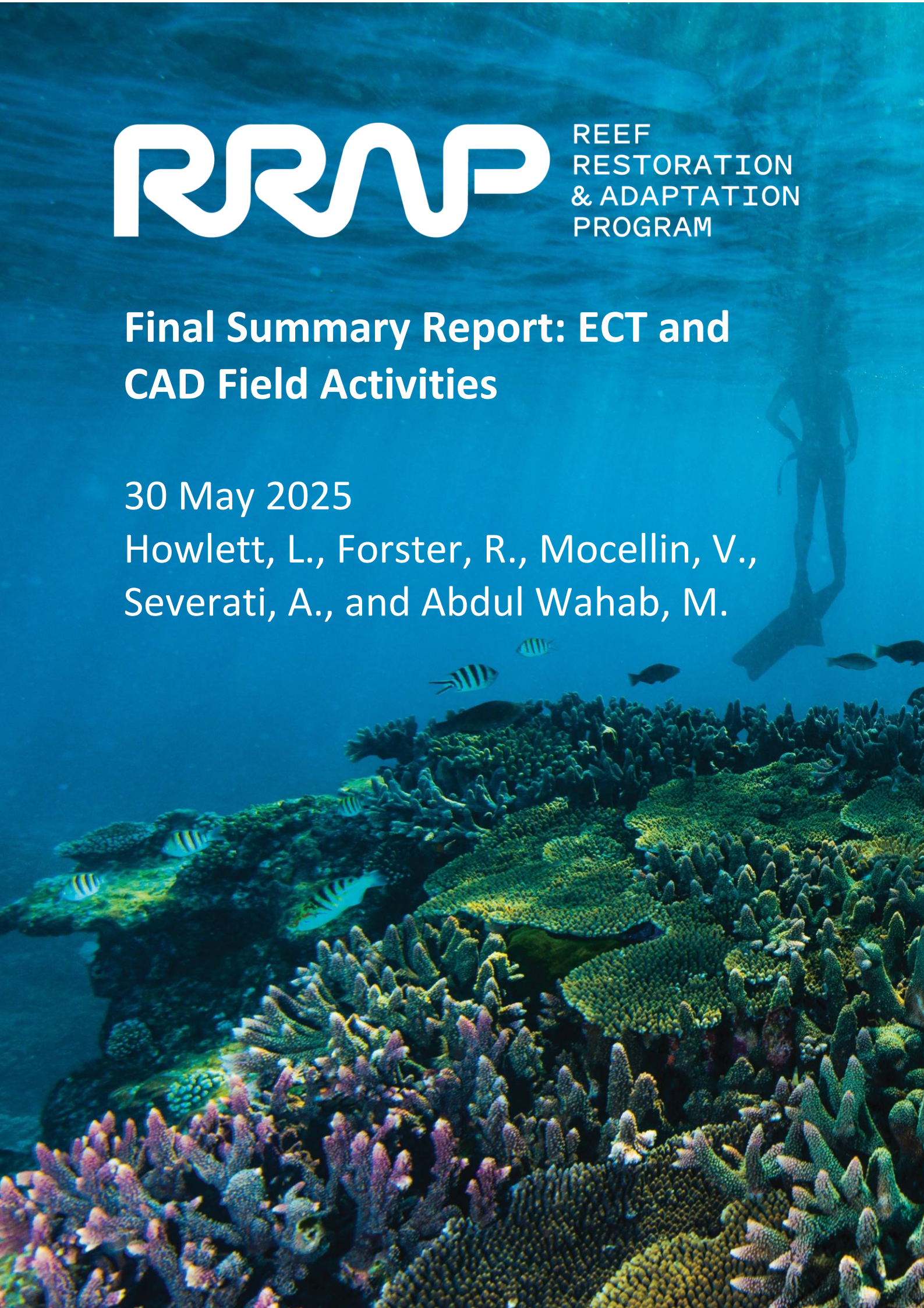


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PROGRAM

# Final Summary Report: ECT and CAD Field Activities

30 May 2025

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## Report Title

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[Cover Page: Coral Reef, Credit: Gary Cranitch, Queensland Museum]

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AUSTRALIA

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The RRAP partners acknowledge Aboriginal and Torres Strait Islander Peoples as the first marine scientists and carers of Country. We acknowledge the Traditional Owners of the places where RRAP works, both on land and in sea Country. We pay our respects to elders; past, present, and future; and their continuing culture, knowledge, beliefs, and spiritual connections to land and sea Country.

We specifically acknowledge and thank the following Traditional Owners of sea Country that this report relates to:

| Location  | Traditional Owner Group                                     |
|---|---|
| Davies Reef   | Bindal  |
| Palm Island Group   | Manbarra  |
| John Brewer Reef  | Manbarra  |
| Moore Reef, Fitzroy, and Sudbury Reefs                        | Gunggandji  |
| Capricorn Bunker Group  | Port Curtis Coral Coast                                     |
| Swains Reefs  | Port Curtis Coral Coast                                     |
| Magnetic Island and Myrmidon Reef                             | Gurambilbarra Wulgurukaba                                   |
| Mackay and St Crispin Reefs                                   | Eastern Kuku Yalanji  |
| Lizard Island Group, Martin Reef, No Name Reef and Hicks Reef | Hopevale Congress and Walmbaar Corporation<br>Cape Melville |
| Tydemman Reef and Hicks Reef                                  | Cape Melville   |
| Keppels Islands   | Woppaburra  |

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# 1 Background

Within the Reef Restoration and Adaptation Program (RRAP), Coral Aquaculture and Deployment (CAD) and Enhanced Corals and Treatments (ECT) subprograms aim to develop methods for the enhancement, production and deployment of corals at scale. The two subprograms comprise of six projects aimed at tackling complementary objectives in parallel, including:

- CAD-01: Coral propagation and deployment
- CAD-02: Engineering large scale coral aquaculture
- CAD-03: Sub-program management, field program and large field trials
- ECT-01: Genetic basis of key traits
- ECT-02: Assisted evolution
- ECT-03: Prokaryotes treatments and coral nutrition

To effectively and efficiently carry out research and development across multiple projects, a joint field program that would service the field-based experimental needs across all ECT and CAD projects was established within CAD-03 (sub-project CAD3-2: Field Program). The overall annual field plan for CAD3-2 provided coordinated access to reefs across latitudinal (regions) and longitudinal (cross shelf) gradients on the Great Barrier Reef (GBR) multiple times per year, to meet field access needs across those sub-projects.

By working with EcoRRAP, another subprogram within RRAP, the Field Program also aimed to overlap with the EcoRRAP ecological reference sites, the AIMS Long Term Monitoring sites and RIMReP designs to optimise ecological and environmental data collection and temporal comparisons. The Field Program initially proposed was designed to support coral collections across large geographic scales including collections of corals for spawning, fragmentation, and aquaria-based experiments. The program also supported the deployment of coral recruits and fragments in the field for research and to make multiple measurements per year on local reefs.

Two full time field technicians facilitated the permitting, organisation and planning of field trips, as well as writing and testing standard operations for deployment, sampling, and data collection. The central coordination of field work via this joint Field Program enabled multiple projects to work concurrently and offered the most effective approach to meet the field requirements of projects across three RRAP subprograms. In the sections below, we give an overview of the CAD and ECT research focus and objectives, alongside planning requirements and considerations, and key outcomes and lessons learnt from the past five years of the Field Program.

## 1.1 CAD research objectives

The CAD subprogram underpins the research directions under the three CAD projects. Broadly, to increase the production of coral seeding units in the facility and facilitate upscaled coral deployments in the field, the CAD concept (Figure 1) comprises of the following principles:

- 1) Harnessing the high reproductive output of corals by focusing on, and optimising, sexual reproduction for production in an aquaculture facility.

- 2) The decoupling of the larval settlement process (i.e., onto concrete sheets) from the deployment process (i.e., seeding devices), to effectively utilise space for production in the aquaculture facility and the transport of propagated corals to the deployment site.
- 3) Guided surface deployments of devices from a vessel to eliminate diver-based operations.

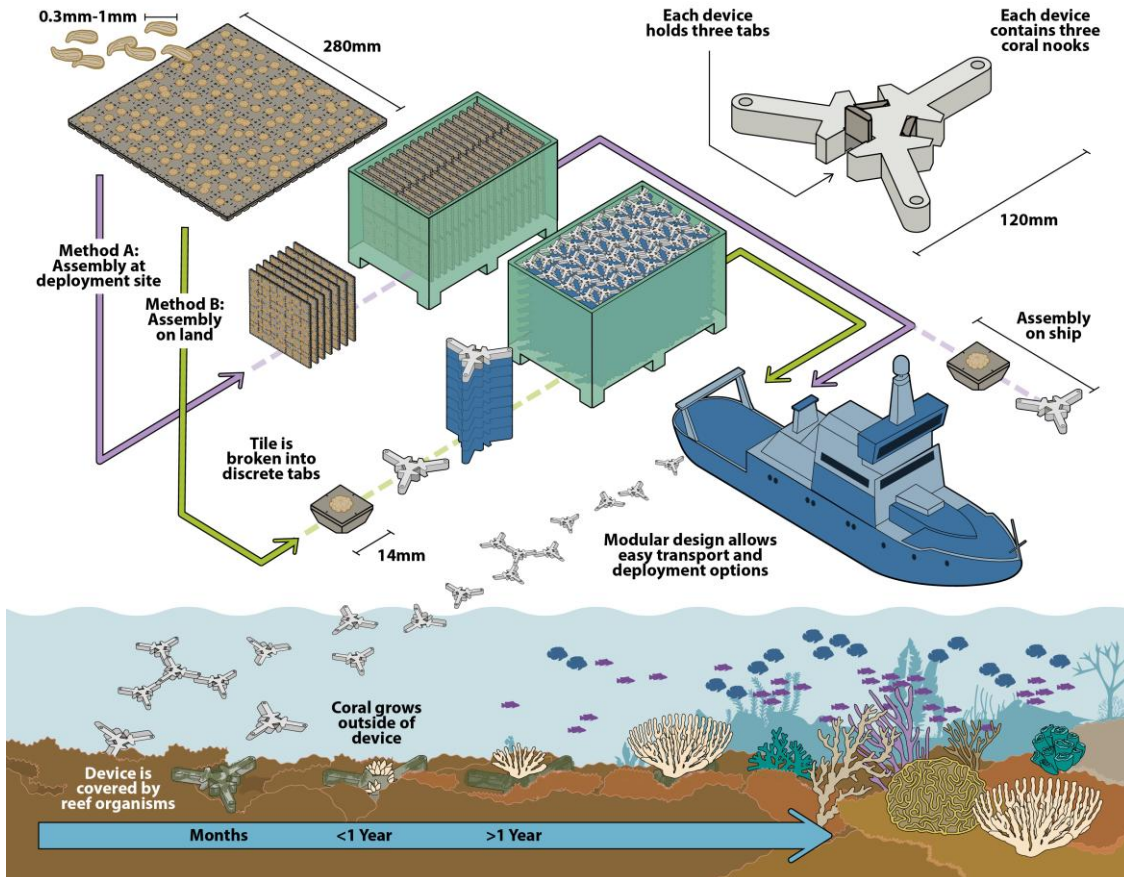


Figure 1: The Coral Aquaculture and Deployment concept to enable the upscaled deployments of seeding corals onto the reef.

Within the aquaculture facility, coral larvae are settled onto specially designed continuous concrete sheets (280×280 mm). Once settled, early corals are referred to as spat, and could be inoculated with cultured *Symbiodiniaceae* and the sheets are held for a short-term nursery maintenance and grow-out at high density in the production facility. Spat may be held in facility for up to 12 weeks while resources (e.g., vessels) are being made available for deployments. During this holding phase, spats are supplemented with live feeds (combination of *Artemia*, Rotifers and microalgae) for nutrition. Sheets with spat are designed to be broken into smaller individual 14×14 mm tabs; totalling 400 potentially useable tabs per sheet. Tabs having live spat are then assembled into the seeding devices for deployment. Assembly of the seeding devices could either be conducted at the facility and transported to the deployment site, or conducted on site whereby the tiles with corals are transported from the facility. Seeding devices are then deployed onto selected sites by releasing them at the surface from the vessel, informed by a smart deployment guidance system which assesses the suitability of the receiving benthic habitat to maximise coral survival immediately prior to automated release.

### 1.1.1 Coral deployments, retention and survival

In parallel to the production of coral seeding units in the facility, upstream and downstream processes were also optimised to 1) maximise the retention of devices once deployed onto the reef, 2) characterise the sinking and landing trajectory of devices that were released from the surface to guide the development of the Deployment Guidance System (DGS), and 3) maximise the survival of seeded corals once deployed. Here, a series of experiments was performed to improve the retention of devices, which tested various device designs and linking configurations under realistic in-field conditions and deployment strategies (i.e. surface deployments; (Ramsby et al., in review)). Additionally, the sinking trajectories of devices and habitat targeting trials are currently in progress to assess device drift through the water column under various environmental, sea state and deployment conditions, e.g. depths, tidal regime and vessel speeds.

Over the duration of RRAP to date, several research projects within sub-project CAD1-3: Drivers of survival, along with CAD-03 and CAD1-2, have conducted 13 experimental deployments (Table 1). The objectives of these experimental deployments were specific to the research questions that needed to be addressed for the individual sub-projects in any given year; nevertheless, these were all aligned towards understanding the ecology and environmental interactions that could affect the retention of devices, the survival and growth of deployed corals for at least one-year post-deployment, and optimisation of survival and growth once deployed. Of note, while survival appear to be variable across years and experiments, this was driven by 1) the experimental nature of the deployments, which included control and treatment devices, which led to a range of deployment outcomes, 2) survival outcomes as a result of different species deployed and the habitat that those species are being deployed into, and 3) a possible batch effect across years even when using the same species of corals.



*Figure 2: Ceramic coral seeding devices on the reef substrate as part of the Large Field Trial 2023 deployment. Photo: Saskia Jurriaans, AIMS.*

Throughout RRAP, via the transition from fixed to free deployments and iterative testing, we were able to achieve incremental gains in survival and design larger scale deployments that could address a range of research questions across ECT and CAD that would minimise batch effects, as potentially seen in earlier years.

Table 1: Summary of deployments that have been completed and currently in progress as part of CAD, and information on retention and survival where available.

| Experiment                            | Stage      | Species   | Fixed/Free     | Duration                | avg survival %     | max survival % |
|---------------------------------------|------------|---|----------------|-------------------------|--------------------|----------------|
| Herbivore exclusion                   | microfrags | <a href="#">Adig</a>                              | Fixed          | 8 mo                    | <b>83</b>          | <b>85</b>      |
| Retention study                       | microfrags | Amil  | Free           | 3 mo                    | <b>32</b>          | <b>67</b>      |
| SCORE devices                         | recruits   | Aten  | Tethered       | 12 mo                   | <b>22</b>          | <b>57</b>      |
| lattice/ groove devices               | recruits   | Aten  | Fixed          | 14 mo                   | <b>56</b>          | <b>88</b>      |
| Triangle Keppels                      | recruits   | Amil, Amur, Maeq                                  | Fixed          | 8 mo                    | <b>54.5</b>        | <b>78</b>      |
| Herbivore exclusion                   | recruits   | Adig  | Fixed          | 8 mo                    | <b>17</b>          | <b>25</b>      |
| Flow experiment                       | recruits   | Aten, <a href="#">Ahya</a> , Amil                 | Fixed          | 12 mo                   | <b>55</b>          | <b>92</b>      |
| Maggie herbivore plots                | recruits   | Aten  | Fixed          | 4 mo                    | <b>48</b>          | <b>76</b>      |
| Large field trial 1                   | recruits   | Aten, Amil  | Free           | 5/ 14 mo                | <b>63/ 25</b>      | <b>-/33</b>    |
| Large field trial 2                   | recruits   | <a href="#">Adig</a>                              | Free           | 3/ 12 mo                | <b>81/ 31</b>      | <b>-/51</b>    |
| Davies flow exp 2                     | recruits   | Mele, Alor, Mtur, Gfas                            | Fixed          | 7 mo                    | <b>73 (yield)</b>  | <b>83</b>      |
| Large Field Trial 3; 2250 devices     | recruits   | <a href="#">Aspa</a>                              | Free-retention | 12 months               | <b>59.8%</b>       |                |
| Large Field Trial 23/24; 9514 devices | recruits   | Amil, <a href="#">Aant</a> , <a href="#">Pdae</a> | Free           | In progress – 11 months | <b>In progress</b> |                |



## 1.2 ECT research objectives

The ECT subprogram underpins the research directions under the three ECT projects. These projects aim to enable the production of coral deployment units with enhanced heat-tolerance, survival and growth under future predicted environmental changes, via the following broad objectives:

- 1) Identify and characterise heat-tolerant corals across the GBR by integrating whole-genome sequencing, phenotypic assessments, and broad-scale field sampling to inform selective breeding and large-scale restoration efforts.
- 2) Develop and evaluate breeding interventions, including selective breeding, artificial selection, and intraspecific hybridisation, to enhance coral heat tolerance in restoration broodstock.
- 3) Enhance coral heat tolerance by developing and testing heat-evolved algal symbionts across coral life stages.

### 1.2.1 Genetic basis of thermal tolerance

Understanding adaptive genetic variation in corals at large spatial scales has historically been constrained by limited genomic tools and the absence of integrated phenotypic performance data. As a result, the identification of genetic markers associated with key coral traits, and their spatial and temporal distribution, has remained a challenge. These limitations have, therefore, posed delays to the development of marker-assisted selective breeding strategies in coral restoration.

To address these gaps, the ECT-01 project employed whole-genome sequencing to investigate relationships between coral host genomic regions, symbiont community characteristics, and heat

tolerance phenotypes across the GBR. Acute heat stress assays and longer-term heat stress experiments, along with opportunistic sampling during natural bleaching events, were used to generate large datasets of paired genotype-phenotype information required for robust analysis.

Fieldwork was a core component of the project, requiring extensive coordination across the GBR. Sampling efforts were strategically planned to select sites that captured both latitudinal (north-central-south) and cross-shelf (inshore-mid-shelf-offshore) variation, reflecting the environmental gradients that drive coral adaptation and resilience. This approach enabled the team to identify patterns of adaptive and neutral genetic variation across diverse reef environments and improve spatial resolution of tolerant genotypes.

Research activities were also integrated with experimental breeding trials under ECT-02. These efforts aimed to evaluate the potential benefits of using phenotyped corals, with multiple heat stress assays (natural and acute) conducted on the same colonies to better understand stress responses. Reef-wide scans of genetic variation were also undertaken, further informing the ecological and environmental context of the genomic data.

### **1.2.2 Selective breeding**

The overarching aim of this subproject within ECT-02 was to develop breeding interventions that leverage natural variation in coral heat tolerance, focusing on selective breeding, artificial selection, and intraspecific hybridisation, to identify and propagate broodstock with enhanced thermal tolerance. Over the first two years, key findings demonstrated the potential of intraspecific hybridisation (crossing individuals from heat-adapted and naïve populations) to generate coral stock with improved heat tolerance compared to purebred stock from naïve populations. Rapid heat stress assays were shown to be effective in identifying broodstock that could produce heat-tolerant coral recruits, though not necessarily larvae, thereby refining the tools available for selective breeding.

Heat stress treatments applied to larval cultures served as a form of artificial selection, eliminating heat-sensitive larvae and enriching the surviving population with thermally resilient individuals. While this approach successfully generated stress-tolerant larval stock, initial results suggested that artificial selection alone may have limited impact on the subsequent performance of coral recruits in reef environments. Moreover, combining multiple interventions, such as selective breeding with inoculation of heat-evolved symbionts, can reveal complex interactions that could affect coral holobiont performance in unexpected ways.

To evaluate the real-world outcomes of these interventions, this subproject required the deployment of selectively bred coral recruits across a range of reef environments and the implementation of fate-tracking methodologies. These deployments were strategically conducted across environmental gradients to assess coral performance under variable reef conditions, enabling a deeper understanding of how interventions translate to survival, growth, and resilience on the reef.

### **1.2.3 Inoculation with thermally enhanced Symbiodiniaceae**

The ECT-02 project also aimed to enhance coral thermal tolerance by manipulating their algal symbionts (Symbiodiniaceae), a critical component of the coral holobiont. The approach involved

the laboratory-based experimental evolution of heat-evolved symbiont strains, which were then introduced into corals to assess their capacity to improve thermal resilience (Figure 3). Initial proof-of-concept work in the first two years of the program demonstrated that heat-evolved algal strains conferred increased bleaching tolerance in *Acropora* larvae, recruits, and adults under controlled conditions.

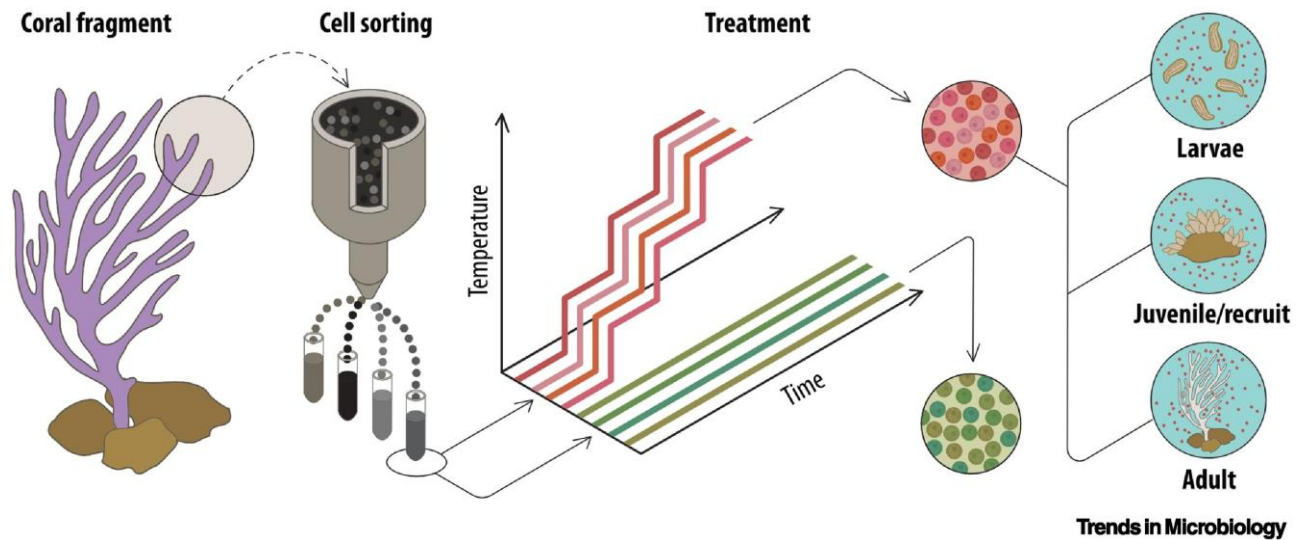


Figure 3: An experimental evolution framework for enhancing Symbiodiniaceae thermal tolerance (Nitschke et al. 2024).

To evaluate the ecological relevance and broader applicability of this intervention, the project expanded testing to include a wider diversity of coral-algal combinations and life stages. A key innovation was the development of a year-round adult coral system using chemical bleaching to facilitate symbiont reintroduction independently of spawning events, enabling more flexible and repeated experimentation.

Importantly, the project also addressed the potential risks and trade-offs of this intervention. By evaluating symbiont performance across coral life stages and species, and monitoring physiological responses under field-simulated conditions, the subproject contributed essential data for risk-benefit analyses – an integral component of the ECT sub-program’s research goals. Support from the joint field program was critical to assess the in-situ performance of corals inoculated with heat-evolved algal symbionts, including monitoring their survival, growth, and bleaching response under natural environmental conditions. Field deployment also enabled the investigation of potential horizontal transfer of heat-evolved symbionts to surrounding coral communities, providing key insights into the ecological consequences and scalability of this intervention.

## 2 Scope and objectives of the ECT and CAD Field Program

The Field Program enables coordinated research field activities across ECT and CAD projects, in conjunction with EcoRRAP sites, within RRAP Phase 1. It provides a collaborative operational structure to align planning, logistics, execution, and data management, supporting innovative and cross-disciplinary research and field operations, focused on reef restoration and coral assisted evolution.

The program scope includes:

- **Joint planning and coordination:** Early engagement between ECT, CAD, and EcoRRAP teams to align research goals, field methodologies, and site planning. This includes coordination of the coral collections and deployments for Large Field Trials and ECT and CAD fieldwork to optimise logistics and enhance shared outcomes.
- **Field preparation and logistics:** Full support for travel arrangements, equipment mobilisation, field and vessel scheduling, site permits, and Work Health and Safety (WHS) compliance. Includes preparation of SOPs, sampling kits, live coral transport systems, and deployment systems.
- **Integrated field operations:** collaborative fieldwork to support CAD Large Field Trials, including various coral deployment experiments, and ECT genomic and phenotypic data collections and experimental treatments.
- **Governance and communication:** Regular cross-subprogram coordination meetings, risk assessments, adaptive planning, and field debriefs. Includes clear communication channels and documentation of lessons learned.
- **Post-fieldwork data management:** Uploading raw data (e.g., deployment logs, survival counts) to shared subproject spreadsheets or cloud-based repositories, and daily or post-campaign data backups to secure servers to prevent potential data loss.

A central element of the program includes the Large Field Trials (LFT) led by the CAD team. These trials, conducted during 2023/24 and 2024/25 spawning seasons, represent experimental large-scale coral deployment studies undertaken under RRAP. Intended to test and refine intervention strategies developed by both CAD and ECT subprograms, the LFTs were designed to evaluate their effectiveness at scale.

The LFT 2023/24 was the largest deployment of coral seeding devices within RRAP to date. Conducted in the central GBR, it introduced several novel scaling elements permitted by the Great Barrier Reef Marine Park Authority (Reef Authority) for the first time, including:

- Free deployment of up to 10,000 seeding devices during a summer spawning event
- Inoculation of all corals with non-heat-evolved, cultured symbionts produced at the AIMS Symbiont Culture Facility
- Deployment of coral spat derived from inshore reef broodstock to mid-shelf reef sites, all within Traditional Owner Sea Country boundaries

The LFT 2023/24 and 2024/25 objectives were:

- **Surface deployment:** Pilot tests of surface-based coral seeding deployments (from vessels), assessing device sinking trajectories, landing profiles, and coral retention and survival across varying habitats.
- **Selective breeding:** Crosses of gametes from more and less heat-tolerant parent corals to enhance the thermal tolerance of resulting spat.
- **Artificial selection:** Application of short-term heat stress to larval cultures to enrich for heat-tolerant individuals.
- **Fouling release coated devices:** Evaluation of non-biocidal antifoulant coatings and their influence on coral spat survival and growth across algal gradients.
- **Single vs linked devices:** Comparison of single versus connected device configurations in terms of coral survival and growth in unstable or rubble-dominated habitats.
- **Single vs multi-species devices:** Assessment of performance differences between devices seeded with single or multiple coral species across a range of environmental conditions and morphologies.
- **Delayed deployment:** Investigation of the impacts of extended facility holding times and variable deployment windows on coral spat survival and performance.
- **QAQC monitoring:** Genetic, microbial, and symbiont community monitoring of deployed and wild coral populations through spatial and temporal sampling.
- **Density dependence:** Determination of optimal coral recruit densities per device for survival and growth.
- **Tile treatment:** Evaluation of coral spat performance when settled onto tiles conditioned with live versus dead crustose coralline algae in field deployments.
- **Symbiont provisioning:** Assessment of survival and growth benefits from provisioning coral spat with cultured (non-heat-evolved) zooxanthellae, as observed in aquaculture.
- **Environmental and community effects:** Quantification of the effects of surrounding biological communities and local environmental variables on coral survival and development.
- **Retention and cementation:** Evaluation of coral retention on devices and subsequent cementation to reef substrates post-deployment.

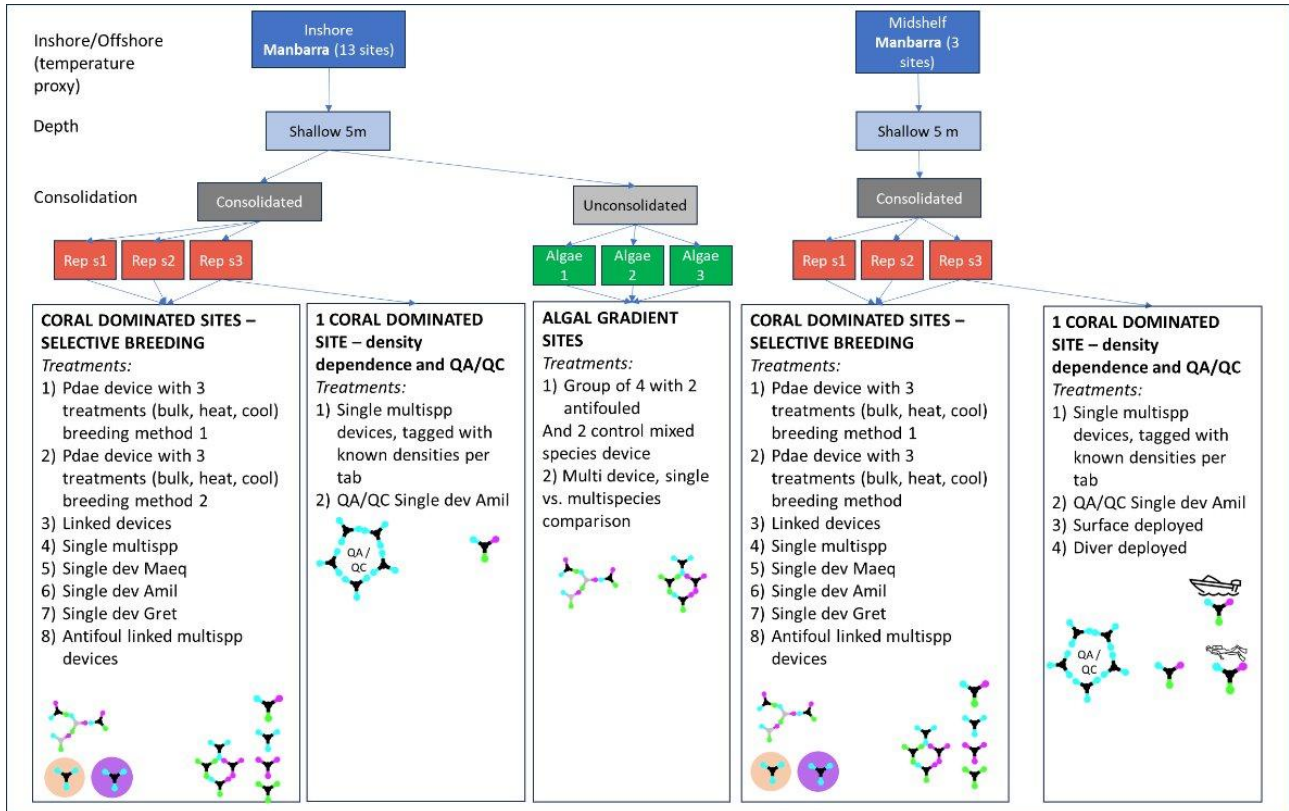


Figure 4: Example of a Large Field Trial experimental design to address multiple research objectives across environmental gradients.

The LFT 2024/25 further tested these objectives during the following summer spawning season, deploying an additional 2,800 seeding devices across mid-shelf and inshore reef sites in the central GBR.

### 3 Field Program Planning and Preparation

A field planning framework was created to manage the parallel projects field objectives and priorities (Table 2). Field program planning commenced at the start of each financial year with budgeting activities. Project teams were contacted to outline anticipated field activities and begin scoping the required resources. This early engagement informed the initial planning of quarterly field trips and the development of an integrated field schedule.

All information was centralised in a Field Planning spreadsheet, which served as the primary tool for tracking vessel and research station bookings, passenger logistics, and equipment requirements.

Following budgeting, permitting processes were initiated where applicable. This ensured that all field activities complied with relevant regulatory and environmental approvals prior to deployment. Engagement with the AIMS Indigenous Partnerships team to seek Free, Prior and Informed Consent (FPIC) from Traditional Owner (TO) groups occurred alongside logistics planning. Regular meetings with subprogram leads were held to clarify research goals, timelines, and cultural considerations, ensuring TO groups remained well-informed of any planned fieldwork activities.

Vessel bookings were a critical early step in the planning process. Each project submitted a “Shiptime Booking Form” to the field team, detailing their specific field requirements. This information enabled the field team to estimate the time and location needs for all ECT and CAD activities. Shiptime requirements were communicated biannually to AIMS Field Operations to secure time aboard AIMS research vessels. In cases where vessel capacity was unavailable or additional flexibility was needed, the field team began the process for booking charter vessels. For short one-day trips, vessels were secured 10-14 days in advance. For longer expeditions, such as those in the Pilot Deployment Program (PDP), charter arrangements and tender processes were initiated up to seven months ahead of scheduled deployments.

Research station bookings followed, informed by the Field Planning spreadsheet, which tracked project needs for accommodation, laboratory space, passenger movement, and equipment.

Comprehensive field logistics planning then brought all elements together. This included the grouping of compatible field projects into consolidated trips to maximise the efficient use of time, resources, and personnel. Prior to each field trip, the field team conducted a planning meeting, or circulated a summary via email, to confirm trip objectives, logistics, and team responsibilities. Agreement from all involved groups was sought to finalise preparations.

Table 2: Field planning framework and timelines.

|   | Month 0 | EOY | Month 1 | Month 2 | Month 3 | Month 4 | Month 5 | Month 6 | Month 7 | Month 8 | Month 9 | Month 10 | Month 11 |
|---|---------|-----|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------|----------|
| <b>Budgeting</b>  |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Contact research team leads - assess field trip needs for each project            | █       |     |         |         |         |         |         |         |         |         |         |          |          |
| Send field requirements to finance team for detailed costings                     |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Finalise field program budget   |         |     |         |         |         |         |         |         |         |         |         |          |          |
| <b>Permitting</b>   |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Initiate permit discussions with Reef Authority                                   |         |     | █       |         |         |         |         |         |         |         |         |          |          |
| Prepare permit application  |         |     |         | █       |         |         |         |         |         |         |         |          |          |
| Initiate pre-application meeting  |         |     |         |         | █       |         |         |         |         |         |         |          |          |
| Consideration of pre-application by Reef Authority                                |         |     |         |         |         | █       |         |         |         |         |         |          |          |
| Submit permit application   |         |     |         |         |         |         | █       |         |         |         |         |          |          |
| Receive feedback on permit application from Reef Authority                        |         |     |         |         |         |         |         | █       |         |         |         |          |          |
| Incorporate feedback and re-submit permit application                             |         |     |         |         |         |         |         |         | █       |         |         |          |          |
| Seek permit approval and delivery   |         |     |         |         |         |         |         |         |         |         | █       |          |          |
| <b>Vessel bookings</b>  |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Start planning joint quarterly vessel trips                                       |         |     |         |         | █       |         |         |         |         |         |         |          |          |
| Send vessel requirements to AIMS Field Operations team                            |         |     |         |         |         | █       |         |         |         |         |         |          |          |
| Assess ship schedule (released biannually) for vessel requirements                |         |     |         |         |         |         | █       |         |         |         |         |          |          |
| Start tender process for charter vessels (for field trips >1 day only, if needed) |         |     |         |         |         |         |         | █       |         |         |         |          |          |
| Assess charter vessel tender applications   |         |     |         |         |         |         |         |         | █       |         |         |          |          |
| Finalise charter vessel(s) bookings (for field trips >1 day only)                 |         |     |         |         |         |         |         |         |         | █       |         |          |          |
| Finalise charter vessel(s) bookings (for 1 day field trips)                       |         |     |         |         |         |         |         |         |         |         |         | █        |          |
| <b>FPIC</b>   |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Engage with AIMS Indigenous Partnerships team                                     |         |     |         |         |         | █       |         |         |         |         |         |          |          |
| Complete FPIC documentation   |         |     |         |         |         |         | █       |         |         |         |         |          |          |
| Present field and research plans and seek approval from TO groups                 |         |     |         |         |         |         |         |         |         |         |         | █        |          |
| <b>Research station bookings</b>  |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Start planning research station field trips                                       |         |     |         |         |         |         | █       |         |         |         |         |          |          |
| Assess research station availability  |         |     |         |         |         |         |         | █       |         |         |         |          |          |
| Complete booking process for research station(s)                                  |         |     |         |         |         |         |         |         | █       |         |         |          |          |
| Finalise research station booking(s)  |         |     |         |         |         |         |         |         |         |         | █       |          |          |
| <b>Field logistics</b>  |         |     |         |         |         |         |         |         |         |         |         |          |          |
| Initiate field planning meetings with research teams                              |         |     | █       |         |         |         |         |         |         |         |         |          |          |
| Consolidate priority field activities for each planned field trip                 |         |     |         |         | █       |         |         |         |         |         |         |          |          |
| Send field plans to research teams for feedback                                   |         |     |         |         |         | █       |         |         |         |         |         |          |          |
| Finalise field plans and activities   |         |     |         |         |         |         |         |         |         |         |         | █        |          |
| Consolidate necessary field equipment   |         |     |         |         |         |         |         |         |         |         |         |          | █        |

## 4 Outcomes and Lessons Learnt

The ECT and CAD Field Program successfully delivered a series of coordinated field activities that achieved key operational and scientific milestones. Notably, the Large Field Trials (LFT) resulted in the successful deployment of over 10,000 deployment devices across multiple reef sites spanning inshore and mid-shelf reefs in the central GBR. These deployments were strategically designed to trial large-scale coral restoration and adaptation, generating data to enhance our understanding of survival and growth of deployed corals under varying environmental and intervention conditions, and to inform the Pilot Deployment Program.

Despite the operational challenges posed by severe weather events, including Tropical Cyclones Jasper and Kirrily, the program maintained momentum through proactive planning and adaptive logistics. These disruptions necessitated the re-deployment of some experiments in summer 2024. However, they highlighted the need for flexibility and responsiveness within project teams to adapt plans and maintain progress under challenging conditions.

A defining feature of the Program was the high level of cross-team collaboration. Staff, vessels, and research station facilities were shared across multiple subprograms and institutions, enabling more efficient use of resources and reducing duplication of effort. This approach fostered stronger integration between research groups and allowed for co-ordinated methodologies, broader spatial coverage, and increased sampling replication. As a result, the datasets generated have higher statistical power and enhanced scientific validity.

In total, 60 field trips over 584 days were conducted as part of the RRAP CAD-03 Field Program (Table 3). The coordinated efforts and shared resourcing model not only improved operational efficiency but also deepened scientific collaboration, strengthening the overall impact of RRAP. In addition, RRAP CAD and ECT staff were activated for three bleaching response trips funded by AIMS over the summers of 2023/24 and 24/25, which gathered valuable in field data and collection of samples that were important in describing the extent and severity of those events.

Table 3: List of field trips and duration throughout RRAP 1.0 with details of projects and activities supported.

| Year   | Date   | Project(s)             | Activities   | Duration (days) |
|--------|--------|------------------------|--|-----------------|
| Year 1 | Oct-20 | CAD-03                 | Spawning collection  | 12              |
|        | Nov-20 | ECT-02                 | Spawning collection  | 10              |
|        | Nov-20 | CAD-03                 | Spawning collection  | 8               |
|        | Jan-21 | ECT-01                 | Tag colonies, deploy temperature loggers and collect fragments for heat stress experiments   | 14              |
|        | Mar-21 | ECT-01                 | Tag colonies, deploy temperature loggers and collect sediment samples and fragments for heat stress experiments  | 20              |
|        | Apr-21 | ECT-01, ECT-02         | Temperature profile experiment and coral collections, tag colonies, deploy temperature loggers and collect fragments for heat stress experiments trip 7555 | 16              |
|        | Apr-21 | CAD-01, ECT-01, ECT-03 | Tag colonies, deploy temperature loggers and collect fragments for heat stress experiments CCA and coral collections                                       | 12              |

|               | <b>Subtotal no. of field trips/days</b> |                                |  | <b>7/92</b>   |
|---------------|---|--------------------------------|--|---------------|
| <b>Year 2</b> | Jul - 21                                | CAD-01                         | Locate and mark reef sites, free deploy empty devices                                      | 2             |
|               | Aug-21                                  | CAD-01, CAD-02, ECT-02, ECT-03 | Device deployment, coral collections, tile removal   | 10            |
|               | Sep-21                                  | ECT-01                         | SSIAB on tagged millepora, QM diversity survey   | 10            |
|               | Oct-21                                  | CAD-01, CAD-02, ECT-02         | Spawning collection, device re-survey, device deployment, coral collection                 | 12            |
|               | Nov-21                                  | ECT-02                         | Coral broodstock collection  | 13            |
|               | Feb-22                                  | CAD-01                         | Device deployment  | 10            |
|               | Feb-22                                  | CAD-01                         | Device deployment and re-survey  | 8             |
|               | Febr-22                                 | ECT-01                         | Tag colonies, deploy temperature loggers and collect fragments for heat stress experiments | 17            |
|               | Mar-22                                  | CAD-01                         | Device re-survey, sediment trap deployment   | 9             |
|               | Mar-22                                  | ECT-01                         | Tag colonies, deploy temperature loggers and collect fragments for heat stress experiments | 14            |
|               | May-22                                  | CAD-01, ECT-02                 | Device deployment and re-survey  | 7             |
|               | May-22                                  | CAD-01                         | Device deployment  | 8             |
|               | Jun-22                                  | CAD-01, ECT-01                 | Device deployment, CCA and sample collection   | 1             |
|               | <b>Subtotal no. field trips/days</b>    |                                |  | <b>13/121</b> |
| <b>Year 3</b> | Jul-22                                  | CAD-01, ECT-01                 | Device deployment and re-survey, sample collection   | 12            |
|               | Jul-22                                  | ECT-01                         | Sample collection  | 12            |
|               | Oct-22                                  | CAD-01, CAD-03, EcoRRAP        | Reef site monitoring, device re-survey   | 7             |
|               | Oct-22                                  | CAD-01, ECT-02                 | Spawning collection, device deployment and re-survey                                       | 14            |
|               | Nov-22                                  | ECT and CAD                    | On Country spawning  | 24            |
|               | Nov-22                                  | CAD-01, CAD-03, EcoRRAP        | Reef site monitoring, device re-survey   | 2             |
|               | Nov-22                                  | ECT-02                         | Brood stock collection and acute heat stress   | 10            |
|               | Dec-22                                  | CAD-01                         | Spawning collection  | 8             |
|               | Dec-22                                  | CAD-01, ECT-02                 | Device deployment and re-survey  | 10            |
|               | Jan-23                                  | ECT-02                         | Device deployment  | 5             |
|               | Jan-23                                  | CAD-01                         | Coral collection   | 17            |
|               | Feb-23                                  | ECT-01                         | Tag colonies, deploy temperature loggers and collect fragments for heat stress experiments | 13            |
|               | Feb-23                                  | CAD-01                         | Device re-survey   | 11            |
|               | Mar-23                                  | ECT-02                         | Device re-survey   | 5             |
|               | Apr-23                                  | CAD-01, CAD-03, ECT-02         | Device deployment and re-survey  | 17            |
|               | May-23                                  | CAD-01, CAD-03, ECT-02         | Device deployment  | 1             |
| Jun-23        | CAD-01, CAD-03, ECT-02                  | Device deployment              | 1  |               |

|   |                                      |                        |   |               |
|---|--------------------------------------|------------------------|---|---------------|
|   | Jun-23                               | ECT-02                 | Device re-survey  | 4             |
|   | <b>Subtotal no. field trips/days</b> |                        |   | <b>19/162</b> |
| Year 4                                  | Jul-23                               | ECT and CAD            | Device deployment and re-survey, finalisation/removal of some experiments     | 17            |
|   | Aug-23                               | CAD-01                 | Device resurvey, finalisation/removal of some experiments                     | 4             |
|   | Sept-23                              | ECT-01                 | Coral collection  | 1             |
|   | Sep-23                               | ECT-02                 | Device re-survey  | 5             |
|   | Oct-23                               | ECT and CAD            | Device deployment and re-survey, spawning collection                          | 14            |
|   | Nov-23                               | CAD-01                 | CCA and coral sample collection   | 1             |
|   | Nov-23                               | CAD-01, CAD-03         | Large Field Trial deployment, spawning collection                             | 11            |
|   | Dec-23                               | ECT and CAD            | Post cyclone and bleaching survey   | 1             |
|   | Dec-23                               | CAD-03, ECT-02         | Large Field Trial deployment, coral collection                                | 20            |
|   | Feb-24                               | ECT-02                 | Device re-survey  | 3             |
|   | Feb-24                               | ECT-02                 | Device re-survey and post bleaching survey                                    | 3             |
|   | Mar-24                               | ECT-02                 | Device re-survey  | 1             |
|   | Apr-24                               | CAD-03                 | Post cyclone survey   | 4             |
|   | Apr-24                               | CAD-01, CAD-03, ECT-02 | Large Field Trial device deployment and re-survey, holding table installation | 14            |
|   | Jun-24                               | CAD-01, CAD-03, ECT-02 | Device re-survey, Deployment Guidance System testing                          | 17            |
|   | <b>Subtotal no. field trips/days</b> |                        |   | <b>14/115</b> |
| Year 5                                  | Aug-24                               | ECT-02                 | Device re-survey  | 6             |
|   | Sep-24                               | ECT and CAD            | Device re-survey, spawning collection   | 22            |
|   | Nov-24                               | ECT and CAD            | Device re-survey, spawning collection   | 9             |
|   | Dec-24                               | CAD-03                 | Large Field Trial deployment, re-survey, brood stock return                   | 15            |
|   | Mar-25                               | CAD-03                 |   | 7             |
|   | Apr-25                               | CAD-01, CAD-03, ECT-02 | Device re-survey  | 19            |
|   | Jun-25                               | CAD-01, CAD-03, ECT-02 | Device re-survey  | 16            |
|   | <b>Subtotal no. field trips/days</b> |                        |   | <b>7/94</b>   |
| <b>GRAND TOTAL no. field trips/days</b> |                                      |                        |   | <b>60/584</b> |

#### 4.1 Challenges, learnings and future opportunities

- 1) CAD/ECT and EcoRRAP sometimes lacked overlap in design and sites, reducing the efficacy of resource sharing for field trips.
  - Joint planning workshops have suggested that combining experimental designs and field programs would benefit all groups by using EcoRRAP sites as natural controls and ECT/CAD sites for genetic sampling and deployments.

- 2) When a single institution, such as AIMS, is tasked with overseeing multi-institutional field trips, it can sometimes result in other institutions feeling excluded or unprepared to contribute to the planning process.
  - To mitigate this issue, it is essential to ensure effective communication between teams by including representatives from each organisation and providing opportunities for input and questions from all participants.
  - An overview of planning processes and institutional requirements should be given at the start of a new project.
- 3) Engagement with the Reef Authority for permitting may be a protracted process and sufficient lead time should be incorporated into the planning/ preparation phase.
  - It is recommended that a permit application be submitted at least a year in advance and active engagement throughout the application process needs to be initiated with the Reef Authority to ensure applications are approved on time. In most cases, the permit was approved later than anticipated and within 1-2 weeks from the first activities being undertaken.
  - For deployments with novel activities, it is recommended that a pre-application meeting with the Authority to discuss these activities is conducted prior to submission of the application
  - At this meeting, ensure that processes requiring the provision of additional information are clearly discussed.
  - A deployment design and monitoring plan should be prepared ahead of the pre-application meeting.
- 4) Large-scale, multi-team deployments can encounter significant issues without clear early planning, leadership alignment, and consistent communication across the project.
  - A preliminary experimental and deployment plan was developed six months prior to the scheduled deployment. This early draft was instrumental in progressing permit discussions with the Reef Authority.
  - Regular workshops with the broader project team in the lead-up to coral spawning helped refine project objectives, identify collaboration opportunities, and streamline shared resourcing across teams.
  - An LFT management and leadership group was established, including sub-program leads, research scientists, postdocs, and field technicians, which proved highly effective in coordinating efforts and maintaining clear communication from spawning through to deployment.
- 5) Single site deployments within eco-regions resulted in loss of deployed corals and reduction in sample sizes due to extreme weather.
  - Replicate sites are needed within eco-regions, potentially across latitudes, to account for any potential weather or cyclone damage (either from freshwater bleaching, flood plumes, high winds, or high temperatures).
  - If current permitting does not support deployments across replicate sites, seek changes to permitting at least one year prior to planned experimental set up.
- 6) Poor data management has been highlighted as a potential concern for future projects.

- Ensure datasheets are accessible and shared across all institutions and organisations involved in the project.
- Maintain consistent nomenclatures across data sets to facilitate temporal and cross-project comparisons.
- Establish and implement file and variable naming conventions early across institutions to address issues related to data retrievability, readability, and organisation.

7) Obtaining Free Prior and Informed Consent (FPIC) from Traditional Owner (TO) groups for research activities on Country and Sea Country is a critical requirement at AIMS. However, delays can occur due to the time needed for engagement and consultation, particularly if not initiated early in the planning process.

- The FPIC process often involves a long lead time, as it depends on the availability of TO groups to meet and consider proposed activities.
- Early identification of collection and deployment sites is essential to trigger timely FPIC processes.
- Engaging the AIMS Indigenous Partnerships team at the outset of planning, well before fieldwork, is a key factor for effective coordination with TO groups.
- For the LFT 2023/24 program, early engagement with the Indigenous Partnerships team helped ensure sufficient time for respectful and informed consultation with the relevant TO groups.

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