Chapter 27

Managing Acanthaster outbreaks: a challenge for the Pacific

Pascal Dumas and Mehdi Adjeroud

Acanthaster planci is a corallivorous starfish, which feeds on coral polyps by extruding its stomach over corals, leaving behind only the white calcareous skeleton of its prey. Large adults (30 to 40 cm in diameter on average) can consume up to 12 m^2 of coral per year. © IRD/P. Dumas

A voracious predator

Sea stars of the genus *Acanthaster* are echinoderms, a group which also includes sea urchins, holothurians, crinoids and ophiuroids, all found in Indo-Pacific coral reefs. Their color varies considerably depending on the region. They usually have 10 to 20 arms with long spines on their upper face, which are coated with a particularly painful and highly toxic steroid venom. Their common name reflects their morphology: "Crown of thorns". Besides *Acanthaster brevispinus*, a species mostly found in deep habitats, recent genetic studies suggest that there are at least four distinct and geographically separate species along a Red Sea - Indian Ocean - Pacific Ocean *continuum*. Once part of the unique species *A. planci*, the populations found in Pacific reefs are now classified as *A.* cf. *solaris*, but their taxonomic status (and the possible existence of several distinct species within the Pacific) is still controversial.

Some specimens can be over 70 cm in diameter and weigh up to 3 kg, but the reputation of acanthasters is mainly due to the effects of their diet on coral ecosystems. Adult acanthasters are voracious predators of coral, which they eat by extruding their stomachs over the coral colonies. Once they have digested the polyps on site, they leave behind them clean and intact calcareous skeletons. These white feeding scars are often one of the first indicators of the presence of numerous acanthasters.

Acanthasters have existed on reefs throughout geological times and they are a natural component of tropical ecosystems. They are relatively scarce on a "healthy" coral reef (only a few individuals per hectare) and their predation has no negative impact on the abundance, cover and diversity of coral assemblages. They even contribute to the maintenance of coral diversity due to their pronounced dietary preferences. In general, fast-growing corals such as *Acropora* and *Montipora* are preferred over slower-growing corals such as *Porites*, leaving more room for less opportunistic species. An adult acanthaster consumes about 10 m^2 of coral per year and has only few regular predators. Out of about thirty recorded species of fish and invertebrates, only a handful (the giant triton *Charonia tritonis* or "Triton's trumpet", the stellate puffer *Arothron stellatus*, the humphead wrasse *Cheilinus undulatus*, and some triggerfish, emperor or boxfish) are known to prey on healthy adults.

Outbreaks of acanthaster populations

While in normal conditions, acanthasters are rather inconspicuous, their populations can, sometimes, explode to extreme levels. They can reach up to several thousand, or even tens of thousands of individuals per hectare, which can persist for months or years over vast reef areas. These unpredictable blooms are one of the most serious biotic disturbances to coral reefs, and their impact is comparable to that of tropical cyclones. Coral mortality can exceed 90% in the most severely affected reef areas, resulting in a profound restructuring of the ecosystem structure and ability to function. The cascading effects of coral disappearance include the physical alteration of habitat, the depletion of prey, and the displacement and relocation of species. These can affect the entire reef community and sometimes lead to a phase-shift where the system becomes totally dominated by algae.

Although fossil records suggest a much older history, the first outbreaks of acanthasters and their consequences were not reported and studied quantitatively until the 1960s. More than a third of the Pacific reefs have been affected by these outbreaks: the Ryukyu archipelago in southern Japan, Palau, Guam, Samoa, the Great Barrier Reef, Vanuatu, Fiji and Kiribati. French coral reefs have not been spared. The Society Islands in French Polynesia experienced a major event between 2006 and 2009. New Caledonia, which had had been

In some years, and for reasons that are not yet well known, acanthasters start to proliferate, with densities reaching several individuals per square meter. After a few months, they can destroy large portions of reefs. The Great Barrier Reef of Australia, French Polynesia, southern Japan, and more recently the Vanuatu archipelago and New Caledonia have experienced these sad outbreaks! © IRD/P. Dumas spared by large-scale outbreaks, was affected in 2000 and more recently in 2012. Despite sustained research efforts by the scientific community, the causes of these proliferations are still insufficiently understood. Some researchers believe that one factor could be the increasing scarcity of acanthasters' natural predators due to the overfishing of commercial species such as tritons, humphead wrasses, emperors, etc. The overall deterioration in water quality, linked to human activities, is also highlighted, but this hypothesis alone cannot explain all outbreaks, especially those observed on unpolluted reefs. For other authors, these demographic explosions could be part of the biological cycle of the species, which is naturally predisposed to large fluctuations as a result of its extraordinary fertility: a single spawning adult female can produce over 100 million eggs in a single breeding season. With hindsight, and thanks to recent scientific advances in genetics, molecular biology and modelling, the highly complex, multifactorial and multi-scale nature of these outbreaks is becoming increasingly evident.

"Acanthaster threat" and global change

In the Indo-Pacific region, the frequency and intensity of outbreaks appears to be increasing, especially in recent decades, with growing awareness of the global changes that are affecting the region. Acanthasters develop best in warm waters (26 to 30°C) in the presence of phytoplankton, and can therefore be particularly sensitive to the effects of climate change. Increased sea surface temperature and nutrient enrichment in coastal waters are the main contributing factors to the survival of larvae, thus increasing the number of adults potentially reaching the reefs at the end of their development. Given the large dispersal capacities of the species, whose swimming larvae can settle several hundred kilometers from their original reef, the growing regional "acanthaster threat" is a real problem in the context of current climate change scenarios. Although there is historical evidence that coral reefs can recover after an outbreak, recovery is generally slow (several decades) and not guaranteed. Acanthaster outbreaks are yet another pressure on ecosystems, which are increasingly weakened by other natural (coral bleaching, tropical cyclones, coral diseases, etc.) and anthropogenic (pollution, overfishing, coastal developments, etc.) disturbances. In the Australian Great Barrier Reef, a recent study reports a 50% decline in coral cover over the last 30 years, half of which is due to recurrent acanthaster outbreaks alone.

In New Caledonia, we have only limited knowledge of these outbreaks and their quantitative impacts on reefs. In line with studies and occasional observations dating back to 1980-1990, the assessment of 18 sites was carried out in 2012 by IRD scientists. Results revealed the existence of localized, potentially mobile, outbreaks with, at times, very high acanthaster densities (up to 500 individuals/ha). The Southwestern Lagoon is the most studied area, where proliferations are restricted to a few sites. Often ephemeral, these outbreaks generally go unnoticed by environmental managers, but they are likely to cause significant damage to corals in the medium and long term, especially to *Acropora* and *Pocillopora*. However, the information provided by users of the lagoon raises concerns about the existence of many outbreaks that are almost totally ignored, both in the South Province (e.g., Boulouparis, Ouaco, South Horn) and in the North Province (e.g., Hienghène, Poindimié, Poum), on the east coast (Côte oubliée, etc.) or on the islands.

Management of the "Acanthaster threat"

In the majority of Pacific countries, where coral resources form the basis of traditional fisheries, acanthaster outbreaks threaten the food security and livelihoods of coastal populations. The issue is also of concern to the tourism industry (diving clubs, hotels, etc.) whose activity can be seriously impacted by uncontrolled proliferation, and environmental managers for whom it is now a conservation issue.

Currently, only human actions can combat the proliferation of acanthasters, more or less successfully, depending on the extent of the phenomenon, the characteristics of the impacted reefs (size, isolation, vulnerability, etc.), the context (socio-economic, environmental) and the available resources (human, financial). The most common methods generally aim at limiting coral losses by minimizing the number of individuals feeding on reefs during an outbreak. The oldest method is the manual collection of acanthasters using a variety of tools such as hooks, sticks, spear guns, bags, etc. to bring them back to shore and destroy them. This method, which requires a large workforce and a long-lasting commitment, has a limited effect in the face of massive, widespread and/or recurrent outbreaks, especially since it requires a good knowledge of the species' biological and ecological specificities (particularly its local spawning period). The injection method, which is more cost-effective, is increasingly replacing collection methods. It involves inoculating a toxic solution that causes the death of acanthasters. However, these treatments have some drawbacks, and the use of several chemicals (e.g. copper sulfate, sodium bisulfate, formaldehyde, ammonia, bleach, etc.) had to be discontinued due to their toxic effect on the environment and other species as well as their high cost. A new approach based on the injection of natural and cheap acidic substances has recently been developed by the IRD. Tests were carried out both in the lab under controlled conditions and in the field and demonstrated the lethal properties of some fruit juices (different varieties of lime and passion fruit), white vinegar and some powdered acids from the agri-food industry. These substances, which cause high mortality even at low doses, are now a highly credible ecological alternative in fighting acanthaster outbreaks. Tested in Vanuatu since 2014, this method was first used in New Caledonia in 2017. A pilot field operation was carried out at Vua islet with the participation of volunteer divers and the IRD's research vessels. It resulted in the eradication of more than a ton of acanthasters over two days and confirmed the efficiency of the method under real conditions.

The unpredictability of these outbreaks makes their management particularly complex, especially for reefs that are frequently exposed to these events, sometimes several years in a row. But as effective as they may be, these methods of control are merely a symptomatic treatment of the phenomenon - much like scooping water out of a punctured boat. They require that any proliferation is detected at the earliest possible moment. This task may seem overwhelming for countries with extensive reef formations, as long-term monitoring requires considerable resources. Alternatives are required to face the difficulty of ensuring the funding of long-term scientific monitoring covering the whole territory. An interesting alternative is the creation of "citizen" monitoring networks, where data collection is provided by the lagoon users themselves. This is the purpose of the participative monitoring program OREANET[13] (Oceania Regional

[13] http://oreanet.ird.nc

The methods for controlling acanthaster outbreaks are limited. In some Pacific island states, fishermen and divers organize campaigns during which acanthasters are collected manually. They are often timely but limited in space, and their efficiency is usually not sufficient to stop severe outbreaks. However, they do help to mitigate damages and involve local populations in the preservation of their reefs. © IRD/P. Dumas

Recently, more sophisticated techniques have been developed that attempt to reconcile field efficiency, low environmental impacts and low costs. For example, lethal vinegar injection kits have been successfully tested, here, around Vua Islet in the Southwestern lagoon of Grande Terre. © B. Preuss

Box 21

The Oreanet program

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The IRD project, OREANET (Oreanet Regional Acanthaster Network) was officially launched in July 2015 with financial support from the Pacific Fund (Fonds Pacifique), the Government of New Caledonia and GOPS (Grand observatoire de la biodiversité terrestre et marine du Pacifique sud et sud-ouest). This project aims at building an operational monitoring network for the "acanthaster threat" in New Caledonia, Vanuatu and Fiji. The success of this network is based on a participative approach, where observations are relayed by lagoon users, with user-friendly tools that allow rapid reporting of acanthasters from a computer, tablet or smartphone.

To date, the OREANET network has recorded over 16,000 acanthasters through more than 300 participative reports from fishermen, coastal communities, boaters, divers, NGOs, diving clubs and associations, scientific organizations, etc. Standardized procedures for the verification of the threat and control in the field have also been developed and validated. The objective is to establish a mapping of threats and provide an operational response framework when an outbreak is reported via the surveillance network.

Acanthaster Network), set up in New Caledonia since 2015. It is based on the voluntary participation of fishermen, boaters, diving clubs, environmental consultants, associations and scientists in monitoring the outbreak (box. 21).

The "acanthaster phenomenon" is now recognized as a major conservation issue. However, the late realization of its magnitude and the existence of recurring controversies regarding the relevance of human intervention, have severely hampered the response capacities of affected countries. Despite their efficiency over the short to medium term, current management strategies are only a temporary solution, treating symptoms rather than the origin of a complex phenomenon whose underlying causes are still largely unknown. The next step requires the development of a global approach, integrating a better understanding of the processes that control the onset, maintenance and spread of acanthaster outbreaks with relation to climate change affecting marine ecosystems: a major scientific challenge.

New Caledonia
World of corals

Scientific direction: Claude E. Payri

IRD Editions
French National Research Institute for Sustainable Development, Marseilles, 2018
Editions Solaris

Translation: Lydiane Mattio
Editorial coordination: Claude E. Payri
Page and cover layout : Pierre-Alain Pantz - Editions Solaris
Printing: Winson Press, Singapour

Cover illustrations

Cover page 1 (from top to bottom):
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ISBN : 978-2-7099-2677-5

Recommended citation:
Payri, C.E. (dir.), 2018 – New Caledonia: world of corals. IRD Editions/Solaris, Marseilles/Nouméa, 288 pp.