Chapter 5

Reef corals of New Caledonia: a diverse and valuable heritage

Francesca Benzoni

Between mountains of corals: a diver swims in a groove between two reef formations covered in the same corals from which they are built, Chesterfield Reefs. © IRD/F. Benzoni

Reef corals may not look like animals at all, but they are in fact very ancient and complex invertebrates. They belong to a group of exclusively aquatic animals called cnidarians, which are believed to have colonized the oceans as early as 600 million years ago. Cnidarians take very different forms, including free-living medusa, suspended or drifting in the water column, or polyps, attached to the bottom of the reef. They can even alternate between these two forms during their life cycle. Whatever the form, the body organization is very simple: a sac-like structure with one opening, surrounded by a crown of tentacles, soft and mostly made of water.

Hard corals spend their whole life, generation after generation, in the form of a polyp, looking much like an anemone. However, although they are close relatives of the colorful sea anemones, their body parts are organized differently and they can build a solid skeleton made of white calcium carbonate (similar in composition to limestone). Leaving a skeleton behind means leaving easily detected evidence in the fossil record.

The earliest known hard coral fossils date back to approximately 240 million years ago, but the study of living species DNA provided strong evidence that hard corals are even more ancient, dating back to the Palaeozoic period about 425 million years ago. This is approximately when the first plants started to colonize the dry part of Earth.

Box 4

The first overseas observation of coral spawning

Pascale Joannot

In 1986, Australian scientists observed coral spawning between the 3rd and 6th nights after the first summer full moon in tropical latitudes. However, this phenomenon had never been observed in French overseas territories before.

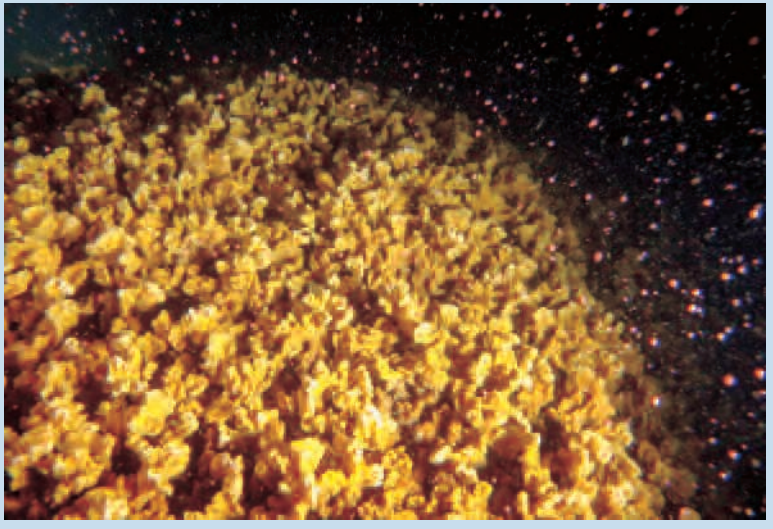
In New Caledonia, on Monday the 13th of November 1989, the day after the full moon, I had mobilized a full team of scientists, divers and journalists, some of whom were observing at sea and the others at the aquarium of Nouméa (Aquarium des Lagons). The latter turned into a nocturnal hive where our flashlights swept the tanks with the hope of finally seeing the famous "night of coral love".

By the end of the fourth night, most of team had given up and on the Saturday evening, the whole team had deserted the aquarium. However, on this same evening (November 18th), the trade winds, well established at that time of the year, weakened and I had the intuition that the corals were about to spawn. I went to the aquarium and in the beam of my torch I finally saw the signal!

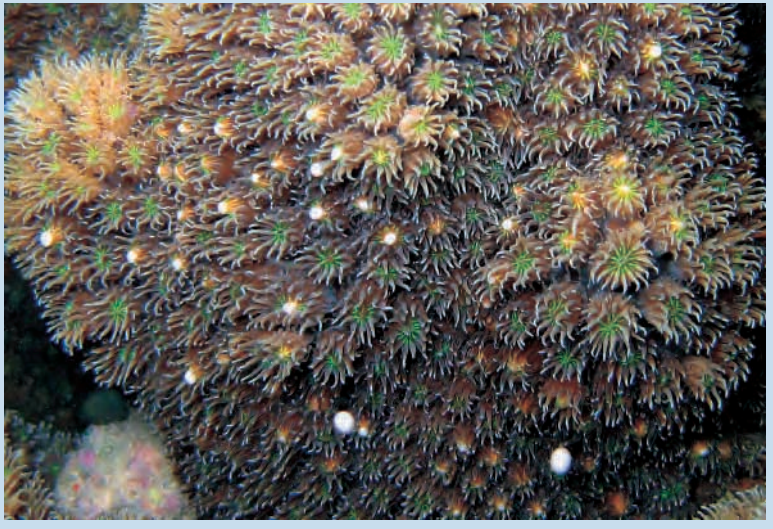
Thousands of small pink pearls appeared shyly on the surface of the corals, ready to randomly venture into the waves. Amazed, I took some pictures and called my colleagues to share this wonderful show.

Alain Gerbault†, then working as a diver for the aquarium, dived in the bay close to the aquarium (Baie des citrons) and confirmed that the spawning also took place at sea and Claude Bretegnier, journalist at RFO, filmed the cloud of eggs of a solitary coral!

With this event, New Caledonia became the first French overseas country where mass coral spawning was observed.



Spawning of the coral *Merulina scabricula* occurred on December 1st 2015 in the lagoon of Nouméa. Gametes are released into the water column and rise to the surface due to their high fatty content. © Biocénose/G. Lasne



Spawning of the coral *Galaxea fascicularis* occurred on September 9th 2009 in the lagoon of Nouméa. The small white balls that escape through the mouth of polyps are the female gametes. They will disperse in the water column where they will be fertilized to produce larvae. © Biocénose/G. Lasne

Zooxanthellate coral species in well-lit conditions form healthy and high cover communities on an outer reef of the west coast of Grande Terre. © IRD/F. Benzoni

On the evolution of hard corals

The first hard corals were nothing like the ones we can observe on a coral reef today: they lived in deep, dark and cold waters and were relatively small. Over time, some of the hard corals have moved up from the depths and adapted to live in shallower waters where they have become increasingly more colonial (i.e., having multiple identical polyps) and have reached larger sizes. At some point, once established in the well-lit shallow waters, hard corals started a symbiotic relationship with unicellular algae living within their tissues. These microalgae associated with marine animals are called zooxanthellae. The association between a marine animal and unicellular algae has been found several times in our oceans because it is an effective win-win situation for both parties. The alga gains physical protection within the animal host while the host has the advantage of living in intimate contact with a primary producer that traps the energy of sun light into sugars through photosynthesis. To put it simply, zooxanthellae provide hard corals with an additional energy supply and conditions that allow it to produce its hard skeleton more efficiently: symbiotic corals are better skeleton producers. However, because zooxanthellae need light, the coral host is forced to live in shallow and well-lit conditions. Today, there are approximately 1,400 living hard coral species. Approximately half of them are devoid of zooxanthellae and live in deeper waters reaching 6,000 m deep. The other half is symbiotic and lives in shallow waters. The latter are mostly, though not exclusively, found in the tropical belt and they are major reef builders, forming and sustaining one of the most diverse, productive and economically important ecosystems: coral reefs. Although comparably less diverse in terms of species, deep water coral reefs, formed by non-symbiotic species of corals, support an important and productive ecosystem which is still relatively poorly known. Both deep and shallow reef systems are valuable and economically important, and they are

currently facing a number of local and global threats such as demographic development and the increasing use of resources. In addition, the warming of the ocean has a direct impact of the coral's vitality (coral bleaching, chap. 25) and ocean acidification. This situation has led scientists to define and declare a global coral reef crisis.

Coral hotspots

Shallow water coral species which form coral reefs are not equally distributed throughout the tropics: the Atlantic and the Indo-Pacific coral fauna are very different from each other, the latter being more rich and diversified. Within the Indo-Pacific region the highest concentration of hard coral species occurs in an area called the "coral triangle", a coral hotspot which roughly includes the Philippines, Papua New Guinea, Indonesia, and Malaysia, and where up to 500 hard coral species can be encountered. This diversity does not only hold for corals, but also for several other invertebrates and fish as well as for marine macrophytes. Several concurrent factors have contributed through time to the formation of this marine hotspot of diversity. Outside this coral triangle, diversity slowly decreases to reach its lowest values in the East Pacific.

New Caledonia is not very far south of the limits of the coral triangle, at the eastern end of the Coral Sea. Its proximity to this world's hotspot of shallow-water marine diversity partially explains the richness and variety of the territory's marine ecosystems and coral reefs. New Caledonian marine and coral reef ecosystems are currently part of the largest French marine protected area to date: the Natural Park of the Coral Sea. They have also been listed as UNESCO World Heritage sites (box. 5).

A geomorphology highly favorable to reef habitats

Another important factor, which can explain the diversity of New Caledonian coral reefs and reef corals is the remarkable heterogeneity of the area's geomorphology. This heterogeneity creates a large diversity of reef habitats sheltering a multitude of marine species (fauna and flora). These include bay and lagoon habitats, where benthic reef species are exposed to important sediment discharges of terrigenous origin, leading to unusual species assemblages, distributions and morphologies (e.g., Prony Bay and Gail Bank) (box. 6).

Hovering on a fragile garden of branching *Acropora* in the inner lagoon of d'Entrecasteaux Reefs, a breeding ground for fish (low hard coral species diversity and high ecological function). © IRD/F. Benzoni

Box 5

Natural Park of the Coral Sea: an abundance of species

Marie-Hélène Merlini and Julie-Anne Kerandel

The scientists are unanimous: what they see when diving on the reefs of remote islands during biodiversity surveys is astonishing! In front of their eyes: bigger and less apprehensive fish, and many predators such as jackfish and groupers with surprisingly curious behaviors. Laurent Wantiez, a lecturer in marine ecology at the University of New Caledonia, is definitive: "Almost every time you dive, you can see between one and ten sharks, schools of humphead parrotfish, big jackfish, dogtooth tuna [...]. All these species are abundant in these reefs (Bioreef campaign 2016) ".

To keep on increasing knowledge

Since 2006, dedicated scientific campaigns have been organized to accurately assess the biological richness of the coral reefs in the natural park. The objective: to carry out a species census based on a previously defined route. The current state of knowledge available for many groups of species in the study areas (Chesterfield, d'Entrecasteaux, Astrolabe) indicates that there is a particularly rich fish community on the d'Entrecasteaux and Astrolabe reefs, including healthy sharks. The Chesterfield Reefs are home to remarkable resources of algae, corals, echinoderms (marine animals such as sea urchins, starfish, holothurians), reef fish (parrotfish, groupers, butterflyfish, etc.), sharks, sea-snakes, etc.

Coral reefs, or reef and lagoon ecosystems, are home to 25% of the marine species known to mankind (MC ALLISTER, 1995; BURKE *et al.*, 2012). As a result of their isolation, the coral reefs in the Natural Park of the Coral Sea can be quite special. For example, because some organisms do not disperse very much or even at all, it is likely that new, and therefore relatively unknown, species may appear. Connectivity between the park's reefs and neighboring countries, which is essential for the proper functioning of ecosystems, is also of interest to scientists. The biodiversity of the natural park is far from having revealed all its secrets.

Lethrinus miniatus (sweetlip emperor) is not fearful and can be aggressive by biting anything that moves. © M. Juncker

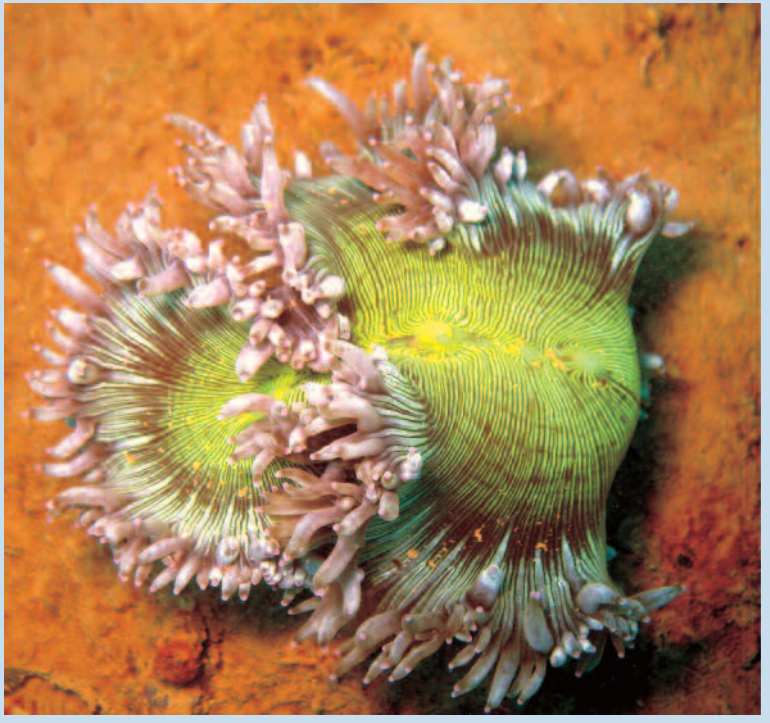
References

BURKE *et al.*, 2012 *Récifs coralliens en péril. Revisité : synthèse à l'intention des décideurs*. World resources institute, Washington D.C., 45 p.
MC ALLISTER, 1995 Status of the World Ocean and its Biodiversity. *Sea Wind*, 9 : 1-72.

Box 6

Best in the mud

Acropora tortuosa producing a mucus that traps sediments (banc des Japonais). © IRD/F.Benzoni

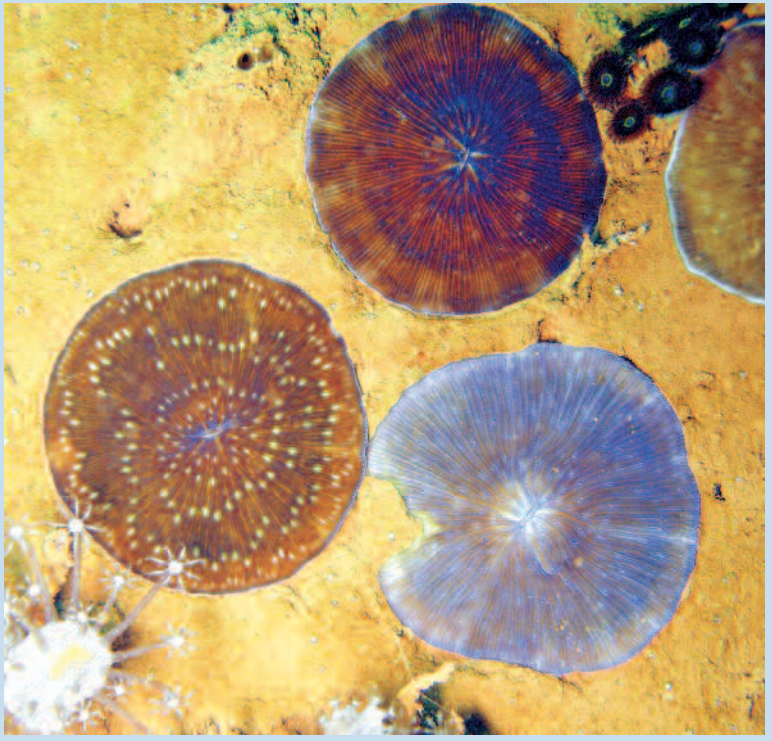


Catalaphyllia jardinei, spreading its soft and colored polyps, which can reach up to 2/3 of the skeleton volume (Gail Bank). © IRD/F.Benzoni

Reef corals usually live and grow in clear and well-lit waters. Experiments have demonstrated that an excess of sediments can deposit on coral polyps and smother them to death. However, clearing off the sediment is not an easy task for an organism which lives attached to the substratum. Consequently, one would expect turbid environments to be a less appealing habitat for corals.

The coastline of Grande Terre offers a number of bays protected from wave-action, where the bottom is covered in fine sediment, or even mud. Some of these bays are naturally charged with red soil, washed off the land, others are affected by discharges due to direct or indirect human activities. A very special community of corals lives in such habitats including species almost exclusively found there, such as the New Caledonian endemic coral *Cantharellus noumeae*.

How do these corals do it? They master two effective strategies which, skillfully combined, allow them to flourish in the mud. The first requires the production of mucus: highly efficient, the slimy mucus abundantly produced by these corals is a precious ally. Once the sediment is trapped in the mucus, the coral clears it off by moving its tentacles. The second strategy involves expanding parts of the polyps so that the sediment accumulates on parts of



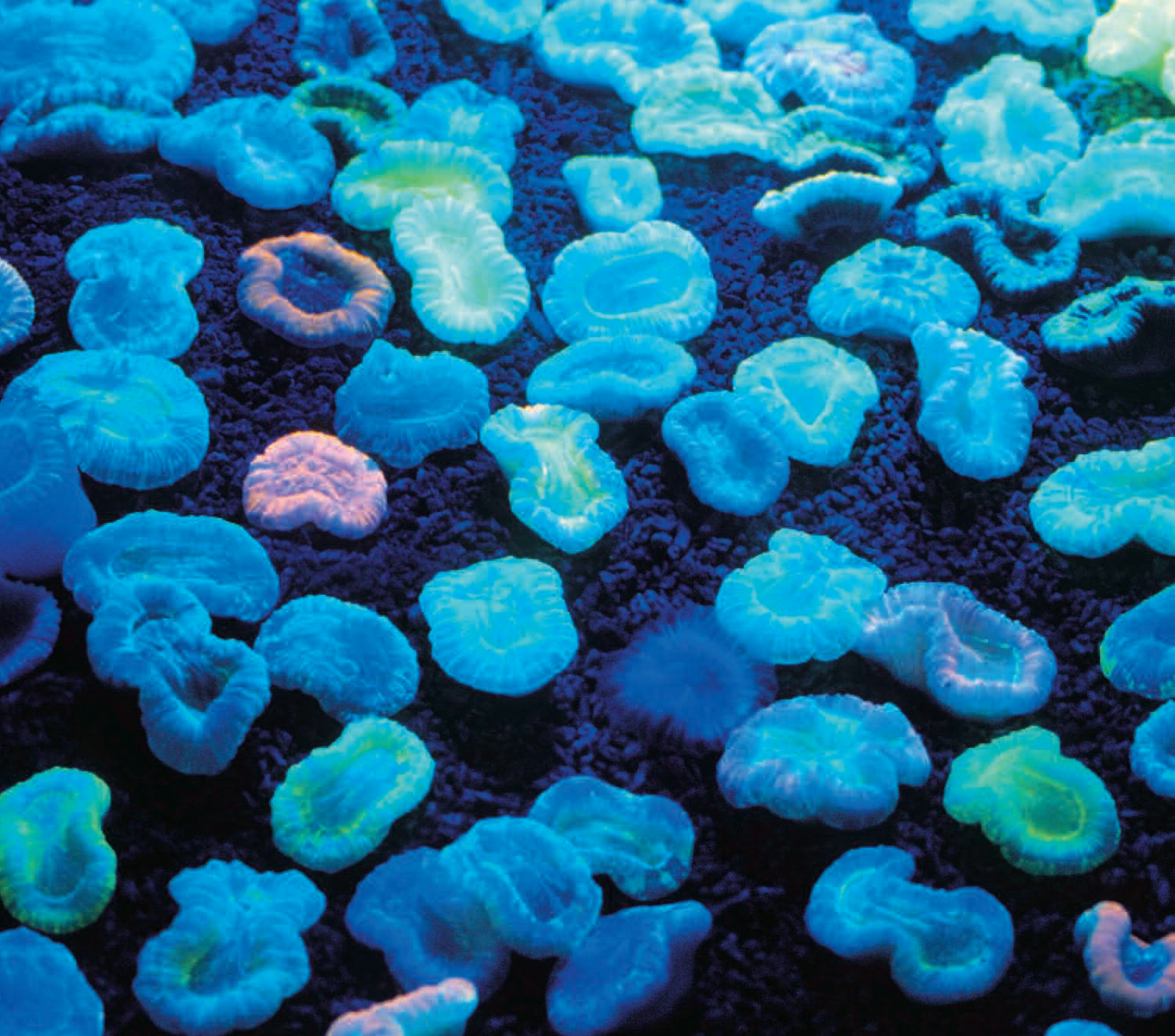
At 35 m, the deep, calm and dark waters of Prony bay hide a colorful community of corals, which are adapted to sediments and life in extreme environments. © IRD/F.Benzoni

The endemic coral *Cantharellus noumeae* is found exclusively in muddy environments around Grande Terre (Port-Boisé). © IRD/F.Benzoni

the body that the animal is able to move or that will be exposed to water movement. Many of these look like colorful flowers blooming over the sediment.

The presence of corals on the soft bottoms of lagoons provides a habitat for a large number of coral-associated animals which otherwise would not thrive in these environments: they sustain an unexpected highly diverse community. The Grande Terre soft bottom coral aggregations, like those in Prony bay or at the Gail Bank, are rarely observed elsewhere in the world and are listed among the singularities of New Caledonia.

Moving from the shallows to the deep, New Caledonia is also currently considered the world's hotspot for deep water coral diversity. The study of New Caledonian hard corals started in the early 1900s but followed very different trajectories for shallow and deep-water species. Deep water corals were sampled using dredging and trawling between 80 and 1,434 m deep during a number of oceanographic campaigns in the 1970s and 1980s (Bathus 3-4, MUSORSTOM 5, 7-9). The study of these impressive collections, hosted at the MNHN (Muséum national d'histoire naturelle, Paris), was only recently finalized by specialists. Results revealed an unprecedented concentration of species diversity in the deep-water ecosystems of New Caledonia, with about 170 species identified, including some species entirely new to science (M. Kitahara pers. comm.) - a diversity much higher than that currently known for the Philippines.



Box 7

Wonderful fluorescent corals

Pascale Joannot

It is in New Caledonia that the first fluorescent corals were collected in 1958 by divers Michel Laubreaux and René Gail (who has since disappeared while diving). They were found on a remarkable, but difficult to access, 35 m deep mud-flat on the Gail Bank, near the Pirogues River.

Dr. Catala, founder of Nouméa's first aquarium, exposed them to ultraviolet light and discovered the fluorescence of these corals, ranging from dark green to bright yellow and a whole series of reds and oranges.

Fluorescent corals are also found near the surface where the same species may have an entirely different fluorescence. The granulations that support the pigments responsible for fluorescent properties are located in the animal's flesh. These pigments belong to the flavin, urobilin and pterin groups (PELOUX, 1960) and in contrast, the calcareous skeleton of the animal does not produce any fluorescence.

I was able to see that repeatedly exposing corals to UV light causes them to bleach. They can recover in a month's time when they are returned to natural light.

In 1996, very calm waters, high temperatures and sun exposure in the New Caledonian lagoons and at the Nouméa aquarium caused significant bleaching of corals, with a rapid or gradual change (depending on colonies) from their natural colors to pastel fluorescent colors including white, pink, yellow or blue. At the aquarium, as the corals bleached, some of them resisted and turned brown. Although each previous summer it had bleached and regained its brown colors as soon as the water cooled down, a colony of *Echinopora* displayed an even more intense pigmentation.

These observations raise questions about the role of the pigments (flavoproteins) responsible for the production of fluorescent colors and the possible "UV screen" role of symbiotic zooxanthellae.

Reference

PELOUX Y, 1960 : Etude. *Histologique des coraux fluorescents de profondeur.* Compte rendu, de l'Académie des Sciences, 250 : 1129-1130.

Mat of *Trachyphyllia geoffroyi* with various pastel fluorescent colors in a tank of the *Aquarium des Lagons.* © P.A. Pantz

Box 8

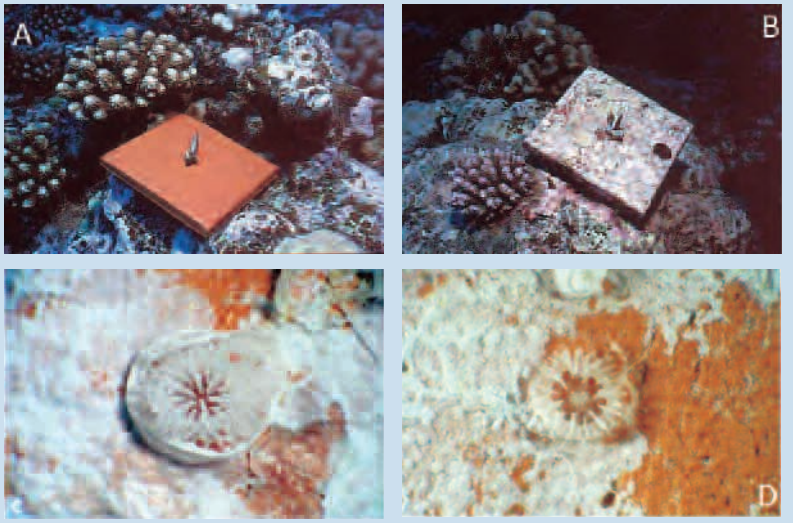
New generations: strong coral recruitment in the southwestern lagoon of New Caledonia

Mehdi Adjeroud and Christophe Peignon

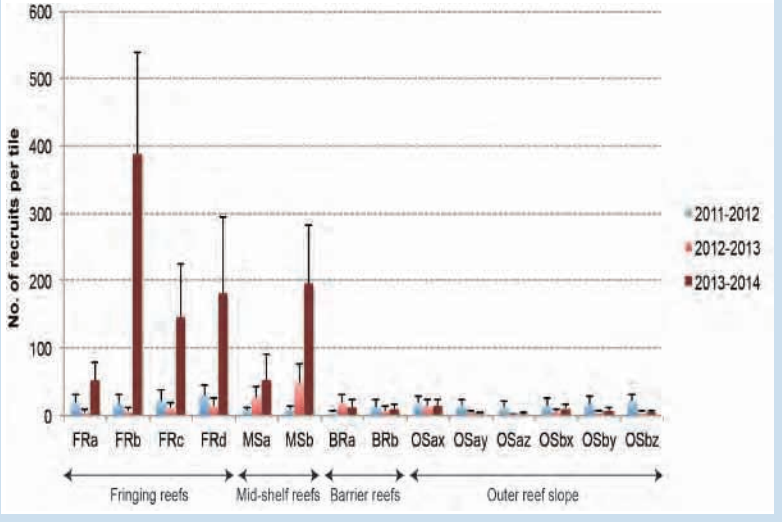
Recruitment, defined as the integration of young individuals into adult populations, is a crucial stage in the life of corals. It influences both the spatial distribution of adult populations and their temporal variability. After major disturbances, such as tropical cyclones, coral bleaching events or outbreaks of predators (e.g., acanthasters), which cause severe mortality in adults, recovery occurs mainly through recruitment. In their first year, recruits are only a few millimeters in diameter. These recruits grow up rapidly but only become adults and able to reproduce sexually, after 4 years, on average.

In order to better understand how New Caledonian corals are structured and maintained, a recruitment study was launched in 2011. Terracotta tiles were placed at 14 sites, representing the main habitats of the southwestern lagoon. These tiles were left on the bottom of the reefs and lagoons for 5 months (October to March) to allow for the settlement of recruits. The tiles were then returned to the laboratory for microscopic examination. At this stage, the morphological characteristics on which species identification is based, are not sufficiently developed and only a few families of recruits can be distinguished.

The results of the first three years of research show that coral recruitment is highly variable in space and time. Compared to other reefs in the Pacific, recruit abundance is often relatively high with a significant peak at some of the sites on fringing reefs and mid-shelf reefs in 2013-14. These rates of recruitment are even higher than those recorded on the Great Barrier Reef in Australia. These results suggest that New Caledonia's reefs have a high capacity for recovery and resilience.



Terracotta tiles used for the recruitment study of corals.
A: Newly deployed tiles.
B: After 5 months on the reef, tiles have been colonized by crustose calcareous algae and corals invisible to the naked-eye. Microscopic photographs of recruits from the two most abundant families in New Caledonia.
C: *Acropodiae*.
D: Pocilloporidae.© IRD/M. Adjeroud



Spatial and temporal variability in the abundance of coral recruits (all families combined) recorded at 14 sites in the four main reef habitats of the southwestern lagoon of New Caledonia. © IRD/M. Adjeroud

In the case of shallow reef corals, although specialists have made remarkable efforts to identify species, and to understand their distribution and ecological role, exploration of the territory's vast reef areas remained relatively scarce until the last decade and, for logistical reasons, studies were mostly limited to the south of Grande Terre. Since 2005, the IRD research center in Nouméa has led a number of scientific cruises onboard the research vessel Alis. The main objective of these cruises is to explore and document the diversity of New Caledonian coral reefs, with a special focus on two main reef organisms: macroalgae and hard corals, which are fundamental for the construction and the functioning of these ecosystems. The occurrence and distribution of these organisms is sampled by specialists during scuba dives down to the limit of the mesophotic zone. The material that has been collected is being studied using both traditional approaches based on the morphological examination of the organisms (shapes, sizes, etc.) as well as modern genetic approaches.

Today, thanks to these scientific campaigns and the unprecedented effort of the scientists involved (over 350 hours of underwater observations by several specialists), we have a better understanding of the diversity and distribution of hard corals throughout the territory, including remote reef areas such as Chesterfield and Bellona in the middle of the Coral Sea, d'Entrecasteaux Reefs, the Loyalty Islands and Isle of Pines. Although reference collections are still being studied, the results already provided a more realistic estimate of the hard-coral diversity as well as a description of previously unknown species. Taking into account the considerable changes that have occurred over the last decade in the way coral species are identified and classified, the current species diversity estimate (based on existing specimens and/or *in situ* illustrations) reaches a total of 390 species. Overall, taking into account both shallow and deep-water corals, New Caledonia harbors an impressive third of the world's living hard coral species.

Taking a step beyond the simple total number of species, and based on the exploration of these different zones, today we can say that each region and group of islands within the New Caledonia EEZ is characterized by unique assemblages of corals and coral habitats. Some are characterized by large high-cover communities structured by a few dominant species (e.g., lagoon sites in the remote Chesterfield or d'Entrecasteaux reefs), while others are made of small, cave-dwelling species which are hidden at the limit of the mesophotic zone. Clearly the unique diversity of New Caledonia's coral reef fauna does not simply lie in the number of species present, but also in the diversity of their associations to create strikingly different reefscapes supporting different associated organisms and productive ecosystems. This is a highly valuable heritage that needs and deserves, not only the conservation management currently in place, but also a continuous monitoring of its state.

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World of corals

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