# CNMI CROWN-OF-THORNS OUTBREAK RESPONSE PLAN 2022

Bureau of Environmental & Coastal Quality BECQ CNMI

COASTAL RESOURCES MANAGEMENT

# Executive Summary

This document provides information regarding the biology of Crown-of-thorns starfish (COTS), and the history of outbreaks in the CNMI, In addition, this plan outlines response protocol and strategies for intervention, mitigation, and communication about Crown-of-thorns starfish outbreaks.

This plan was headed by the Bureau of Environmental and Coastal Quality's (BECQ) Division of Coastal Resources Management (DCRM), in collaboration with multiple local and federal agencies, including the CNMI Division of Fish and Wildlife (DFW), Mariana Islands Nature Alliance (MINA), Johnston Applied Marine Sciences (JAMS), AND National Oceanic and Atmospheric Administration (NOAA). This document is intended to be used by coral reef managers and scientists in the CNMI as a strategic framework for responding to COTS outbreaks as they occur.

The first occurrence of COTS outbreak in the CNMI dated back in 1969, however in recent years, an increase in the density has been observed throughout CNMI's reefs prove worrisome. As climate change and its associated stressors continue to affect our reefs with increasing intensity, COTS outbreaks can significantly hinder the recovery of coral populations between disturbance events and have the potential to cause long-lasting damage to reef habitats. It is in the best interest of all stakeholders that local managers are prepared for and equipped with the tools needed to responds to Crown-of-thorns outbreaks. In this document, there are 4 primary components outlined and describe in detail:

1. Intervention strategies
2. Outbreak response protocol
3. Data Management and Reporting
4. Mitigation
5. Communications Strategy

Effective management of COTS requires planning and preparation before such events occur. The CNMI Crown of Thorns Outbreak Response Plan provides a strategic approach for response that is agency-driven, action-oriented and will help minimize threats to CNMI reefs by improving coordination and capacity for active response by CNMI agencies and other partners. This plan provides an up-to-date standard operating procedure to be followed, before, during and after COTS Outbreaks, along with descriptions of the roles and responsibilities of relevant stakeholders.

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**Cover Page:** Photo of *Acanthaster planci* feeding on *Montipora* sp. at Lao Lao Bay, CNMI in 2020 [Photo Credit: Denise Perez].

# Acknowledgements

To be written…..

# Acronyms

| | |
|---|---|
| BECQ | Bureau of Environmental and Coastal Quality |
| CNMI | Commonwealth of the Northern Mariana Islands |
| COTS | Crown-of-thorns sea star |
| DCRM | Division of Coastal Resources Management |
| DFW | Division of Fish and Wildlife |
| EOR | Eyes of the Reef |
| JAMS | Johnston Applied Marine Sciences |
| LTMMP | Long-term marine monitoring program |
| MINA | Mariana Islands Nature Alliance |
| MMT | Marine Monitoring Team |
| NOAA | National Oceanographic Atmospheric Administration |
| OPD | Office of Personal Development |
| POC | Point of contact |

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# Background

## Crown-of-Thorns Biology

Crown-of-thorns starfish are made up of several species occurring in the Pacific and Indian Ocean. In the western Pacific, *Acanthaster planci*, is the sole species present on coral reefs [1]. COTS typically prey on live coral of various genera where one adult COT is estimated to consume 5-13 $m^2$ per year of live coral [2,3]. In comparison to the corallivorous sea star, *Culcita novaeguineae*, which consumes 1 $m^2$ per year of coral tissue [3]. *A. planci* consume a wide range of coral species, preferring a diet of *Acropora* and *Pocillopora* spp. [4]; once depleted COTS will feed on other genera, such as *Monitpora* and *Astreopora* spp. If coral are scarce, juveniles can pause their growth for up to 6 years, and adult COTS can switch to feeding on filamentous and foliose algae [3].

COTS have multiple natural defenses to avoid predation. The eggs and larvae contain sapponins, toxic chemicals that are bitter tasting, which deter feeding by planktivorous fish [5]. As adults, sea stars can curl up into a ball, protecting their soft tissue undersides, and leaving only the toxic spines exposed. The adults have relatively few natural predators, except for the giant trumpet snail (*Charonia tritonis*).

### Life Cycle

*Acanthaster* spp. are broadcast spawners, and synchronize spawning events to increase reproductive success. A single female can produce 0.5 - 65 million eggs per year depending on the body size [1,6]. Within the first 24 hours of fertilization, the embryos hatch into the filter-feeding larval stage which lasts a total of eleven days (Figure 1). The first larval stage, bippinaria, occurs in the first three days and begin feeding on phytoplankton. The second stage, brachiolaria, develop arms, are active swimmers in the last 8 days, and start to test substrates for settlement. COTS larvae experience high mortality during this stage from planktivorous fish, such as damselfish [7]. Similar to other echinoderms, the larvae stage are able to clone themselves to increase the COTS population [3].

**ONE ADULT FEMALE CAN PRODUCE 0.5 - 65 MILLION EGGS PER YEAR**

Once the larvae settle and metamorphose into a juvenile starfish with five arms, the diet switches to consumption of crustose coralline algae (CCA) for the first 6 months. Once juveniles are > 8 mm in size, they switch to a corallivorous diet [3]. Settlement stage of *Acanthaster* spp., ranging from 2 – 65 mm, were observed to occur most frequently in forereef areas between 8 – 14 m depth [8], and were more likely to be found in coral rubble habitats between spur and groove reef slips in the Great Barrier Reef [8]. During the juvenile to sub-adult stage (6 month - 2 years), the arms and spines begin to elongate and the diet switches to coral. As the starfish grows bigger, feeding rates increase into the adult stage (2 - 5 years), when spawning aggregations are most active. Feedings rates are reduced and reproduction ceases in the senile stage (> 5 years) [1].

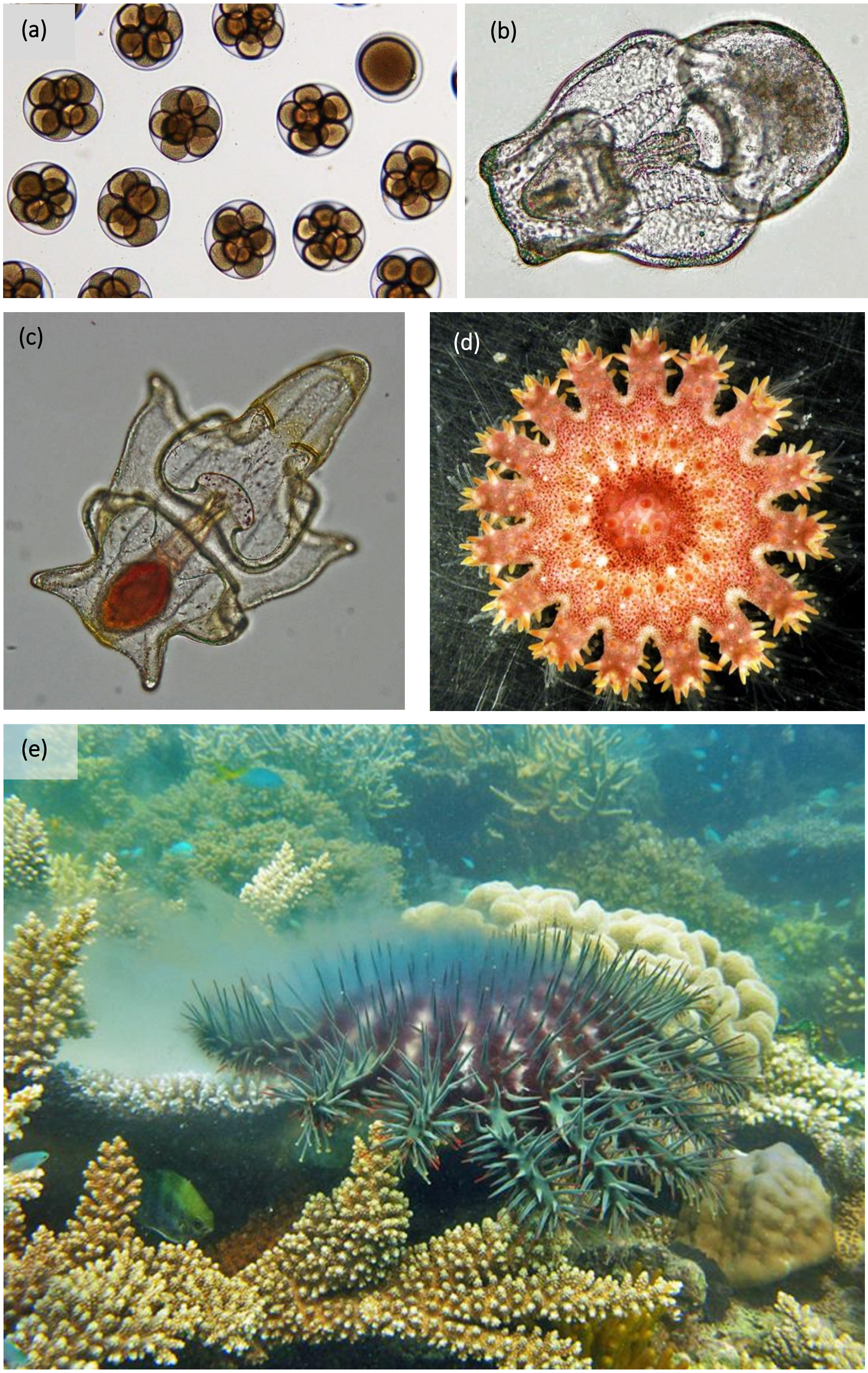


**Figure 1. Life cycle of *Acanthaster cf. solaris,* a sub-species of *A. planci* native to Great Barrier Reef, Australia: (a) fertilized eggs within the first 10 hours, (b) the first larval stage, bippinaria, range between 0.5 - 0.8 mm and begin filter feeding, (c) second larval stage, brachiolaria, range between 0.8-1.5 mm in size [Photo credit: Zara-Louise Cowan, (d) juvenile COTS from Lizard Island, size 32 mm [Photo credit: Jean-Paul Hobbs], (e) adult male spawning at Lizard Island, Australia [Photo Credit: Anne Hoggett & Lyle Vail] (source: https://lirrf.org/posts/cots-life-stages/).**

## Outbreaks

Two theories have hypothesized the cause of crown-of-thorns outbreaks, which may be due to increase in larval recruitment following nutrient enrichment and trophic cascades from overfishing. A study conducted on the Great Barrier Reef Marine Park observed that COTS outbreaks were more likely to occur in fishing areas within the park versus no-take zones [9]. In addition, occurrence of outbreaks was less frequent in mid-shelf and offshore reefs that are less accessible to non-commercial fisherman [9].

One hypothesis states that increased fishing pressure on predatory fish causes a trophic cascade, which disrupts the natural population controls on crown-of-thorns. A decline in predatory fish would lead to an increase in piscivores that feed on a variety of invertebrates that would prey on COTS juveniles. Therefore, there is a possibility that heavy fishing pressure can lead to trophic cascades, which decreases the natural predators of juvenile COTS.

There is also evidence relating nutrient enrichment from terrestrial runoff or upwelling events to COTS outbreaks [10,11]. The increase in nutrients supports phytoplankton populations that serve as the primary diet for COTS larvae. Chlorophyll a concentrations, a proxy measurement of phytoplankton density within oceanic waters, that occur between 0.6-1 $\mu g\ L^{-1}$ serve as ideal conditions for COTS larvae [10]. In addition, COTS larvae have the ability to clone themselves which happens more frequently in areas with higher nutrient concentrations [3]. The migration of *Acansthaster* spp. into shallow waters may occur during spawning windows when larval survival is increased [11]. Such a strategy would increase reproductive success for spawning aggregations. Higher densities of COTS, > 3 $ha^{-1}$, increases the fertilization rate during spawning events [1,12], leading to a build-up of the population over time and secondary outbreaks.

In the CNMI, causes of outbreaks has yet to be determined and could be a result of a combination of factors. *Acanthaster planci*, have evolved strategies for survival, with lower predation and cloning ability during the larval stage. When corals are scarce, the ability to pause growth during the juvenile stage and switch diets would also allow for the population to build up over time. Since 2017, CNMI’s reefs have been in a recovery stage from mass coral bleaching events. The COTS outbreaks in the CNMI coincided during this recovery period, and could be due to nutrient enrichment, fishing pressure, or availability of coral to signal COTS juveniles to grow into the adult stage. Future studies could assess the juvenile COTS population versus fish population at sites around the islands. Or monitor phytoplankton and Chlorophyll a concentration with remote sensing, and use of local water quality data to predict timing of COTS outbreaks. In Australia, the availability of such information has allowed researchers to identify the cyclical nature of outbreaks in the Great Barrier Reef, and are now able to predict when and where outbreaks occur in the region [13].

## Outbreaks in the CNMI

Earliest reports of outbreaks occurred in the 1960s, when *Acanthaster planci* was discovered to be decimating reefs in the Great Barrier Reef, Australia. A team of scientists were tasked to assess *A. planci* populations across Pacific islands over concern other regions were also experiencing outbreaks. In 1969, outbreaks were recorded in Rota, Tinian, and Saipan, along with severe coral mortality. A normal population was defined as 20 COTS per twenty minute search or 30 COTS per hectare [14]. It may be possible that at the time, the CNMI had higher percent coral cover to sustain such high-density COTS populations, or there wasn't enough baseline information prior to studying outbreaks. In response to the outbreaks, a bounty was set to collect the adult sea star for 15 cents each. Funds were exhausted in one week with the community collecting over 4000 COTS in Saipan. In the early 2000s, a COTS outbreak occurred in the Marianas that necessitated removal by community efforts. Data collected by the NOAA team also documented outbreaks in Rota, Asuncion, and Pagan in 2007. The NOAA team defined an outbreak as > 40 COTS per 20 minute swim [15].

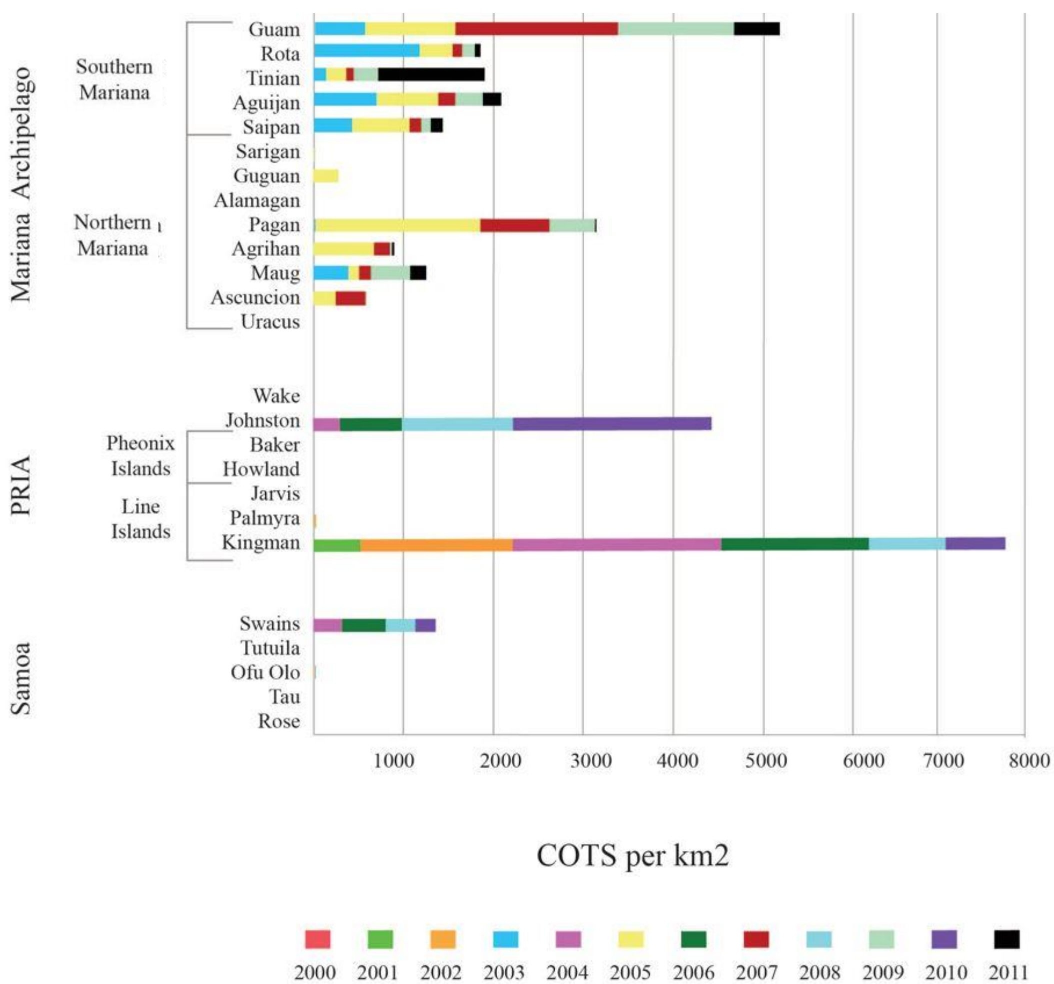


**Figure 2. Densities of COTS per km² from towed-diver surveys conducted in the U.S. Pacific islands from 2000-2012, by NOAA Pacific Islands Research Center.**

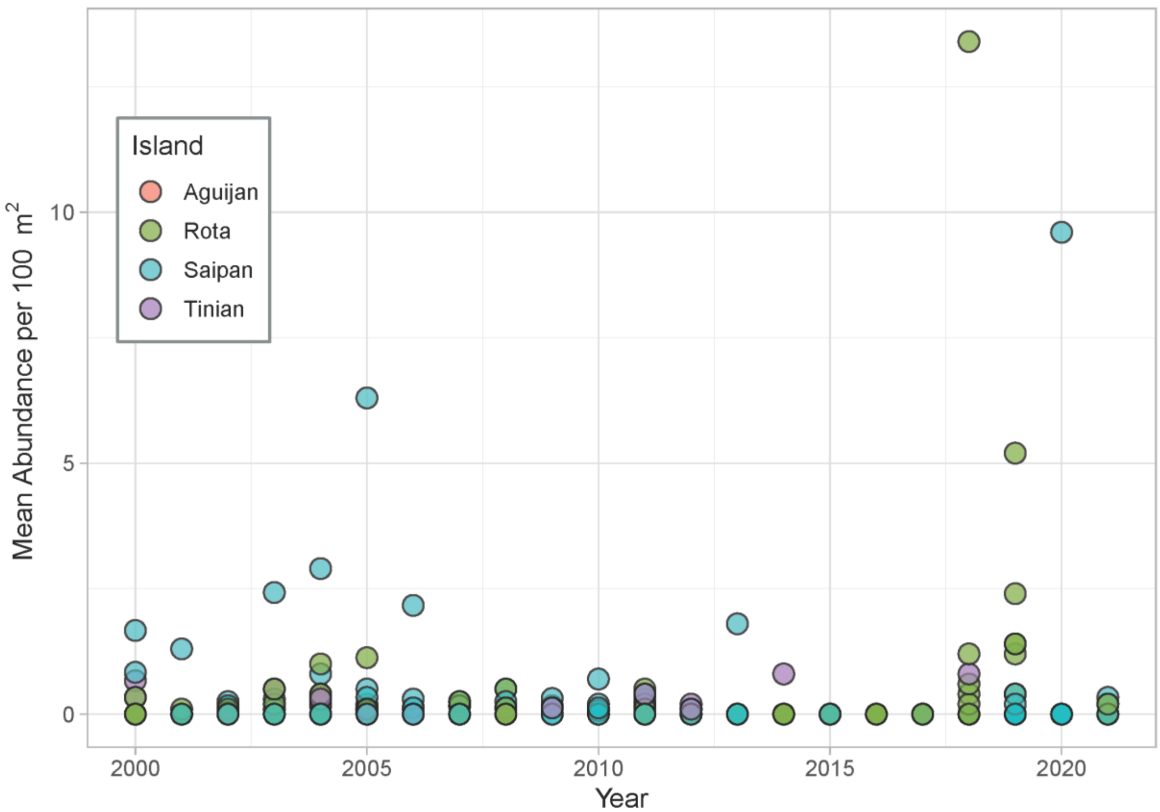


**Figure 3. Mean abundance of *Acanthaster planci* per 100 m² for long-term marine monitoring sites around Rota, Tinian, Aguijan, and Saipan.** [16].

Most recently, the latest NOAA cruise identified outbreaks around Pagan in May 2022 (T. Oliver, personal communication, 2022).

In the past four years, an increase in density has been observed throughout CNMI's reef sites. In 2018, MMT counted 67 COTS in a 500 $m^2$ area off the north coast of Rota. Additionally, MMT has documented in a single dive, aggregations of > 120 individuals in 2019, and > 150 individuals at Bird Island sanctuary in 2020, which surpass outbreak thresholds. The definition of an outbreak depends on the survey method, region, and the percent coral cover for the area. In the past outbreak thresholds have been defined as: > 40 COTS observed on a 20-minute swim [15], 10 COTS $ha^{-1}$ for reefs with 20-50% coral cover [17], 5- 10 COTS $ha^{-1}$ depending on coral cover [18], or 30 COTS $ha^{-1}$ in Guam [19].

In Saipan, there have been multiple reports from dive groups of > 10 COTS at several dive sites, including Wing Beach, Ice Cream, Lao Lao, and Grotto in 2020. In 2019 and 2020, Dive Rota recorded aggregations of > 50 COTS at several dive sites off the west and southern coast of Rota, including Coral Gardens and Senhanom Cave. The MMT has documented an increase in aggregations in shallow waters (Figure 3), ~ 8-10 m depth, and prevalence of scarring on coral colonies from COTS predation.

In the past 20 years of monitoring, including during outbreak years, the average density of COTS was 0.27 per 100 $m^2$. Since 2018, the MMT has documented densities 10x higher than the overall average (Figure 4). The MMT has not documented such high numbers since 2003 – 05.

## Future Risks

Although in 2022, there has been a decline in reports of COTS outbreaks for Saipan and Rota, the CNMI must be ready to respond to potential secondary outbreaks in the coming years. The ability for juveniles to feed on algae while waiting for coral to recover, means an outbreak can occur years after a disturbance such as a mass coral bleaching event. In addition, the impacts of climate stressors on the COTS population, such as ocean warming and acidification, is not yet well understood. Larvae and juveniles were observed to have enhanced growth in warmer temperatures, while juveniles had faster growth under lower pH scenarios [20,21]. However, larval development was negatively impacted with combined warmer temperature and acidification impacts [20,21].

In the next 10-15 years, annual bleaching is projected to occur within the CNMI [22]. Crown-of-thorns outbreaks put reefs at risk of losing any gains in coral recovery, and can hamper coral restoration efforts. This will reduce overall resiliency needed to adapt to current and future climate related stressors. Monitoring and early intervention of crown-of-thorns outbreaks is a critical strategy needed for managing the CNMI's coral reef resources.

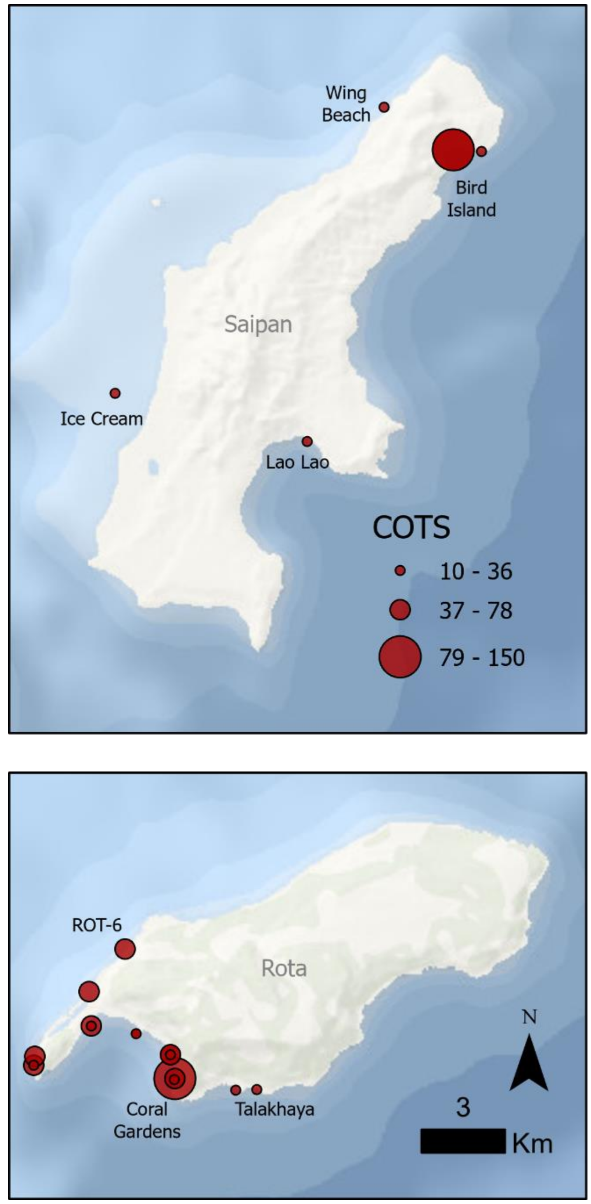


**Figure 4. Map of crown-of-thorns sightings (> 10 COTS per dive) in the CNMI between 2018-2020, including popular dive and long-term marine monitoring sites at Talakhaya on Rota, and for Saipan: Wing Beach, Ice Cream, Bird Island, Grotto, and Lao Lao Bay. Coral Gardens and Bird Island had aggregations (> 100 individuals) in 2020, and at Bird Island in 2019. No official outbreaks have been reported for Tinian, however, this does not confer exclusion of the island from past exposure or risk of future outbreaks. (Data source: LTMMP, CNMI DCRM; M. Michaels, personal communication, 2021).**

# Intervention Strategies

A combination of methods may be used to respond to COTS outbreaks or aggregations depending on the scale of effort required. The most common is removal of the sea stars and disposal on land, which many community efforts undertake with lack of funding. Outbreak programs with more resources utilize an injection method to eradicate COTS, which serves as an efficient culling method. The following section outlines CNMI's permitting requirements, and an overview of removal and injection methods.

## Permitting and Regulation

CNMI regulations protect invertebrates from unregulated harvest, and a scientific research license application from the Division of Fish and Wildlife would be needed to conduct any outbreak response for crown-of-thorns (Division of Fish and Wildlife Scientific

Research License Application).

*CNMI administrative code § 85-30.1-430 Harvest of Other Invertebrates: (a) Harvesting: No other invertebrates may be taken except as permitted by the Director. Any permit issued by the Director is subject to special conditions as determined by the Director* [23].

## Removal

One intervention method is the physical removal of adult COTS by SCUBA or free divers, and disposal or burial on land. In Vanuatu, response efforts have also included bagging up adult COTS within rice sacks that are held underwater. The lack of water movement within the bags causes COTS mortality within 24 hours. The carcasses are then released into the water to decompose, and the process is repeated.

Once outbreak levels reach into the thousands, the logistical difficulty in removal, transport, and disposal of COTS, in addition to the manpower needed to address such events exponentially increases. Physical removal is also difficult to implement due to the many venomous spines on the exterior of the starfish that causes intense pain at the site of injury. The possibility of stopping the outbreak is very low, but physical removal efforts can help impede the spread and magnitude of the outbreak.

## Injection

An efficient method for outbreak response involves injection of bile salts or acetic acid (household vinegar) into COTS, which causes 100% mortality within 24 – 48 hours [24,25]. Carcasses quickly decompose or are consumed by scavengers over several days leaving no negative impacts to the adjacent area [24,25]. A variety of fish have been observed feeding on dead COTS after injection such as butterflyfish, damselfish, triggerfish, and pufferfish [25]. The method has been successfully applied in other Pacific regions including the Great Barrier Reef Marine Park, Guam, and Vanuatu.

**Figure 5. Injection of a crown-of-thorns sea star with acetic acid during an outbreak response at East Bay, Saipan in 2021 [Photo credit: Denise Perez].**

A COTS applicator is used to inject the bile salts or vinegar into an adult *A. planci*. The COTS applicator is composed of an injector with a needle extension and hose adaptor that attaches to a plastic bottle (Prodigy Instruments COTS Applicator). Currently, COTS applicators are manufactured by Prodigy Instruments and the Association of Marine Park Tourism Operators serves as the worldwide distributor. Injections are most effective when administered at sites between the COTS arms, where the solution is distributed immediately through the sea star [25]. If the injection site is on the oral disk, the solution may be expelled via the stomach and mouth [25]. A 16-gauge needle or smaller has been shown to be most effective to prevent the bile salts or vinegar from leaking out of the injection site [24].

If using vinegar, 20 mL is effective in immobilizing COTS in the first 24 hours, and 100% mortality within 48 hours [24]. The reduction of pH from vinegar injections causes acidosis within the sea star and subsequent necrosis of the tissues [24]. On one dive a SCUBA diver may be able to administer between ~100 - 125 injections. The widespread availability of vinegar and low cost, makes this a simple cost-efficient option for outbreak response.

If using bile salts, 10 mL is required for 100% mortality of COTS within 48 hours [25]. Bile is the digestive mixture produced by vertebrates to digest lipids, and commercially available bile salts are collected from bovine or ovine [25]. The bile salts act as a detergent, disrupting cell membranes and causing tissue damage inside the sea star [25]. The bile salts must be mixed prior to use, and expires within several days. Bile Salts No. 3 (Oxoid®), is a more refined, potent mixture typically used in laboratories for mixing culture media, and has been demonstrated to induce 100% mortality within COTS. This is more effective than Oxgall (Difco®), freshly dehydrated ox bile harvested from the gall bladder, which induced 80% mortality within COTS [25]. Although a smaller volume of bile salts is needed for inducing mortality compared with vinegar, the cost, limited shelf life, and special ordering required can prohibit widespread use of bile salts. However, the lower volume needed for injection makes bile salts ideal for severe outbreaks. A field trial at Lizard Island, Great Barrier Reef, had divers injecting up to 5 - 6 COTS per minute with bile salts [25].

# Response Protocol

Effective management of crown-of-thorns outbreaks requires planning and preparation before such events occur. Although, we do not have enough information to predict when population spikes will happen, the long-term marine monitoring data provides baseline information to determine thresholds for when and which interventions are most appropriate to apply. The response protocol outlined in this plan is broken up into 3 phases, consisting of: Phase 1 – Early Detection, Phase II – Intervention, and Phase III – Emergency. Population thresholds are defined for each phase, the type of intervention, and groups involved in implementation (Figure 6). Lead roles are defined for steps that must be implemented within each phase to coordinate response, data management, and outreach to the public (**Error! Reference source not found.**).

## Phase I: Early Detection

Routine monitoring of CNMI's reef is critical for tracking the *A. planci* population and identifying potential outbreaks early. Once the population has increased to outbreak levels, it can be years before the population begins to decline. Early intervention must be implemented to reduce severity and magnitude of future outbreaks [13].

The long-term marine monitoring program at DCRM has been tracking COTS populations across Rota, Tinian, Aguijan, and Saipan for over 20 years. Benthic invertebrate surveys are conducted along the reef slope, which includes 15 fore-reef sites on Saipan, five on Tinian, twelve on Rota, and two on Aguijan. The surveys are conducted on SCUBA, as the diver lays out five transect lines (50 m length) along the reef contour at ~8-10 m depth, and counts crown-of-thorn individuals within one meter on each side of the transect. An example datasheet for benthic invertebrate surveys is included in the Appendix: Datasheets.

| Phase | Threshold | Response | Partners |
|---|---|---|---|
| Early Detection | Ongoing | Active Monitoring | DCRM<br>Citizen-Scientists |
| Intervention | > 3 per dive | Maintain low densities via injection. | DCRM<br>MINA<br>JAMS |
| Emergency | > 100 per dive at multiple sites | Physical Removal & Injection | DCRM<br>Dive groups<br>MINA<br>JAMS |

**Figure 6.** ***Acanthaster planci*** **population thresholds to initiate each phase of outbreak response and intervention to be applied.**

The LTMMP is designed to survey sites every 2 years to be able to cover such a large spatial area across 4 islands. However, the frequency of surveys does not allow the MMT to track movement of COTS aggregations around the islands. Therefore, implementing citizen science programs and involving the community in detecting reef threats is essential for early detection of COTS outbreaks.

The Eyes of the Reef (EOR) program is a citizen science program that trains community members on detecting and reporting reef threats, such as coral bleaching and disease, algal blooms, marine debris, and COTS outbreaks. The program targets SCUBA divers, snorkelers, and fisherman that frequently are in the water and can report any signs of reef disturbance through Reef Report, found on DCRM's website ([www.dcrm.gov.mp](www.dcrm.gov.mp)). Reef Report is an ArcGIS application, where community members can submit photos and information on disturbances such as driving on the beach, illegal trash dumping, etc. The reports are available online to the public through the GIS dashboard, and are reviewed by DCRM to follow up on any enforcement actions needed. Check out an example report of a COTS sighting in the Reef Report Example. At the minimum, reports should include the location (waypoint if available), number of COTS spotted, dive time, and depth.

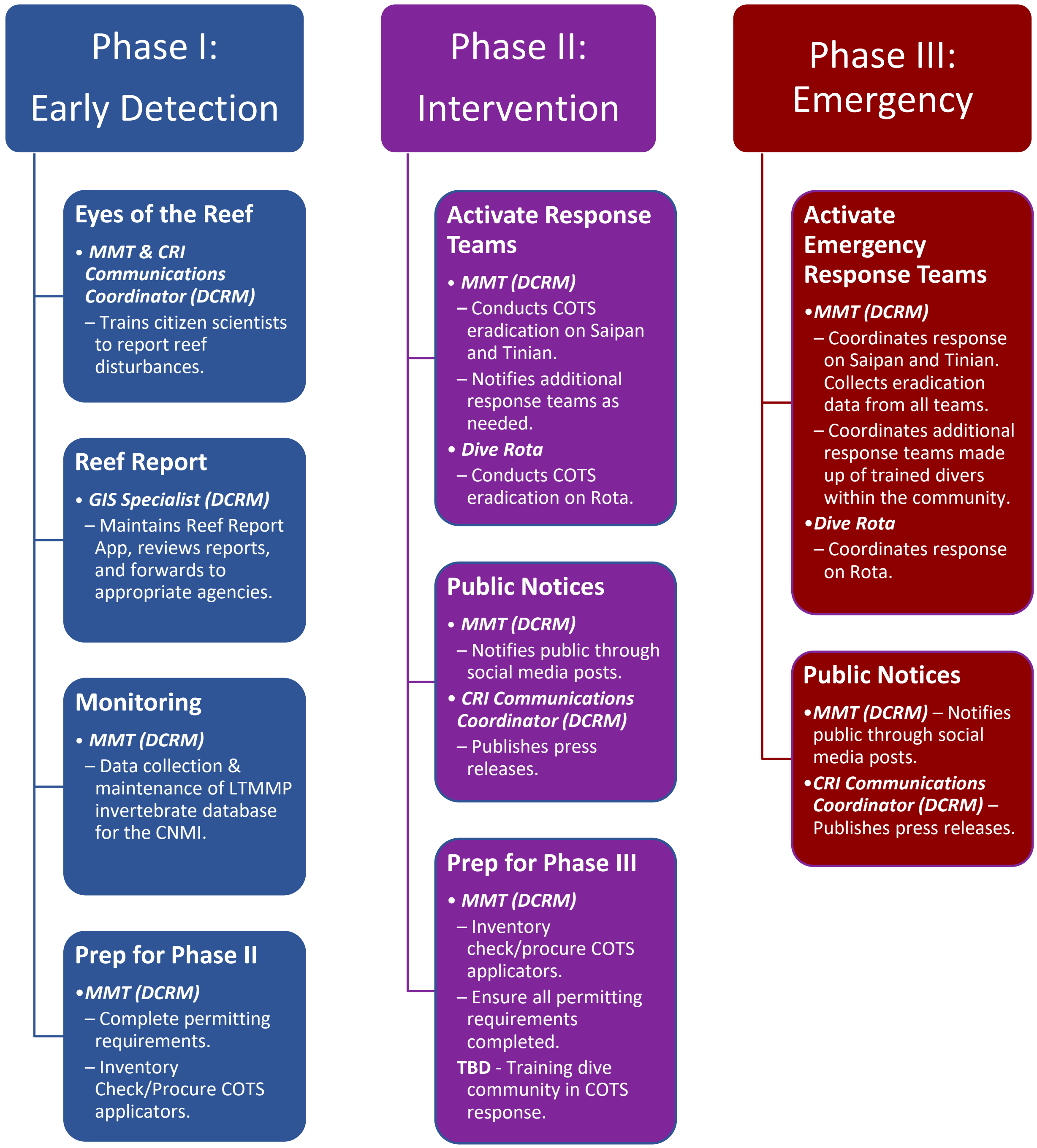


**Figure 7. Flow chart detailing flow of information, points – of – contact for response teams, and steps interventions are activated.**

## Phase II: Intervention

**Phase II is initiated once monitoring teams detect and verify that aggregations of > 3 adult COTS observed on a dive are increasing in frequency along the forereef, and/or occurrence of > 1 adult COT in reef flat or lagoon habitat.** The threshold was determined due to the low occurrence of adult COTS that typically occur on CNMI's reefs. In addition, more than three adult COTS within the same vicinity increases chances for reproductive success, which leads to population spikes [12,13]. Therefore, early intervention during Phase II would be effective in reducing the magnitude or delaying the occurrence of a widespread outbreak.

Community reports will be validated by DCRM's marine monitoring team, who will survey the area for COTS and determine if eradication is necessary via the injection method. If DCRM is unable to respond, diver response teams at Micronesia Islands Nature Alliance or Johnston Applied Marine Sciences will be notified. Point of contacts for response teams and other roles outlined in Phases 1 – 3 are listed in **Error! Reference source not found.**.

## Phase III: Emergency

**Once densities of adults COTS reach > 100 individuals per dive at multiple sites, Phase III Emergency will be initiated.** In Phase III, additional response teams of trained divers will be activated to assist in COTS response using both intervention methods of injection and/or removal. Divers will be recruited from community groups, and will be required to attend the Eyes of the Reef training for identifying reef disturbances/stressors, and additional COTS response training for using injectors, data collection, and reporting. An email chain can be created to notify and coordinate response teams of outbreaks. DCRM's marine monitoring team will continue to serve as the lead for response coordination and data management.

**Table 1. Point of contacts for each organization's role in Phase 1 – 3 of outbreak response.**

| Organization | Role | POC | email |
|---|---|---|---|
| **Division of Coastal Resources Management (DCRM)** | Marine Monitoring Team | John Iguel | mmt@dcrm.gov.mp |
| **DCRM** | CRI Communications Coordinator | Marlyn Naputi | mnaputi@dcrm.gov.mp |
| **DCRM** | GIS Specialist | Dianne Pablo | GIS@dcrm.gov.mp |
| **Division of Fish and Wildlife** | Permitting | | |
| **Johnston Applied Marine Sciences** | Diver Response Team | Lyza Johnston | ljohnston@jamssaipan.com |
| **Dive Rota** | Diver Response Team | Mark Michaels | mark@diverota.com |
| **Micronesia Islands Nature Alliance** | Diver Response Team | David Benavente | dbenavente.mina@gmail.com |

# Data Management and Reporting

Invertebrate population data collected by DCRM's LTMMP is publicly made available after a 2-year embargo. The data is available upon request, or can be downloaded from NOAA National Centers for Environmental Information (NCEI, [26]). Information from community reports and eradication efforts will be collated and archived by DCRM's MMT.

Citizen science data submitted through the Reef Report application are publicly available online through the DCRM webpage. The dashboard provides a breakdown of incidents, location, and each report can be opened by the user for more details. Check out an example report of a COTS sighting in the Reef Report Example. At the minimum, reports should include the location (waypoint if available), number of COTS spotted, dive time, and depth.

## Data Collection

During eradication efforts, monitoring the number of COTs removed/injected is critical information needed to understand outbreak severity and planning future response efforts. In a response team of 2-3 divers, one person should be assigned the task to collect data and help spot the adult sea stars. An example datasheet is available in the Crown **– Of – Thorns Outbreak Survey Example**. The diver can use a marked PVC pipe or clipboard for scale to measure the adult *A. planci* in cm. During severe outbreaks, the size can be binned for efficiency. For each adult sea star, note down the depth in meters, which can also be binned as done in the example datasheet provided.

A diver can be assigned to tow a surface buoy equipped with a GPS to track the area covered by response teams. This information is supplemental, but is especially beneficial to calculate the density of outbreaks (number of COTS per $m^2$). Tracking settings will depend on the make and model of the GPS unit.

If additional time is available, data can be collected to assess coral mortality and prevalence of COTS scars. This type of data is not required for eradication efforts, but will be dependent on the response team's level of expertise.

# Mitigation

In the past 2 or 3 years, the establishment of several coral restoration projects in Saipan opens up the opportunity for mitigation options to offset any coral loss from outbreaks. Heavily hit sites that have been exposed to COTS predation may be prioritized for coral outplanting to facilitate recovery, increase species/genetic diversity, and structural complexity.

However, successful mitigation of any sites exposed to outbreaks will require frequent reporting/monitoring of coral predation and the COTS population to accurately attribute coral mortality to COTS predation. COTS scars on corals are characterized by loss of tissue which appears white with exposure of the coral skeleton. The appearance looks very similar to discoloration from bleaching or various diseases (Figure 8). Confirmation of COTS predation is conducted by close inspection of the coral colony to detect loss of tissue, and the occurrence of COTS within several meters of the affected area.

Ideally, coral outplanting would occur outside of outbreak phases to improve survivability of coral fragments. The length of outbreaks, and the possible occurrence of secondary outbreaks, will not allow for pausing restoration efforts which are critically needed for recovery of CNMI's reefs and as a mitigation strategy for current and future climate change impacts including: ocean warming and acidification, and sea level rise.

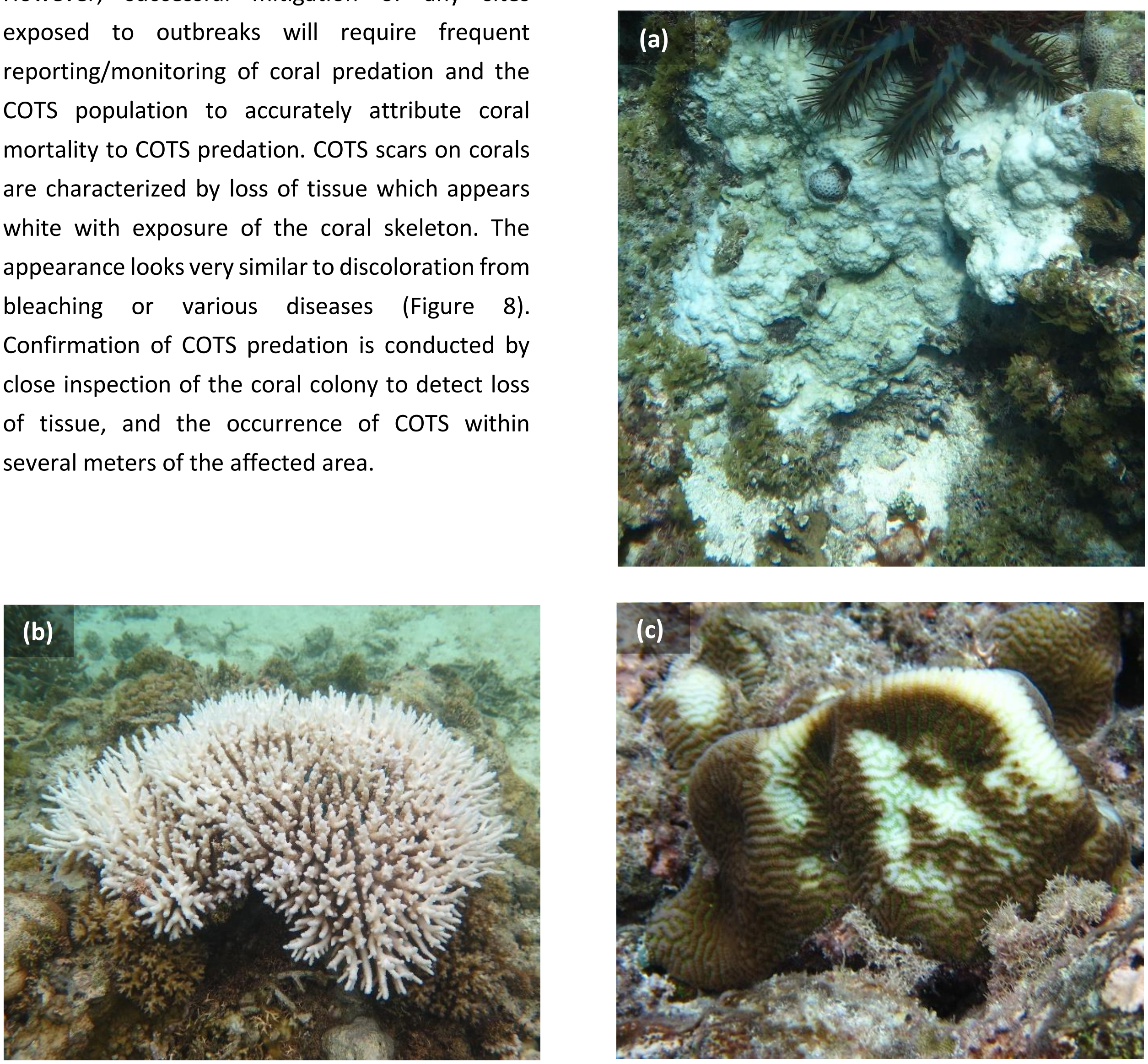


**Figure 8. Example of (a) COTS predation on a coral colony, *Montipora* sp., exhibiting tissue loss that looks similar to (b) coral bleaching, pictured here is an *Acropora* sp., and (c) abnormal tissue discoloration that can occur from disease or physical abrasion, example shown of a *Leptoria phrygia* colony. [Photo credit: Denise Perez].**

Monitoring of coral outplanting efforts is essential not only for documenting survivability and growth of coral fragments, but as a preventative strategy for responding to any COTS outbreaks that may occur in the area. During workshops for developing the CNMI Restoration Action Plan, response to COTS outbreaks was listed as an intervention strategy for outplanting sites located within the *Acanthaster planci* habitat range. Therefore, it is recommended that restoration programs disregard population thresholds established for Phase II and III, and respond to any adult COTS within the vicinity of a restoration area to ensure survivability of coral outplants.

# Communications Strategy

Current outreach efforts for disseminating information about COTS outbreaks consists of posting on social media pages managed by DCRM's long-term marine monitoring program. This includes MMT's Facebook page and the Restoration team's Instagram account. In addition, active communication with local dive operators and recreational SCUBA divers have proved essential in documenting the magnitude and spread of previous outbreaks. For example, the outbreaks on Rota in 2019, were well documented by Dive Rota, and reports from local divers in Saipan assisted in directing areas where response efforts were needed. Continuing these strategies during Phases 1 - 3 is critical for implementation of the outbreak response plan.

Further community engagement can be achieved through expanding outreach content to DCRM's social media pages, which can be actively shared by other organizations or community members. During Phases 1 - 3, additional public releases can be published through local newspapers to expand public awareness of COTS outbreaks, advertise trainings for citizen science programs, such as Eyes of the Reef, and online reporting platforms such as the Reef Report application on DCRM's website. Public releases and Eyes of the Reef trainings will be organized by DCRM's Coral Reef Communications Coordinator and the NOAA Coral Fellow until 2024. Future coordination of citizen science programs will require additional capacity, such as funding a disturbance response coordinator starting in 2024.

# Next Steps

The COTS outbreak response plan is meant to be a living document that should be periodically updated. Below is a suggested timeline for updates:

- **Once per year** - Update point of contacts for response teams, permitting, and outreach as needed.
- **Every 5 years**:
  - Update intervention thresholds based on coral recovery or percent cover.
  - Reconvene stakeholders to evaluate any changes needed to overall response strategy, mitigation, and outreach parts of the plan.

Coordination of outbreak response will rely heavily on DCRM's marine monitoring team. In the future, additional capacity is needed to assist in overall coordination with the addition of a disturbance response coordinator, who would be responsible for responding to COTs outbreaks, coral bleaching and disease, etc. Funding will need to be identified to hire a coordinator by 2024. In the next two years, expansion of the Eyes of the Reef program and training COTS response teams may necessitate updating the response protocol and outreach strategy by the disturbance response coordinator once hired.

In the future, long-term sources of funding should be identified to aid in emergency response. The funding can help support training the local dive community, incentives or reward system for COTS removal and reporting outbreaks. Emergency funds would especially be critical to support response efforts in the Northern Islands, where outbreaks have been reported at Pagan in 2022 (T. Oliver, personal communication, 2022).

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# Appendix

## Prodigy Instruments COTS Applicator

# Division of Fish and Wildlife Scientific Research License Application

**COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS**
**DIVISION OF FISH & WILDLIFE**

**SCIENTIFIC RESEARCH LICENSE APPLICATION**
**Revised May 14, 2013**

Pursuant to 2 CMC §85.30.1-205, all scientific research, attempts to gain or collect data, and/or exploratory studies for academic or commercial purposes in the CNMI are regulated activities. A permit is therefore required to ensure the integrity and conservation of wildlife, fisheries, and habitat; personal and public safety; the legitimacy of project, best practice methodology, qualifications of participants; due diligence, identification of responsible and liable parties; compliance with local and federal laws, regulations, and customs; and that CNMI's scientific, ecological, cultural, and economic interests are considered, represented, and advanced.

**Printed Name and Affiliation of Principal Investigator (PI):**

**Position Title of PI:**

**Contact Address for PI:**

**Printed Names and Affiliations of Co-Investigators:**

**Name of Project:**

**Date Project Will Begin:**

**Date Project Will End:**

**Assurance:** Through the voluntary submission of this application, I hereby certify that I am familiar with applicable state and federal regulations pertaining to my research activities. I further certify that the information submitted in this application is complete and accurate to the best of my knowledge and belief. I understand that failure to follow the regulations or any false statement submitted in this application may subject me to penalties under applicable state and federal Laws. Furthermore, I understand that the License I may receive on the basis of this application will be accompanied by conditions that I agree to follow in full. I understand that failure to do so may also subject me to the penalties and/or revocation and non-renewal of the license.

**Signature of PI:**

**Date:**

**Project Description:** Provide a summary for each project you intend to perform. If habitat will be modified, then specify what type of and how much (in $m^2$) vegetation will be modified. For marine studies and especially corals, be specific about where divers and equipment will come into contact with the bottom substrate. The project description should explicitly address the following concerns:

- What is your research question?
- What are your hypotheses?
- How will you test your hypotheses?
- Is the species you propose working with locally or federally protected, or is it closely associated with protected species, habitats, or resources? If so, then what local and federal permits do you have (or need) that will allow you to work with this species?
- Will your proposed work occur in or affect a protected area or habitat? If so, then how will you ensure that the area or habitat will not be damaged by your activities?
- What training do you have to work with the species or in the conditions that you propose?
- How might your proposed actions affect the species of concern?
- How might your proposed actions affect non-target species, habitats, or resources in the area?
- How might your proposed actions affect your personal safety or well-being?
- How might your proposed actions affect public safety and best interest?
- What actions will you take to minimize or avoid negative consequences of your proposed actions?
- What insurance or bonding do you have that would provide for an emergency response or compensation for unanticipated "take" of animals and/or habitat?
- What are the anticipated uses of your data and benefits of your proposed project?
- What will you do to ensure these anticipated benefits are realized?
- Will specimens (including tissue and genetic material) be collected? If so, where will they be stored? What will their ultimate fate be?
- What will be done with the results and conclusions you generate as an outcome of your research?

- What is your source of funding, what is the total amount of the award, and approximately what portion (in dollars or percent) of the total award will be spent in the CNMI?

- Will there be any commercial applications of your research, or the knowledge or materials produced by it?

**Submission of Application:** A completed application form, the Project Description, all relevant permits and licenses, all supporting documents, and proof of fee payment should be submitted physically or electronically in a single document to:

Office of the Director

Division of Fish & Wildlife

Box 10007, Lower Base

Saipan, MP 96950

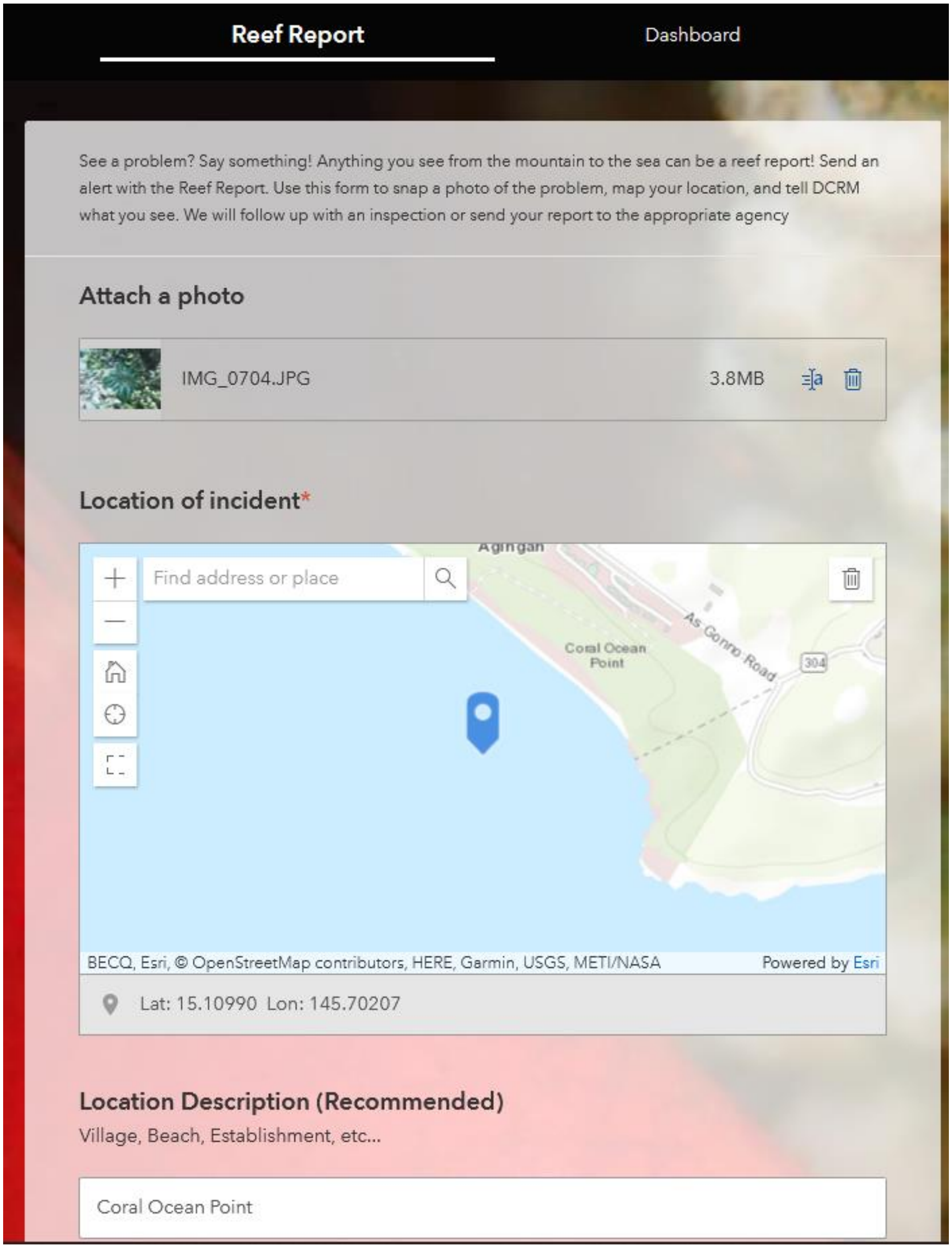
Applications are reviewed for merit and completeness. The review process could be lengthy and include both internal and external reviewers. Amendments and revisions could be requested. Applications become the property of CNMI Division of Fish & Wildlife upon submission.

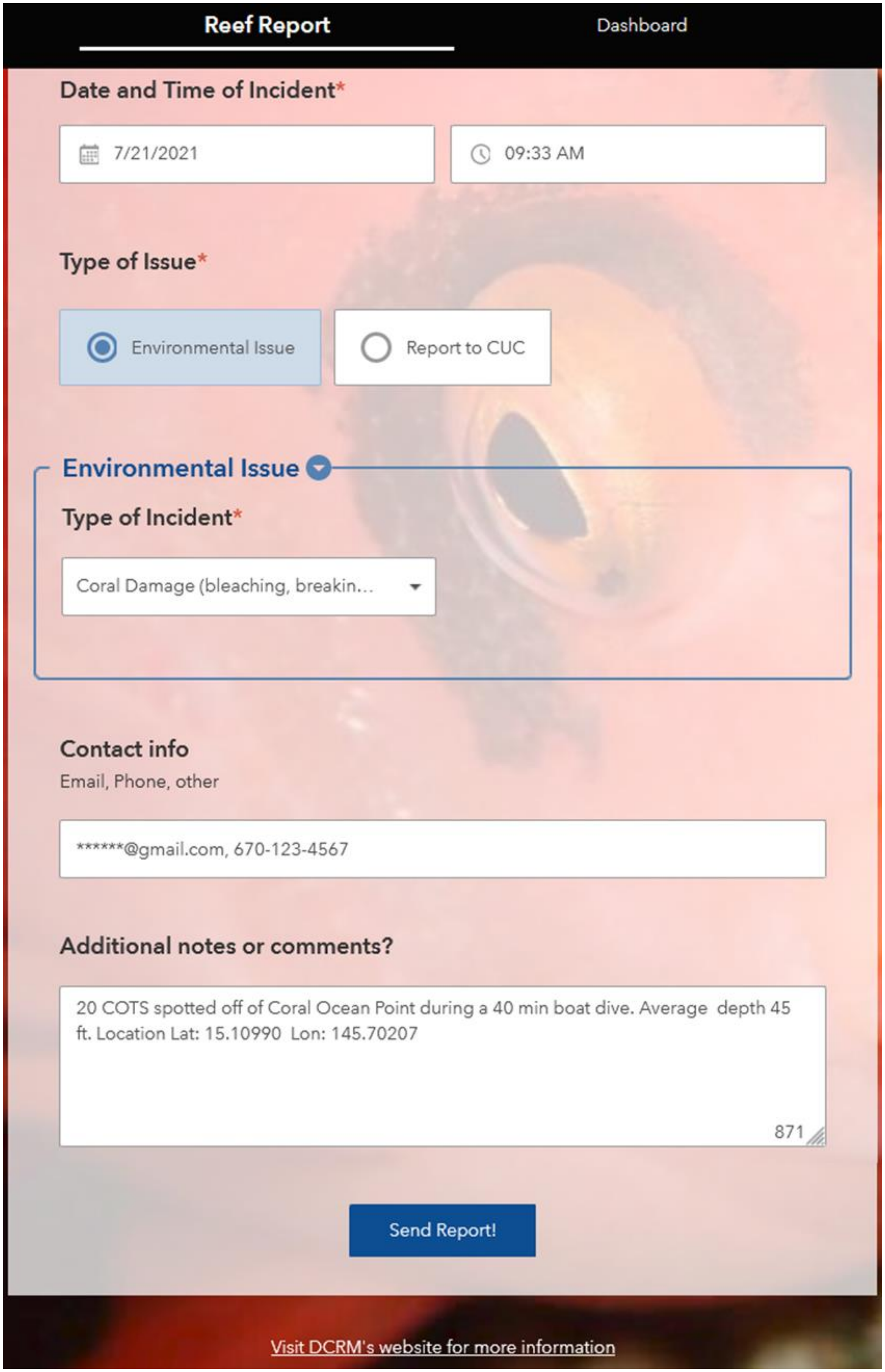
**Fees:** Fees for Scientific Research License applications are published in the Division of Fish &

Wildlife Fee Schedule (available by request or online). Fees must be paid to the CNMI Treasury.

## Reef Report Example

Uses: Online reporting system for community members to submit information on reef disturbances during early detection, intervention, and emergency phases. Accessible online at [www.dcrm.gov.mp](http://www.dcrm.gov.mp)




Reef Report
Dashboard
Date and Time of Incident*
7/21/2021
09:33 AM
Type of Issue*
Environmental Issue
Report to CUC
Environmental Issue
Type of Incident*
Coral Damage (bleaching, breakin...
Contact info
Email, Phone, other
******@gmail.com, 670-123-4567
Additional notes or comments?
20 COTS spotted off of Coral Ocean Point during a 40 min boat dive. Average depth 45 ft. Location Lat: 15.10990 Lon: 145.70207
871
Send Report!
Visit DCRM's website for more information

# Datasheets

## Benthic Invertebrate Survey Example

Uses: General survey for monitoring benthic invertebrate populations during early detection and pre-outbreak phases.

**CNMI Marine Monitoring Program**
**Outer Reef Quantitative Invertebrate Survey**

V2.2 (2001)

| | | | | | | |
|---|---|---|---|---|---|---|
| | Observer: | | | | | |
| | Site Name: | Survey area for each transect is 50 m long and 2 m on each side | | | | |
| | Date and Time: | Transect 1 | Transect 2 | Transect 3 | Transect4 | Transect5 |
| | ***Stichopus chloronotus*** Medium, greenish black, big spikes | | | | | |
| SEACUCUMBERS (BALATE') | ***Holothuria atra*** medium to large, black, often sand covered | | | | | |
| | ***Holothuria edulis*** Medium, black with red belly | | | | | |
| | ***Holothuria whitmaei (=nobilis)*** Large, black, sandy, few large teats on side | | | | | |
| | ***Thelenota ananas*** Large, reddish, spikes all over top | | | | | |
| | ***Actinopyga mauritiana*** Medium, hard, brown with white mottling | | | | | |
| | ***Actinopyga miliaris*** Large, black, white anal teeth, prickly looking | | | | | |
| | ***Bohadschia argus*** Large, eye spots, spits cuverian tubules | | | | | |
| | ***Bohadschia sp. (Note Color Pattern)*** Large, spits cuverian tubules | | | | | |
| | ***Euapta/ Synapta sp.*** Snakey, long, soft | | | | | |
| SEAURCHINS | ***Echinostrephus aciculatus*** Small, short thin spines, burrows in rock | | | | | |
| | ***Echinometra mathaei (Note color)*** Small, short thick spines, in grooves or holes | | | | | |
| | ***Echinothrix spp.*** Large, long spines, | | | | | |
| | ***Diadema spp.*** Thin, long spines | | | | | |
| SEASTARS | ***Linckia laevigata*** Large blue seastar | | | | | |
| | ***Linckia guildingi*** Large brown seastar | | | | | |
| | ***Culcita novaguinea*** Pillow star | | | | | |
| | ***Acanthaster planci*** Crown of Thorns Seastar | | | | | |
| | ***Crinoids (any kind)*** | | | | | |
| CLAMS&TROCHUS | ***Trochus niloticus*** Topshell; ALILENG TULOMPO | | | | | |
| | ***Turbo spp.*** Turbo; ALILENG | | | | | |
| | ***Tridacna crocea*** Smallish giant clam embedded in rock; HIMA | | | | | |
| | ***Tridacna sp.*** Giant clam embedded in rock; HIMA | | | | | |
| | ***Lambis lambis*** "Five finger" snail; TORO | | | | | |
| | ***Octopus cyanea*** Octopus; GAMSON | | | | | |
| | ***Panilurus spp.*** Spiny Lobster MAHONGANG; PAPANGPANG | | | | | |

## Crown – Of – Thorns Outbreak Survey Example

Uses: Focused survey on crown of thorns during pre-outbreak and outbreak phase. Can be used to assess aggregations and eradication efforts to collect size and population information.

**COTS Outbreak Assessment**

Observer: ____________ Site : ____________ Date: ________ Dive time: ________

| | COTS Size Bracket | | | | | |
|---|---|---|---|---|---|---|
| Depth Range (m) | < 10 cm | 10 - 20 cm | 20 - 30 cm | 30 - 40 cm | 40 - 50 cm | > 50 cm |
| 0 - 9 | | | | | | |
| 10 - 14 | | | | | | |
| 15 - 19 | | | | | | |
| 20 - 24 | | | | | | |
| > 25 | | | | | | |

| Coral Predation Assessment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tissue Loss | | | | | Tissue Loss | | | |
| Coral Species | 0 - 25% | 25 - 50% | 50 - 75% | 75 -100% | Coral Species | 0 - 25% | 25 - 50% | 50 - 75% | 75 -100% |
| | | | | | | | | | |
| | | | | | | | | | |
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