Crown-of-Thorns Starfish
Control Innovation Program

SYNTHESIS & IMPACT REPORT

2021–2024

Australian Government

REEF TRUST

Great Barrier Reef Foundation

Australian Institute of Marine Science

CSIRO

James Cook University Australia

The University Of Queensland Australia

Australian Government Great Barrier Reef Marine Park Authority

Reef Authority

Reef & Rainforest Research Centre

ACKNOWLEDGEMENT

Reef Traditional Owners have been caring for land and sea Country for more than 60,000 years, using Traditional Knowledge passed down through ancestral lines for millennia. The COTS Control Innovation Program extends its deepest respect and recognition to all Traditional Owners of the Great Barrier Reef and its Catchments, as First Nations People holding, the hopes, dreams, traditions and cultures of the reef.

‘*Great Barrier Reef*’ artwork by Melanie Hava, Mamu Aboriginal woman, Dugulbarra and Waribarra family groups, from the Johnstone River catchment of the Wet Tropics of Far North Queensland and the adjoining Great Barrier Reef Sea Country.

CONTENTS

Cover Image: Rick Abom, RRRC

FOREWORD

Anyone who has been lucky enough to visit a coral reef knows just how special they are. Colorful and teaming with life, these ecosystems are a nursery and safe haven for a quarter of all marine life and support a billion people worldwide.

But with global warming expected to surpass 1.5°C this century, the stakes have never been higher for the future of these vibrant ecosystems and the communities that depend upon them.

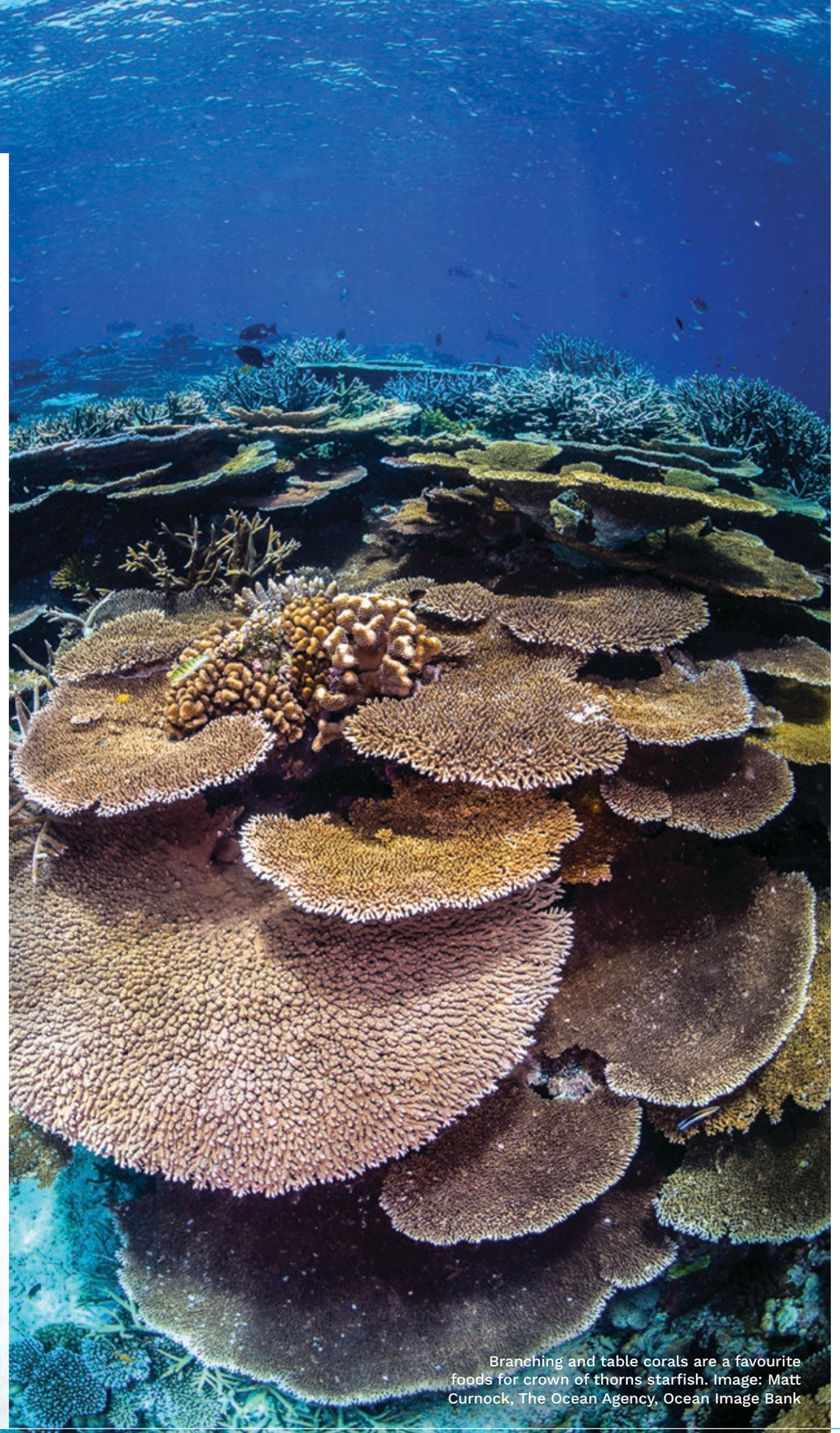
In response, global efforts have ramped up to protect coral reefs and promote their resilience in the face of accelerating environmental change. Here on the Great Barrier Reef (GBR), outbreaks of coral-eating crown-of-thorns starfish (COTS) are a major threat to reef health that can be alleviated with direct action.

Over the past four years, the Reef Trust Partnership between the Australian Government and the Great Barrier Reef Foundation has invested in a ***COTS Control Innovation Program*** (CCIP). This mission-focused research program has brought together Australia's best and brightest minds to improve our capacity to predict, detect and respond to these damaging outbreaks.

On behalf of CCIP's Steering Committee, researchers, managers and stakeholders, it's my pleasure to share a synthesis of our collaborative efforts and impact to date. We have delivered innovations across all aspects of the Integrated Pest Management cycle, directly supporting the COTS Control Program in protecting coral throughout the World Heritage listed GBR.

The impact CCIP has generated in just a few years is a remarkable testament to what's possible when passionate, brilliant people roll up their sleeves and work together.

Dr. Mary Bonin
CCIP Program Director



Branching and table corals are a favourite foods for crown of thorns starfish. Image: Matt Curnock, The Ocean Agency, Ocean Image Bank

THE CHALLENGE

Urgent action and innovation are needed to build coral reef resilience

Coral reefs are one of the most valuable ecosystems on Earth, supporting immense biodiversity and providing billions of dollars in services including food, coastal protection and tourism. They are also one of the most imperilled ecosystems, with escalating impacts of climate change compounding upon local threats, leading to predictions that the planet's reefs will be lost within a few generations.

> ***Humanity must act with evidence-based urgency, ambition and innovation to change the trajectory for this ecosystem, which is the canary in the coalmine for climate's impact on oceans, before it's too late.***[1]

The coral reef crisis has driven a shift in management toward approaches that actively build the resilience of reefs and the people that depend on them. Resilience-based management identifies and prioritises actions that reduce local threats and support natural resistance and recovery processes.

Crown-of-thorns starfish outbreaks are a major contributor to coral reef degradation across the Indo-Pacific. When in outbreak numbers, these coral-eating pests can wipe out 90% of the live coral on a reef, destroying the habitat of countless other species in the process. The branching coral species that are most vulnerable to COTS outbreaks are also among those most susceptible to climate-induced coral bleaching. These branching corals are critical for reef biodiversity, providing food and shelter to many other reef-dwelling species.

COTS Control Program diver culling coral-eating starfish
Image: Rick Abom, RRRC

On Australia's Great Barrier Reef periodic waves of COTS outbreaks have plagued the reef for decades. These outbreaks are a major driver of habitat loss for this globally iconic ecosystem, threatening its biodiversity and the cultural and social values it provides for Traditional Owners, coastal communities and tourists.

Controlling these outbreaks is part of Australia's Reef 2050 Plan[2], the overarching resilience-based strategy to manage the GBR's biodiversity, health and values in a changing climate.

But controlling COTS outbreaks is easier said than done. Each starfish is capable of producing millions of offspring that can disperse across large distances, causing outbreaks to spread across many reefs. They are also highly cryptic and nocturnally active, making it extremely challenging to detect the early stages of an outbreak and manage it effectively across the more than 3,000 individual reefs that make up the GBR ecosystem.

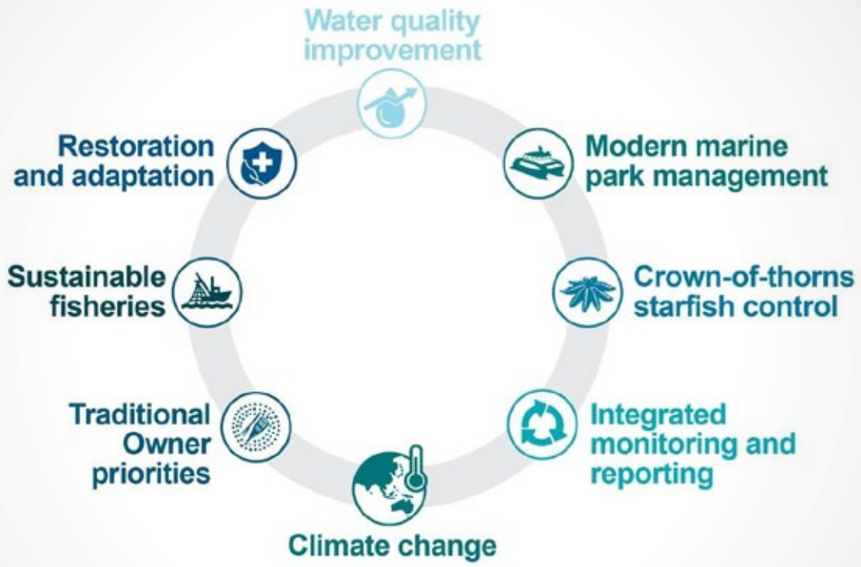
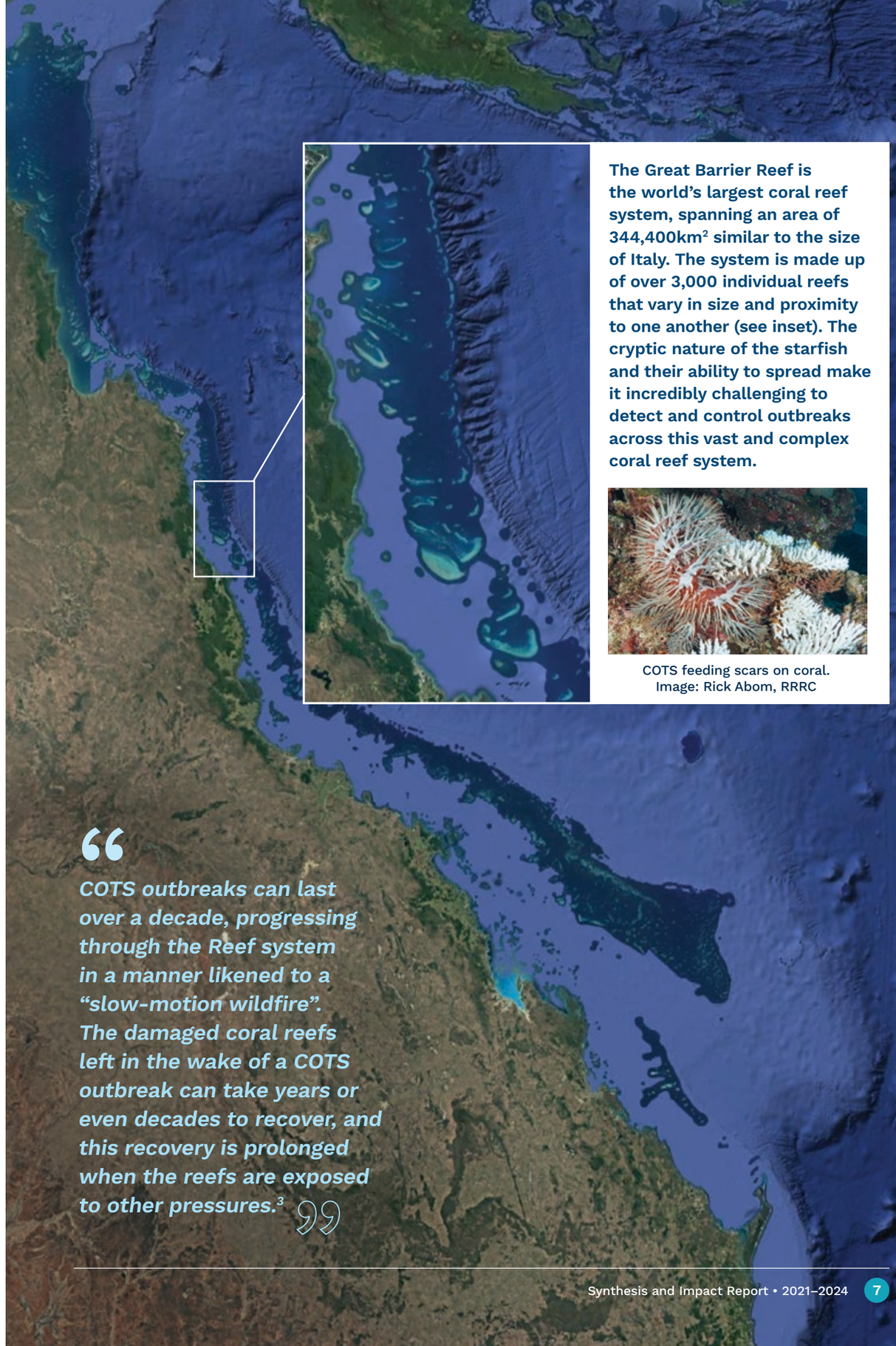


Figure 1. COTS control is a key priority for managing the Outstanding Universal Value of the World Heritage listed Great Barrier Reef[2]



The Great Barrier Reef is the world's largest coral reef system, spanning an area of 344,400km² similar to the size of Italy. The system is made up of over 3,000 individual reefs that vary in size and proximity to one another (see inset). The cryptic nature of the starfish and their ability to spread make it incredibly challenging to detect and control outbreaks across this vast and complex coral reef system.

COTS feeding scars on coral.
Image: Rick Abom, RRRC

"COTS outbreaks can last over a decade, progressing through the Reef system in a manner likened to a "slow-motion wildfire". The damaged coral reefs left in the wake of a COTS outbreak can take years or even decades to recover, and this recovery is prolonged when the reefs are exposed to other pressures.[3]"

THE COTS CONTROL PROGRAM

A world-first example of Integrated Pest Management in a marine ecosystem

The COTS Control Program is a highly collaborative effort, led by the Great Barrier Reef Marine Park Authority in partnership with the Great Barrier Reef Foundation, the Reef and Rainforest Research Centre, and a network of other government, research and tourism industry partners and vessel contractors.

Over the past decade, research breakthroughs have enabled the COTS Control Program to expand its scale of operations and improve its efficacy. Foremost among these is the application of an ***Integrated Pest Management*** (IPM) approach, developed through a suite of research[4] conducted by the National Environmental Science Program (NESP) Tropical Water Quality Hub between 2015-2020. IPM is an environmentally sensitive approach designed to minimise a pest's ecological, economic and social impacts.

Today, a fleet of five to six control vessels with over 100 trained crew operate across the length of the GBR managing coral-eating starfish. Their targeted on-water activities, including monitoring, surveillance and manual culling using a single-shot injection method, are guided by an IPM decision framework.[5] Data and information collected in the field are used by program managers and stakeholders to assess progress in achieving targets and inform strategic planning.

Underpinned by a combination of research, innovation and operational expertise, the COTS Control Program effectively protects coral across several hundred reefs each year.[6] It is considered one of the most scalable and feasible management actions available to protect corals on the Great Barrier Reef and is critical for its long-term health and resilience.

Despite progress, challenges remain. More reefs need pest management across the vast scale of the GBR than are possible to control with current tools and finite resources. Early, proactive action is key to supressing outbreaks and preventing coral decline. Yet persistent knowledge gaps in COTS biology and population dynamics limit capacity to forecast outbreaks, and the current culling and surveillance tools have limitations that reduce their efficiency at the earliest outbreak stages.

COTS control is a key action to build reef resilience because every coral protected from COTS can reproduce and help repopulate areas damaged by bleaching or other impacts.

New knowledge, tools and capability are needed to better **predict** when and where COTS populations will outbreak, more effectively **detect** early increases in COTS numbers, and strategically **respond** to outbreaks at scale, before they impact coral and reef diversity. Research and innovation to improve the IPM approach will ensure the COTS Control Program saves as much coral as possible today and keeps pace with the mounting pressures on the reef from climate change.

Overview of Integrated Pest Management

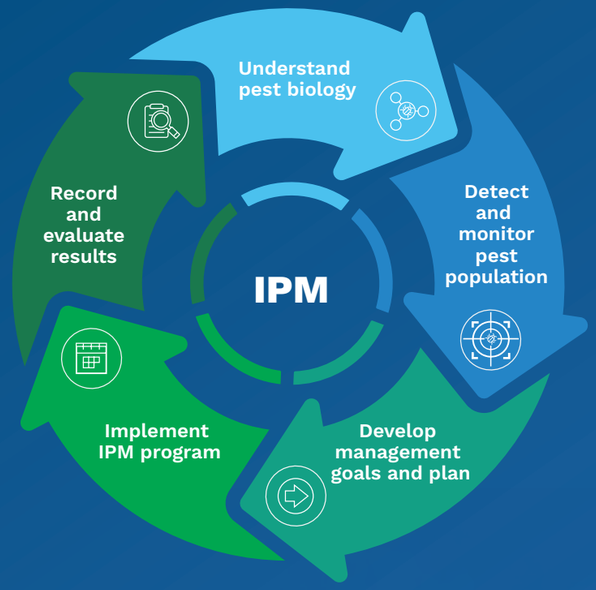


Figure 2. Steps in the Integrated Pest Management process

Integrated Pest Management is a holistic approach to managing the ecological, economic and social impacts of a pest species. IPM programs typically involve five key steps. These steps are iterative, and robust science is needed to support each one:

1. Understand the pest and its biology, including its life cycle and natural enemies.
2. Detect and monitor the pest and its impact on the environment, especially high value sites.
3. Develop action thresholds and a plan for when and where action will be taken if thresholds are exceeded.
4. Implement controls, typically a combination of manual, biological and chemical methods.
5. Evaluate results, assess costs and benefits, and adapt for greater efficacy and efficiency.

COTS control crew heading to work.
Image: Blue Planet Marine

OUR MISSION

A targeted research program aimed at boosting capacity to predict, detect and respond to COTS outbreaks at scale across the Great Barrier Reef

Supported by a $9.8 million investment from the Reef Trust Partnership, the COTS Control Innovation Program (CCIP) mobilised and convened Australia's leading reef research and management organisations to collaborate on solutions to address the COTS threat. The program brought together over 90 multi-disciplinary experts from 11 organisations, with a clear focus on delivering innovation that builds capacity to predict, detect and respond to damaging outbreaks.

From design to delivery, CCIP has taken a collaborative and mission-oriented approach. A Steering Committee with broad stakeholder representation, including research, industry, Traditional Owners and government, has ensured that a range of perspectives and interests were considered in direction setting and adaptive decision-making. A Research Impact Plan guided the delivery of an integrated portfolio of 21 projects across 3 subprograms, mapping the expected contribution of each project to achieving program-level impacts.

Initial field testing of COTS surveillance technology
Image: Mary Bonin, GBRF

Aunty Lola Tiger learning about COTS at a CCIP project workshop, Heron Island Research station. Image: Dr. Kenny Wolfe, UQ

Figure 3. Overview of the CCIP theory of change model that guided delivery and united organisations and multi-disciplinary researchers around a shared mission

Researcher searching for COTS using new SALAD survey method. Image: Dr. Ceimon Caballes, JCU

"It takes a certain amount of trust, and I think this is where having a longer-term investment in the partners working together means that you build those relationships that can make this thing much more efficient than it would otherwise be.[7]

COTS researchers, managers and stakeholders together at workshop, Townsville 2023. Image: GBRF

AN INNOVATIVE WAY OF WORKING

Delivering collaborative and integrated innovation for real-world impact

Innovation is not only about creating new tools or technology, it's also about approaching problems differently and working together in new ways. After decades of investment in research under competitive funding models, CCIP has taken a fresh approach that fosters partnerships, trust and shared accountability to drive impact:

- Collaboration was incentivised through the partnership and governance model.
- A comprehensive Design Phase[8] was used to bridge institutional and disciplinary silos when developing project work plans.
- Synergies and connections across projects in the portfolio were identified and supported, making the whole greater than the sum of the parts.
- Stakeholders from the COTS Control Program were engaged regularly throughout research delivery and were embedded as members of the project teams, ensuring outputs were fit-for-purpose.
- Impact mapping and regular workshops kept the multi-institutional and multi-disciplinary team focused and aligned on our shared mission.

RESEARCH IMPACT AT A GLANCE

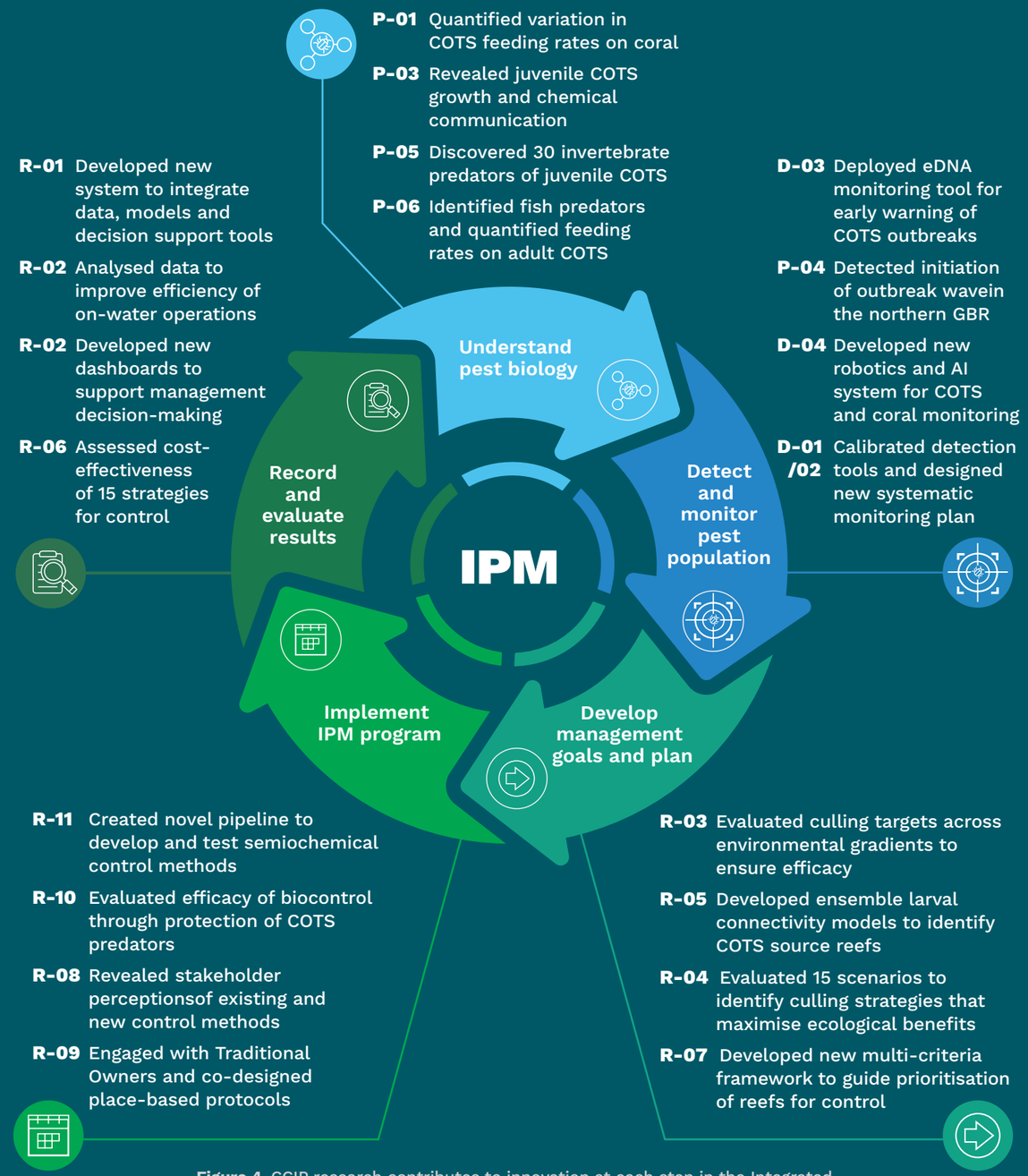


Figure 4. CCIP research contributes to innovation at each step in the Integrated Pest Management approach that is applied in Australia's COTS Control Program

IMPACT HIGHLIGHTS

UNDERSTANDING THE PEST

Understanding a pest's biology and ecology is fundamental to effective Integrated Pest Management. Despite decades of research on COTS, there are still significant knowledge gaps[9] that limit our ability to model outbreak dynamics accurately, predict the times, places and points in the life cycle when COTS populations are most vulnerable to management, and improve detection and control methods. CCIP has made discoveries that provide novel insight into the life cycle and natural enemies of this notorious coral-eating pest.

A COTS outbreak on the GBR. Image: Morgan Pratchett, JCU

Project P-01
In-situ feeding rates

Delivered new data to fine-tune the ecological models that guide control efforts, using 3D photogrammetry and intensive field monitoring to quantify COTS feeding rates and how they vary with body size and coral prey availability.

Project P-03
Juvenile ecology and resilience

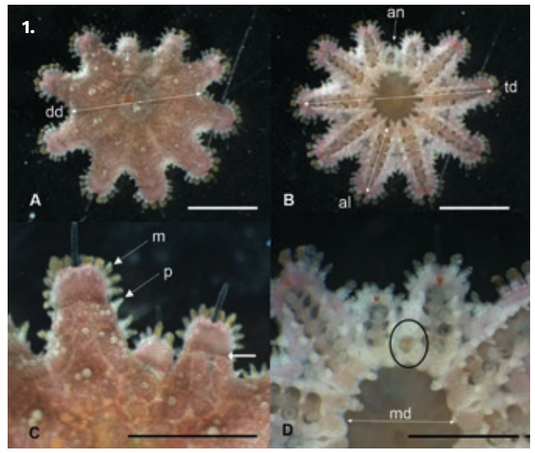
Shed light on a major blind spot in the COTS life cycle and revealed the innate capacity for juvenile chemical communication that could unlock new control methods, through investigation of the behaviour, growth and biochemistry of juvenile COTS.[10]

Project P-05
Benthic predation in rubble

Revealed that invertebrates, including the decorator crab *Schizophrys aspera*, are important predators of juvenile COTS and may play a role in outbreak suppression, using a combination of laboratory experiments, field surveys and eDNA gut contents analyses.[11]

Project P-06
Fish predation rates and zoning

Identified the spangled emperor *Lethrinus nebulosus* as a potentially important predator that suppresses COTS numbers on reefs that are protected from fishing, by measuring predation rates on adult COTS in the field.



1. Morphological traits could be used to predict the age of wild-caught juvenile COTS. Image: Maria Byrne, USYD
2. Decorator crab, *Schizophrys aspera*, feeding on tiny pink juvenile COTS. Image: Dr. Kennedy Wolfe, UQ
3. Spangled emperor are a predator of crown-of-thorns starfish and also a fisheries target. Image: Shutterstock

IMPACT HIGHLIGHTS

DETECTION AND MONITORING

Effective and efficient pest management relies on early detection and timely action. However, COTS are highly cryptic, often hiding in reef crevices during daylight hours making detection difficult. They are also patchily distributed, making it challenging to monitor changes in their abundance across the entire scale of the Great Barrier Reef. Current methods to monitor their distribution and detect developing outbreaks suffer from low accuracy, especially when COTS numbers are still low. Crucially, this is when COTS are most amenable to efficient management action. CCIP has expanded the detection and monitoring toolbox to give control crews an edge in their pursuit of the pest.

Feeding scars are a key indicator used in detection and monitoring. Image: Shutterstock

Project D-03
Operationalising eDNA monitoring

Provided a new tool for early warning of emerging outbreaks, by developing an eDNA monitoring method that detects low densities of COTS on a reef and trialling it with control crews, Marine Parks rangers and tourism operators.[12]

Project P-04
Pre-outbreak monitoring

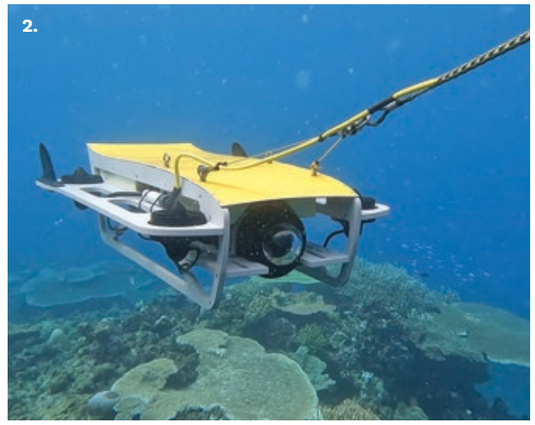
Detected subtle increases in pest numbers that signal initiation of a new outbreak wave, by deploying a novel scooter-based survey method to monitor COTS populations across the northern and far northern regions of the GBR.[13]

Project D-04
The COTS surveillance system

Developed an image-based surveillance system that provides real-time data on the locations of COTS and their feeding scars to guide deployment of control crews, using cutting-edge robotics and machine learning technologies.

Project D-01 & D-02
COTS monitoring design and tool calibration

Supported decision-making and evaluation of pest management progress, by designing a monitoring plan and calibration model that integrates the data collected across the expanded COTS detection and monitoring toolbox.



1. CCIP researcher collecting demographic data on COTS populations. Image: Dr. Ceimon Caballes, JCU
2. COTS surveillance technology uses Machine Learning to detect COTS in real-time. Image: Mary Bonin, GBRF
3. Queensland Parks and Wildlife (QPWS) staff conducting COTS eDNA sampling onboard Reef Resilience. Image: Sascha Taylor, QPWS

IMPACT HIGHLIGHTS

DEVELOPING PLANS AND TARGETS

Many decisions need to be made when implementing a pest management program. What cull targets should we aim for when implementing control and should these vary in different locations and conditions? Which reefs should we prioritise for action? How should limited resources be deployed across the vast scale of the Great Barrier Reef to maximise ecological and economic benefits? CCIP has delivered a suite of sophisticated modelling and decision support tools that answer these questions and guide control planning and operations.

Divers inspect the reef for signs of coral-eating starfish. Image: Sutterstock.

Project R-03
Reef-scale ecological modelling

Confirmed effective action thresholds for culling when resources are limited and coral growth is impacted by marine heat waves, by modelling existing culling targets and their ability to limit coral loss under multiple scenarios.[14]

Project R-04
Regional ecological modelling

Predicted that a GBR-wide strategy will deliver the greatest gains in hectares of coral area saved, by using two ecosystem models to assess 15 different strategies for deploying COTS Control Program effort across the GBR.

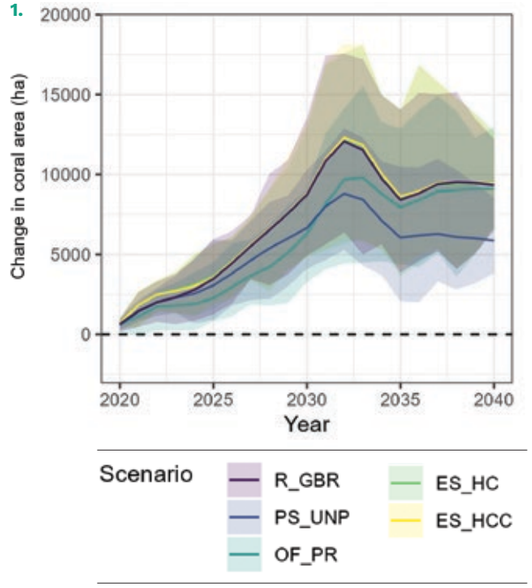
Project R-05
COTS dispersal modelling

Provided more accurate and robust information to identify reefs for control that are most likely to spread outbreaks, by developing an ensemble of three biophysical models that predict the dispersal of COTS larvae across the GBR.[15]

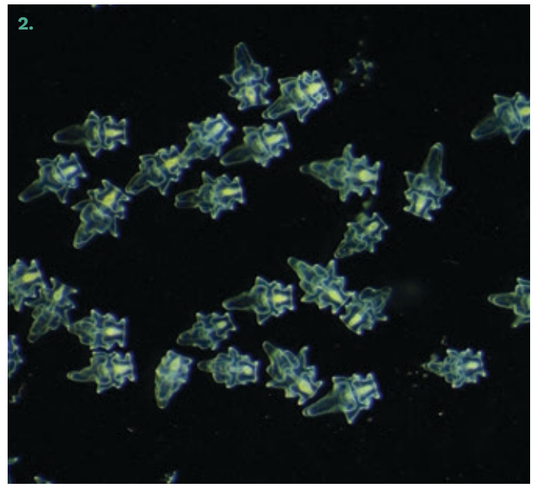
Project R-07
Reef prioritisation framework

Ensured that the prioritisation of reefs for COTS control is repeatable and transparent, by developing and applying a Multi-Criteria Decision Analysis framework that incorporates multiple data sets, values and perspectives in decision-making.

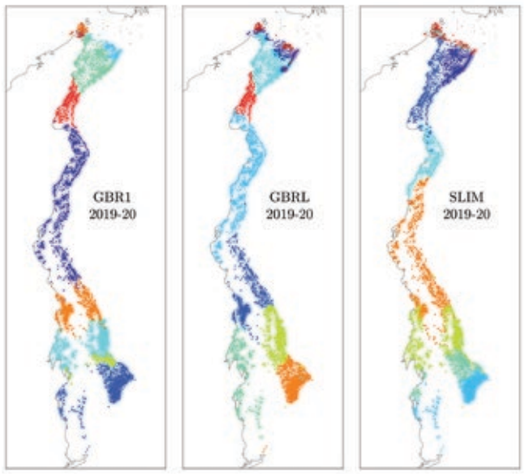
1.



2.



3.



1. Models estimate how much coral can be saved using different control strategies. Image: R-04 Report, UQ
2. COTS larvae disperse on ocean currents to spread outbreaks. Image: AIMS, Frances Patel
3. Models predict COTS larval dispersal across regions of the GBR. Image: R-05 Report, JCU

IMPACT HIGHLIGHTS

IMPLEMENTING PEST CONTROLS

Integrated Pest Management programs typically use a combination of manual, biological and chemical control methods. The COTS Control Program uses one method, manual culling, with no other methods currently available. Although this method is effective when applied in a targeted way,6 it has technical limitations and the social acceptability of control methods, current and future, has never been formally evaluated. Expanding the control toolbox could deliver a step-change in the scale, efficacy and efficiency of COTS management. Any method used to control COTS must be safe and supported by the communities that care for the Great Barrier Reef. CCIP has delivered pioneering research that paves the way for new control methods and sheds light on social and cultural perspectives regarding these methods.

COTS Control Program diver culling coral-eating starfish. Image: Rick Abom, RRRC

Project R-10
Fish predator conservation for biocontrol

Predicted that predator biocontrol can deliver reef resilience benefits over the next 10-25 years, by modelling the efficacy of scenarios to protect and enhance the abundance of COTS predators as a novel form of biocontrol.

Project R-11
Semiochemical biocontrol

Identified several promising attractants that could be used to control COTS, by developing a novel pipeline for the discovery, characterisation and production of semiochemicals and confirming in laboratory experiments that they illicit behavioural responses from wild COTS.[16]

Project R-08
Stakeholder perceptions

Revealed widespread but tentative public support for COTS control that informed development of a new social license framework, by conducting 47 interviews and surveying >1,000 people to understand their views on existing and novel COTS control methods.[17]

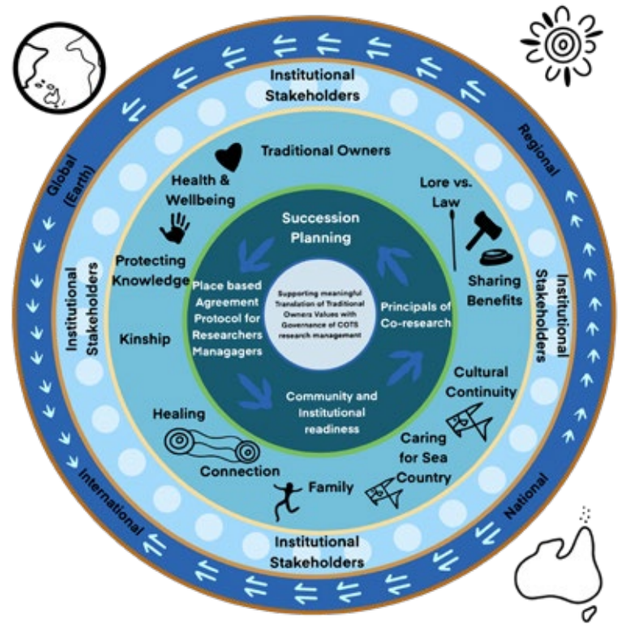
Project R-09
Traditional Owner co-design and values

Guided COTS research and management to align with the priorities and needs of Reef Traditional Owners, by engaging with over 20 Traditional Owner groups and developing a co-design approach that delivered two place-based engagement protocols.

1. Researchers tested the response of COTS to semiochemical attractants. Image: AIMS, Jo Hurford
2. Model describing Reef Traditional Owner priorities and interests. Image: Ty'a Dynevor and Michell Blake

1.

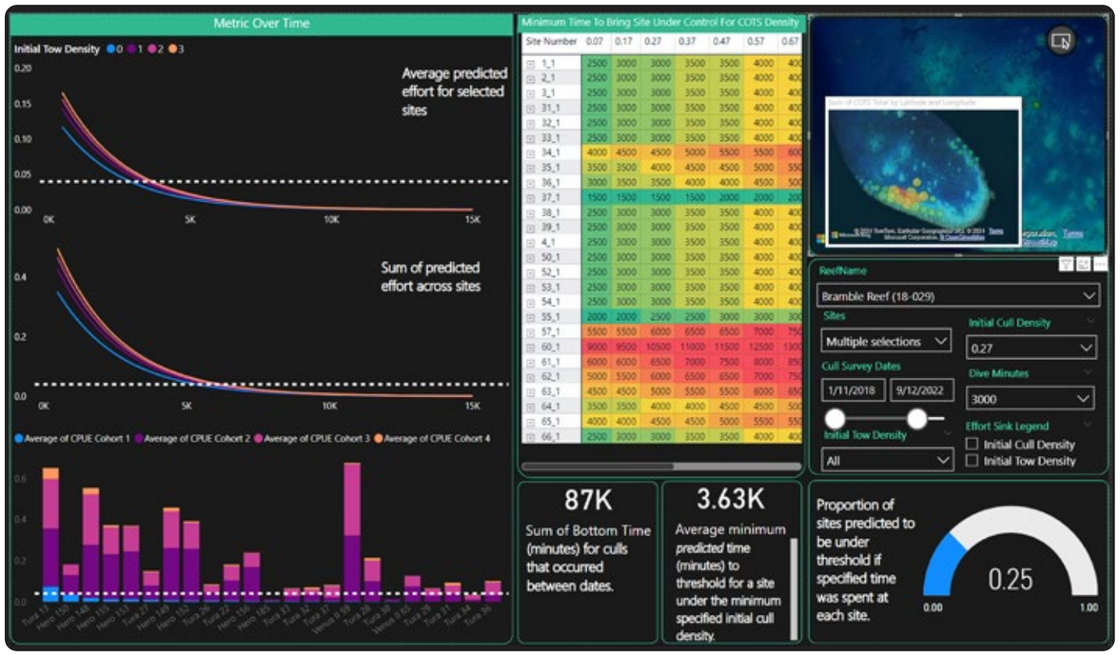
2.



IMPACT HIGHLIGHTS

EVALUATION AND IMPROVEMENT

Integrated Pest Management is a dynamic and ongoing process that relies on data to assess progress and adapt based on the latest information. The COTS Control Program was designed for adaptive management, collecting significant data on COTS numbers and coral health across hundreds of reefs on the GBR that can be used to assess performance. Visualisation and analysis of these data support planning and operations, and hold the key to improvements in effectiveness, efficiency and cost. CCIP has delivered a suite of new tools and analyses that connect research and management, supporting COTS Control Program decision-making, evaluation, and improvement.



Dashboard tool developed to guide decision making around effort sinks. Image: R-02 Report

Project R-01
Data and Information system

Facilitated efficient and secure sharing and analysis of data across COTS managers and researchers, by designing and implementing a COTS Information System that brings together data from the Control Program and CCIP.

Project R-02
Empirical decision support

Revealed opportunities for increasing operational efficiency by adjusting the frequency of surveillance and establishing effort thresholds, through the development of digital workflows and analyses of Control Program data.

Project R-02
Tools for research translation

Enabled more adaptive, real-time decision making by reef managers and COTS Control crews, by designing six Microsoft PowerBI dashboards that translate key research insights and an on-water app that processes and interprets data in real-time during control voyages.

Project R-06
Cost effectiveness of COTS control

Revealed that targeted control generates a net benefit to the Australian people and a GBR-wide deployment strategy is among the most cost-effective to maximise the coral area saved, by modelling the economic costs and benefits of 15 different strategies for deploying COTS Control Program effort.

COTS Control Program diver culling coral-eating starfish. Image: Rick Abom, RRRC

RESEARCH TRANSLATION

Working in partnership with end-users to put science into practice

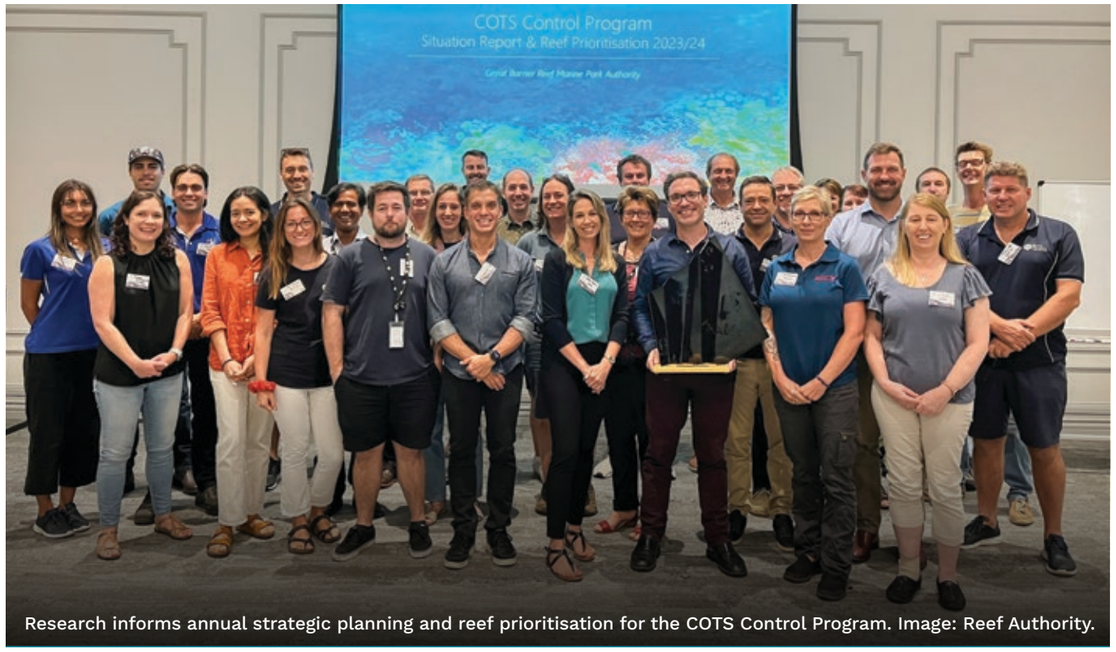
The job is not done when research is completed. To achieve real-world impact, research outputs need to be accessible and used by the people that need them. Investment in this *research translation* step is a crucial, and sometimes overlooked, part of the impact equation.

Throughout development and delivery CCIP researchers have worked in close partnership with control crews, reef managers and other stakeholders to ensure research is fit-for-purpose. After three years of dedicated research effort, CCIP has delivered over 120 outputs including new knowledge, plans, decision support tools, modelling predictions, methods and technologies[7].

These outputs can be applied across many different aspects of the COTS Control Program's activities, including:

- Innovating tools and methods used for on-water operations and data collection
- Guiding tactical deployment of surveillance and culling teams on a reef
- Informing annual strategic planning including which reefs to target in a region
- Updating frameworks that guide overarching management goals and policies
- Supporting governance, engagement and communications with stakeholders

In 2024-2025, CCIP continues to support impact by investing in eight new projects that work in partnership with end-users to apply high priority research outputs in COTS management.



Research informs annual strategic planning and reef prioritisation for the COTS Control Program. Image: Reef Authority.

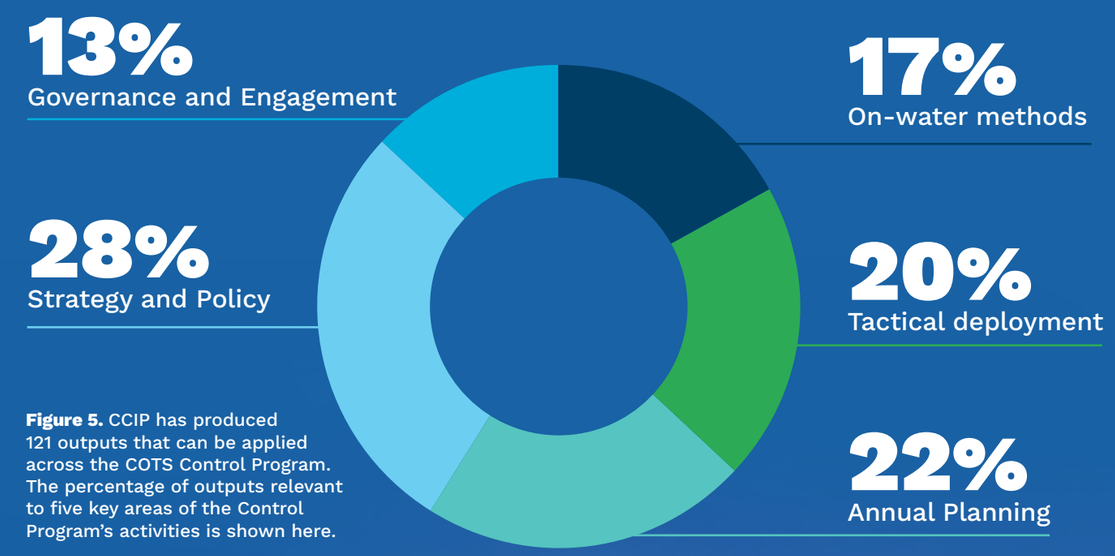


Figure 5. CCIP has produced 121 outputs that can be applied across the COTS Control Program. The percentage of outputs relevant to five key areas of the Control Program's activities is shown here.

> ***"The very close relationship with the managers and the operators, that's been quite distinctive. So, the researchers can see how their research is going to be taken up and used. And the operators and the managers can give really quite direct feedback to the research to help them focus their research on the most important things ... they're probably the main ingredients of success."***[7]

CCIP researcher collecting demographic data on COTS populations. Image: Dr. Ceimon Caballes, JCU

Case Study

Our research is already making a difference

Researchers and managers trialled new COTS detection tools together

Collaborative learning is a hallmark of CCIP's approach and a major field effort in March 2023 was exemplary of how the program created opportunities for researchers and end-users to collaborate and put science into practice.

This field effort brought together 24 researchers, reef managers and COTS control crew members from 7 organisations to test new COTS detection and monitoring tools (i.e. eDNA, scooters, robotics and machine learning) and calibrate them with existing methods (i.e. manta tow surveys).

The team coordinated their efforts across two large vessels, collecting calibration data at 16 sites across 7 reefs. Following the fieldtrip, the data was analysed and used to design a new multi-tool monitoring program that is now being operationalised on the Great Barrier Reef.

Researchers, control crews and reef managers testing new COTS detection tools. Image: Scott Foster, CSIRO

Case Study

Our research is already making a difference

Using new tools, an emerging outbreak was detected and early response initiated

There have been four recorded waves of COTS outbreaks on the Great Barrier Reef since the 1960's. These outbreak waves generally start in the north and spread south over a period of 15 years, leaving infested reefs heavily damaged in their wake.

Early detection and suppression of these outbreak waves is the ultimate goal for COTS management, but it has never been possible until now. During CCIP, researchers used new detection tools, including scooter surveys and eDNA, to detect subtle increases in pest numbers that signalled initiation of a new outbreak wave.[12,13]

In response, the COTS Control Program boosted its coral defending fleet with two additional vessels that began controlling the earliest stages of an outbreak wave for the very first time. Only time will tell, but this proactive action has the potential to deliver benefits at scale by mitigating the spread of the outbreak wave across the Great Barrier Reef over the next 15 years.

QPWS staff conducting COTS eDNA sampling onboard Reef Resilience. Image: Sascha Taylor, QPWS

COTS Control program vessels responding early to the next outbreak wave. Image: Blue Planet Marine

LOOKING TO THE FUTURE

Over the last four years, CCIP has demonstrated the value of a collaborative and mission-oriented approach where multi-disciplinary experts work alongside managers to develop and deliver research with impact.

The outcome is a suite of innovations that are now being applied in Australia's world-leading approach to Integrated Pest Management in a marine ecosystem.

Underpinned by research and innovation, the COTS Control Program has evolved into a proven and effective part of Australia's resilience-based management strategy for the Great Barrier Reef.

Yet as we look ahead to 2050, escalating pressure from climate change highlights the urgency of intensifying our efforts to safeguard the Reef's biodiversity, health and values.

Without ongoing investment in research to inform and adapt the IPM process, the positive outcomes achieved to date will no longer be possible into the future.

New research is needed to deliver further improvements in efficiencies for COTS detection and response at scale, integrate COTS control with other emerging interventions, and guide decisions and actions that strengthens the Reef's resilience and adaptation to a rapidly changing climate.

CCIP has built a strong and growing community of practice that can rise to this challenge, maximising Australia's return on investment in COTS control in the decades to come.

Image: The Ocean Agency, Ocean Image Bank

As we look ahead to 2050, escalating pressure from climate change highlights the urgency of intensifying our efforts to safeguard the Reef's biodiversity, health and values.

Healthy coral reefs are among the most valuable ecosystems on Earth. Image: Matt Curnock, Ocean Image Bank

CITATIONS & SELECTED CCIP PUBLICATIONS

1. United Nations News. World could lose coral reefs by end of century, UN environment report warns. 2020. Accessed 7 Jan 2025. https://news.un.org/en/story/2020/12/1080582

2. Commonwealth of Australia. Reef 2050 Long-Term Sustainability Plan 2021–2025. 2023. https://www.dcceew.gov.au/parks-heritage/great-barrier-reef/publications/reef-2050-long-term-sustainability-plan-2021-25

3. Great Barrier Reef Marine Park Authority. Crown-of-thorns starfish Strategic Management Framework. 2020. Townsville. https://elibrary.gbrmpa.gov.au/jspui/retrieve/ee11c8e5-875c-4da2-8ab0-0033ed31cced/GBRMPA-CoTS-strategic-management-framework.pdf

4. Erdmann S, Johnson J, Abom R, Waterhouse J, Haynes D. Innovations in Crown-of-Thorns Starfish control on the Great Barrier Reef: A Synthesis of NESP Tropical Water Quality Hub research. 2021. Report to the National Environmental Science Program. Reef and Rainforest Research Centre Limited, Cairns (61pp.). https://nesptropical.edu.au/wp-content/uploads/2022/08/v20220805-Project-6.1-Synthesis-Report.pdf

5. Fletcher CS, Bonin MC, Westcott DA. An ecologically-based operational strategy for COTS Control: Integrated decision making from the site to the regional scale. 2020. Reef and Rainforest Research Centre Limited, Cairns (65pp.). https://nesptropical.edu.au/wp-content/uploads/2020/04/NESP-TWQ-Project-3.1.1-Technical-Report-2.pdf

6. Matthews SA, Williamson DH, Beeden R, et al. Protecting Great Barrier Reef resilience through effective management of crown-of-thorns starfish outbreaks. 2024. *PLoS One* 19(4). doi.org/10.1371/journal.pone.0298073

7. Clear Horizon. Reef Trust Partnership End-of-Portfolio Evaluation: COTS Control Results Table. 2024.

8. Fletcher CS, Bonin MC, Caballes CF, et al. Design of the COTS Control Innovation Program: a technical report and recommendations. 2021. A report to the Australian Government by the COTS Control Innovation Program (149 pp.). https://barrierreef.org/uploads/CCIP-Design-Phase-Technical-Report.pdf

9. Pratchett MS, Caballes CF, Cvitanovic C, et al. Knowledge gaps in the biology, ecology and management of pacific crown-of-thorns starfish, Acanthaster sp., on Australia's Great Barrier Reef. 2021. *Biological Bulletin.* 241(3):330-346. doi.org/10.1086/717026

10. Webb M, Clements M, Selvakumaraswamu P, McLaren E, Byrne M. Chemosensory behaviour of juvenile crown-of-thorns sea star (Acanthaster sp.), attraction to algal and coral food and avoidance of adult conspecifics. 2024. *Proceedings of the Royal Society B.* 291:20240623. doi.org/10.1098/rspb.2024.0623

11. Wolfe K, Desbiens AA, Patel F, et al. eDNA confirms lower trophic interactions help to modulate population outbreaks of the notorious crown-of-thorns sea star. 2025. Proceedings of the National Academy of Sciences U.S.A. 122: e2424560122. doi.org/10.1073/pnas.2424560122

12. Uthicke S, Doyle JR, Gomez Cabrera M, et al. eDNA monitoring detects new outbreak wave of corallivorous seastar (Acanthaster cf. solaris) at Lizard Island, Great Barrier Reef. 2024. *Coral Reefs.* 43:857-866 doi.org/10.1007/s00338-024-02506-8

13. Chandler JF, Burn D, Caballes CF, et al. Increasing densities of Pacific crown-of-thorns starfish (Acanthaster cf. solaris) at Lizard Island, northern Great Barrier Reef, resolved using a novel survey method. 2023. *Scientific Reports.* 13:19306. doi.org/10.1038/s41598-023-46749-x

14. Rogers JGD, Plagányi ÉE, Blamey LK, Desbiens AA. Validating effectiveness of crown-of-thorns starfish control thresholds to limit coral loss throughout the Great Barrier Reef. 2024. *Coral Reefs.* doi.org/10.1007/s00338-024-02560-2

15. Choukroun S, Stewart OB, Mason LB, Bode M. Larval dispersal predictions are highly sensitive to hydrodynamic modelling choices. 2024. *Coral Reefs.* doi.org/10.1007/s00338-024-02563-z

16. Harris RJ, Hillberg AK, Bastin LD, et al. A family of crown-of-thorns starfish spine-secreted proteins modify adult conspecific behaviour. 2025. iScience. doi.org/10.1016/j.isci.2025.112161

17. Lockie S, Bartelet HA, Ritchie BW, Sie L, Paxton G. Quantifying public support for culling crown-of-thorns starfish (Acanthaster spp.) on the Great Barrier Reef. 2024. *Conservation Science and Practice.* doi.org/10.1111/csp2.13252

The COTS Control Innovation Program is funded by the partnership between the Australian Government's Reef Trust and the Great Barrier Reef Foundation.

CCIP partner institutions include the Great Barrier Reef Foundation (GBRF), Australian Institute of Marine Science (AIMS), CSIRO, James Cook University (JCU), and University of Queensland (UQ. Researchers from the University of Sydney (USYD), Queensland University of Technology (QUT), University of the Sunshine Coast (USC), Southern Cross University (SCU) and the University of Tasmania (UTAS) also contributed to the program.

The CCIP's Steering Committee include members from CCIP partner institutions, an Independent Chair, and representatives from the Great Barrier Reef Marine Park Authority (the Reef Authority), the Reef and Rainforest Research Centre (RRRC), a Reef Traditional Owner, the tourism industry, and the Department of Climate Change, Energy, the Environment and Water (DCCEEW).

The outcomes and impacts delivered through this research program have been made possible through the collaborative efforts of 90 multi-disciplinary experts from 11 organisations.

CCIP extends a special thanks to Emma Lawrence (CSIRO), Cameron Fletcher (CSIRO), Morgan Pratchett (JCU) and David Williamson (Reef Authority) for their leadership roles in delivering this program.

We also thank the individual project leaders and their entire project teams for their outstanding contributions:

Project P-01 team, led by Morgan Pratchett (JCU)
Project P-03 team, led by Maria Byrne (USYD)
Project P-04 team, led by Morgan Pratchett (JCU)
Project P-05 team, led by Kennedy Wolfe (UQ)
Project P-06 team, led by Peter Doll (JCU)
Project D-01 team, led by Emma Lawrence (CSIRO)
Project D-02 team, led by Emma Lawrence and Scott Foster (CSIRO)
Project D-03 team, led by Sven Uthicke (AIMS)
Project D-04 team, led by Scott Bainbridge (AIMS) and Brano Kusy (CSIRO)
Project R-01 team, led by Cameron Fletcher (CSIRO)
Project R-02 team, led by Cameron Fletcher (CSIRO)
Project R-03 team, led by Éva Plagányi (CSIRO) and Jacob Rogers (CSIRO)
Project R-04 team, led by Scott Condie (CSIRO), Peter Mumby (UQ) and Christina Skinner (UQ)
Project R-05 team, led by Severine Choukroun (JCU) and Michael Bode (QUT)
Project R-06 team, led by Gabriela Scheufele (CSIRO)
Project R-07 team, led by Michael Bode (QUT) and Cameron Fletcher (CSIRO)
Project R-08 team, led by Stewart Lockie (JCU)
Project R-09 team, led by Vincent Backhaus (JCU)
Project R-10 team, led by Daniella Ceccarelli (AIMS) and Leanne Currey-Randall (AIMS)
Project R-11 team, led by Cherie Motti (AIMS)

Crown-of-Thorns Starfish
Control Innovation Program

SYNTHESIS & IMPACT REPORT

2021–2024