CRISP

Coral Reef InitiativeS for the Pacific
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COMPONENT 3D - Project 3D3
Studies of coral diseases in New Caledonia

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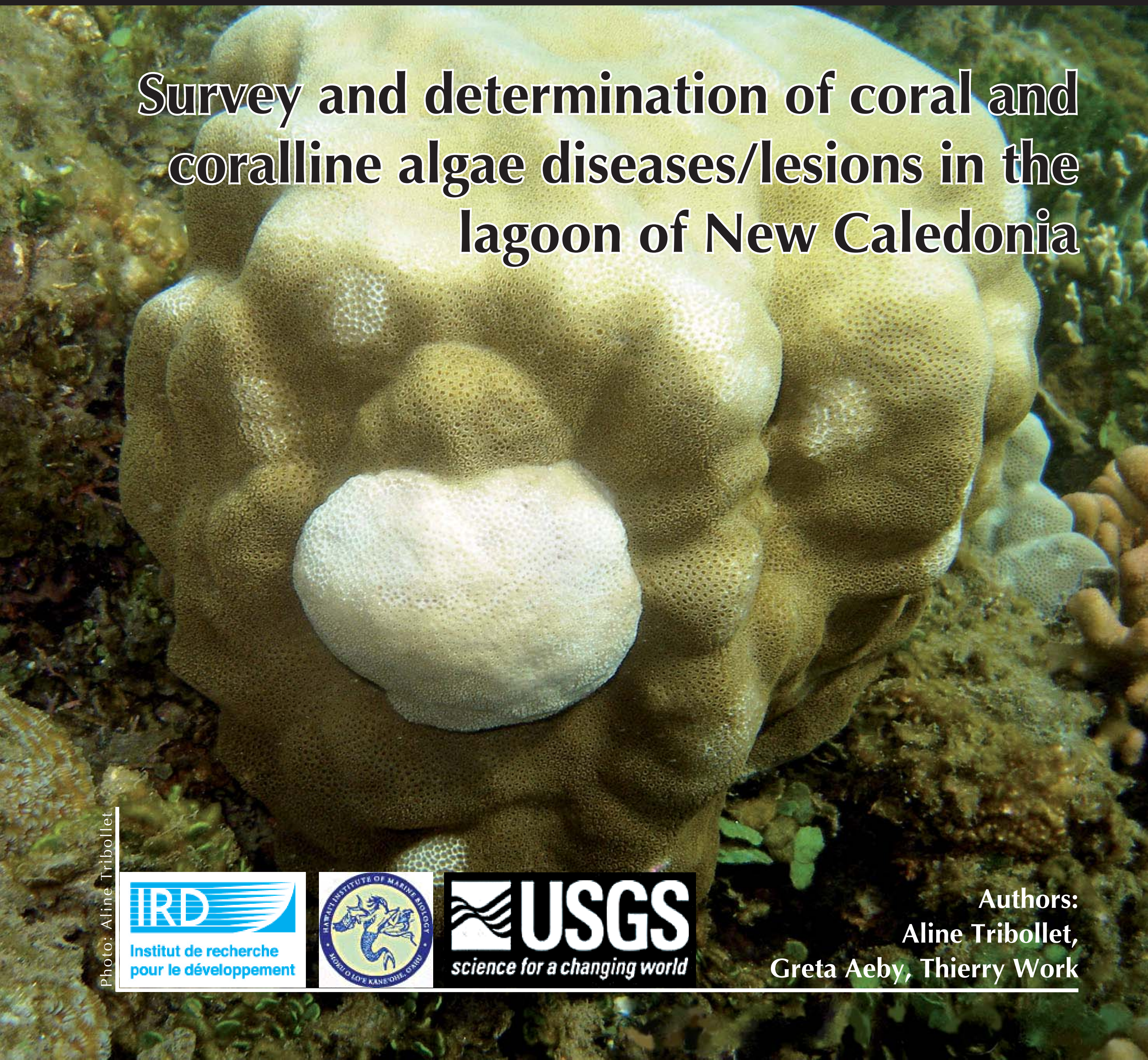
SCIENTIFIC REPORT



Survey and determination of coral and coralline algae diseases/lesions in the lagoon of New Caledonia

Photo: Aline Tribollet

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USGS science for a changing world

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The CRISP Coordinating Unit (CCU) was integrated into the Secretariat of the Pacific Community in April 2008 to insure maximum coordination and synergy in work relating to coral reef management in the region.

The CRISP Programme is implemented as part of the policy developed by the Secretariat of the Pacific Regional Environment Programme to contribute to the conservation and sustainable development of coral reefs in the Pacific.

The Initiative for the Protection and Management of Coral Reefs in the Pacific (CRISP), sponsored by France and established by the French Development Agency (AFD), is part of an inter-ministerial project that began in 2002. CRISP aims to develop a vision for the future of these unique ecosystems and the communities that depend on them and to introduce strategies and projects to conserve their biodiversity, while developing the economic and environmental services that they provide both locally and globally. CRISP also, has a role in fostering greater integration in this area between developed countries (Australia, New Zealand, Japan, USA), French overseas territories and Pacific Island developing countries.

The initiative follows a specific approach designed to:

- associate networking activities and fieldwork projects;
- bring together research, management and development endeavours;
- combine the contributions of a range of scientific disciplines, including biology, ecology, economics, law and social sciences;
- address the various land and marine factors affecting coral reefs (including watershed rehabilitation and management);
- avoid setting up any new body but supply financial resources to already operational partners wishing to develop their activities in a spirit of regional cooperation. This is why the initiative was established on the basis of a call for proposals to all institutions and networks.

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This approach is articulated through a series of thematic objectives:

Objective 1: Improved knowledge of the biodiversity, status and functioning of coral ecosystems.
Objective 2: Protection and management of coral ecosystems on a significant scale.
Objective 3: Development of the economic potential represented by the use values and biodiversity of coral ecosystems.
Objective 4: Dissemination of information and know-ledge; and capacitybuilding and leadership with local, national and international networks.

The CRISP Programme comprises three major components:
Component 1A: Integrated coastal management and watershed management

- 1A1: Marine biodiversity conservation planning
- 1A2: Marine Protected Areas
- 1A3: Institutional strengthening and networking
- 1A4: Integrated coastal reef zone and watershed management

Component 2: Development of coral ecosystems

- 2A: Knowledge, beneficial use and management of coral ecosytems
- 2B: Reef rehabilitation
- 2C: Development of active marine substances
- 2D: Development of regional data base (ReefBase Pacific)

Component 3: Programme coordination and development

- 3A: Capitalisation, value-adding and extension of CRISP programme activities
- 3B: Coordination, promotion and development of the CRISP programme
- 3C: Support to alternative livelihoods
- 3D: Vulnerability of ecosystems and species
- 3E: Economic task force

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Survey and determination of coral and coralline algae diseases/lesions in the lagoon of New Caledonia

by

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Acronym: "Coral diseases in New Caledonia"

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Country: New Caledonia

Locality: Lagoon of New Caledonia

Abstract

Coral reefs are increasingly threatened by various factors such as rising sea surface temperature, ocean acidification, pollutants, and terrigenous inputs resulting from climate change and human activities. Sediment stress on corals can lead mortality or morbidity with attendant loss of the substratum upon which many fish and invertebrates depend. The lagoon of New Caledonia is the largest in the world, and this unique ecosystem with high diversity of marine life and high rate of species endemism has merited its classification as a UNESCO World Heritage Site. To date no study has been carried out on the state of health of corals and crustose coralline algae. Such information is critical as New Caledonia has land use patterns such as mining and agriculture that can directly impact nearshore reefs in the form of runoff and landbased pollution A good indicator of the health status of a coral reef is the health of the corals that comprise that reef. We thus surveyed 14 nearshore and offshore reefs throughout the northern and western lagoon and documented prevalence of lesions on corals and crustose. Twenty three types of lesions and diseases were found in 92% of surveyed reefs in low abundance. They affected 12 genera of corals including the main reef framebuilders such as massive *Porites* and *Acropora*. The most common coral diseases encountered were *Porites* growth anomalies and *Acropora* white syndrome. Two crustose coralline algae diseases were observed, CCA white band disease and CLOD. Based on this first survey, the reefs of the lagoon of New Caledonia have uniformly low (< 3%) prevalence of lesions. However diseases such as white syndrome in acroporid corals should be monitored closely as such diseases have the potential to cause widespread and rapid loss of coral cover as seen in other regions of the Pacific and Western Atlantic. Results of this survey are a valuable first step to developing our understanding of coral reef health in the Lagoon of NC and provide a basis for more focused and comprehensive studies of this topic in the region.

Context and objectives of the project

Coral reefs are one of the most diverse and complex marine ecosystems allowing the survival of about 1/10 of the world population. Their resilience results from the maintenance of the balance between constructive and destructive forces. Constructive forces are mainly growth and calcification of corals and crustose coralline algae- the main reef framebuilders- while destructive forces are mostly bioerosion processes (Glynn 1997). Unfortunately, human activities and climate change are increasingly threatening this delicate balance by impacting both forces (Atkinson and Cuet 2008). Coral growth and calcification are negatively impacted by ocean acidification and rising sea surface temperature (Kleypas et al. 1999; Anthony et al. 2008), and the ability of corals to calcify is further compromised by dissolution of carbonate substrates by boring microflora (Tribollet et al. 2009) and eutrophication (Carreiro-Silva et al. 2005). Environmental factors can also affect, indirectly, reef framebuilder health by increasing the abundance of some predators (e.g. the sea star *Acanthaster planci*), and parasites (bacteria, microboring fungi) which can cause diseases or partial tissue loss (Antonius and Lipscomb 2001).

Recently, coral disease has emerged as a serious threat to coral reefs worldwide and a major cause of reef deterioration (Weil et al. 2006). The numbers of, species affected, and the distribution of diseases have all increased dramatically within the last decade (Porter et al. 2001, Green and Bruckner 2000, Sutherland et al. 2004, Weil 2004). Epizootics of coral disease have resulted in significant losses of coral cover. An outbreak of white syndrome (white band disease) in the 1980’s killed acroporid corals throughout the Caribbean (Glatfelter, 1982, Aronson and Precht, 2001), and a recent outbreak of white pox disease in the Florida Keys reduced the cover of *Acropora palmata* by up to 70% (Patterson et al., 2002). In the Caribbean, coral disease has been implicated as a major factor contributing to the decline of coral reefs resulting in ecological phase shifts from coral to algal-dominated ecosystems (Hughes, 1994, Aronson and Precht, 2001, Porter et al., 2001, Sutherland et al., 2004). Disease has also emerged as a problem within the Indo-Pacific. Willis et al. (2004) found a 20-fold increase in white syndrome on the Great Barrier Reef between 1998 and 2002. Disease outbreaks have also now been reported from across the Indo-Pacific including Hawaii (Aeby 2006), American Samoa (Work and Rameyer 2005), and Indonesia (Haapkyla et al. 2007). Increased anthropogenic stress on near shore environments, overfishing, and environmental conditions associated with global climate change have all been implicated as contributing to increases in observed disease levels (Harvell et al., 1999, 2002, Lipp et al.1999; Colwell 2004).

The Indo-Pacific region poses a serious challenge for the management of emerging coral diseases because it is significantly larger than the Caribbean and supports entire communities that depend on reefs for their livelihood (Hughes et al. 2003). Understanding disease dynamics on reefs within the Indo-Pacific is critical if we are to conserve these valuable and unique resources. Hampering our efforts to manage coral diseases is the lack of baseline information making it difficult to determine whether or not disease levels are changing through time. It is critical that we develop an understanding of what diseases occur on the reefs, how widespread they are and which species of coral are most affected. Baseline disease surveys also provide a basis to assess status and trends of coral reef health over time.

To date, no study or survey of coral diseases has been carried out in New Caledonia, a large island in the Southwest Pacific that has the longest continuous barrier reef in the world including fringing reefs, patch reefs, and double barrier reefs (Laboute and Richer de Forges

2004; Andréfouët et al. 2006). Currently, more species (8500) have been documented from New Caledonia reefs than any other reef area in the world (Payri and Richer de Forges 2006). In July 2008, about 60% of reefs were incorporated as a UNESCO World Heritage site because of their uniqueness and global significance in terms of biodiversity, endemism and beauty. However, reefs of New Caledonia are prone to both natural and man-made threats. Cyclones have been know to severely reduce coral cover (Wilkinson, 2008), and New Caledonia has an active nickel mining and agricultural industry that results in extensive runoff laden with pollutants that are particularly severe during the wet season (Fernandez et al. 2006). In addition, reefs are subject to episodic industrial chemical spills. For example, in 2009 thousands of liters of pure sulphuric acid were released from a Nickel mine close to a world heritage reef in the south lagoon of New Caledonia resulting in the loss of thousands of fish and invertebrates. It is thus urgent to acquire a baseline of the state of health of New Caledonian reefs if we are to disentangle effects of human activities and climate change which will impose its own set of impacts on coral reefs (Hoegh-Guldberg, 1999). Baseline surveys documenting coral reef health will aid governmental policy makers and local agencies bettering their endeavours to protect coral reefs in this tropical region while allowing sustainable development of local populations. It will also contribute to the survey of coral reefs worldwide as part of the Global Coral Reef Monitoring Network (Wilkinson 2008).

In this context, the main goal of the study was to determine the health status of coral and coralline algae in the lagoon of New Caledonia in near shore reefs comprising coastal reefs impacted by terrigenous inputs and/or anthropogenic activities such as mining pollutants and eutrophication, and comparatively less impacted offshore barrier reef, some of which are part of the world heritage (Fig. 1). We systematically documented lesions on corals and crustose coralline algae by surveying several reefs selected across the lagoon and hypothesized that corals and crustose coralline algae in more impacted near shore reefs would have higher levels of disease compared to offshore reefs. Our specific objectives were:

(1) To document the baseline levels of disease in the major genera of corals and coralline algae in New Caledonia (NC) by surveying two sites each in 7 inshore-offshore profiles around the "Grande Terre" (largest island of New Caledonia, Fig. 1).

(2) To systematically describe gross and microscopic morphology of lesions in corals

(3) To identify microscopically filaments of the boring microflora which live in coral skeletons underneath lesions and diseases. Some boring filaments such as fungal filaments have been identified as parasites of coral tissues and may be responsible for coral diseases or death of unhealthy coral tissues (Bentis et al. 2000; Golubic et al. 2005).

This is the first study where both coral tissues and skeletons are simultaneously investigated to determine potential pathogens responsible for lesions and/or diseases.

Material and Methods

Studied sites

Six inshore-offshore profiles were studied across the lagoon of New Caledonia (Fig. 1) and one set of surveys conducted in front of the nickel processing plant and a paired reef further out away from the plant between the 25th of January and the 5th of February 2010. For logistic reasons, they were mostly located on the west coast of the Grande Terre, from south to north (Table 1). Only one profile was located on the east coast, around the Col d'Amos area. Inshore fringing reefs were usually ranged between 1 and 4 m depth, while offshore reefs were located on the outer reef slope between 10 and 16 m depth. Only one lagoonal site was studied (Sèche croissant) with a water depth of about 3-5 m. It was located near Nouméa city. Table 1 provides the list of names of studied reefs and a brief description. Figure 2 highlights each surveyed reef structure and turbidity.

In situ observations and collection

The baseline levels of coral and crustose coralline disease at each of the selected sites were documented using two 25 m x 2 m belt transects with visual counts (total 100 m^2 area of reef). Two transect lines were laid end to end along depth contours separated by approximately 5 meters. A team of five divers swam along transect, with one diver identifying and enumerating coral colonies (Work & Aeby 2006). Corals were identified to the genus level and substrate characteristics were documented by point-intercept method whereby the substratum underlying the tape measure was recorded at 50 cm intervals. These protocols have been used successfully for broad-scale disease surveys in other areas of the Indo-Pacific (Aeby, 2006, Williams et al. 2008, Work et al. 2008a,b). The average percent coral cover and colony density per m^2 were determined from the diver surveys. Assessment of the number of diseased colonies per m^2 was determined from the diver surveys. As time allowed, the reefs were further searched for other signs of coral disease and to develop coral species occurrence lists.

Laboratory analyses

Histological approach of pathogens in coral tissues

For characterization of gross lesions, entire colony and lesions were photographed with a digital camera. The following data were recorded: date, location, and depth of collection. Grossly, lesions were classified into three broad categories including tissue loss, discoloration, and growth anomaly. Tissue loss was characterized as acute, subacute or chronic (Work & Aeby, 2006). Discoloration was subdivided into bleaching (white discoloration), mottling (multiple large irregular coalescing areas covering the colony), dark spots (Work*, et al.*, 2008), CLOD for coralline lethal orange disease (Littler & Littler, 1995), and other for all patterns of discoloration not fitting the aforementioned categories. Growth anomalies were categorized as described (Work*, et al.*, 2008). Modifiers of lesions were as follows: 'diffuse' comprised lesions continuous over ≥ 20% of the colony, 'localized' were lesions confined to < 20% of the colony, and 'multifocal' consisted of multiple (>10) small (2-5 mm) areas over the colony. Gross lesions were not mutually exclusive.

For histopathology, coral fragments (2-5 g) were collected with chisel or bone shears and placed into individually numbered whirlpak bags in seawater. Fragments with lesions were collected ensuring that normal and lesioned tissues were incorporated. When possible, paired apparently normal fragments were also collected. Fragments were fixed in Z-Fix (Anatech Ltd.) diluted 1:5 with seawater within 90 min of collection and allowed to fix for at least 24 h. Corals were decalcified in dilute formic acid/formaldehyde solution (CalExII, Fisher Scientific) until the skeleton was completely dissolved. Tissues were dehydrated in alcohol series, embedded in paraffin, sectioned at 5 µm, placed on microscope slides and stained with hematoxylin and eosin.

Microscopic changes were broadly categorized as Tissues, Zooxanthellae, or Invasives. Tissue changes included suspect wound repair, mucus deposition, tissue fragmentation, abnormal polyp development, necrosis, atrophy, or cellular infiltrates (pigment or granular cells). Zooxanthellae changes included vacuolation or depletion. Invasives included sponges, algae, fungi, cnidaria, crustacea, cyanobacteria, or unidentified metazoan. Microscopic changes were not mutually exclusive, and in such cases, the most severe change took priority when assigning categories.

Petrographic approach of boring microflora in coral skeletons

Fragments of corals and CCA were collected to investigate endolithic biota from fragments with and without lesions (and healthy portions for control). Samples were preserved in zinc formalin or silicate gel for later molecular analysis of microborer diversity as it remains poorly understood, especially that of the chlorophyte of the genus *Ostreobium*. Skeletal fragments (< 1 cm^3) were embedded in a specific resin (araldite) after several baths of ethanol and acetone for dehydration, sectioned (20-30 µm), and stained with Toluidine blue. This technique highlights microborers (cyanobacteria, microalgae and fungi), possible interactions between microborers and coral/CCA tissues, and determination of species by light microscopy (Tribollet et al. 2002). .

Results/Discussion

Coral reef characteristics

Thirty eight coral genera were identified with the numerically dominant coral genera found to be *Acropora* (avg. 43% of the coral community), *Porites* (avg. 11.7%) *Montipora* (avg. 11.0%) and *Pocillopora* (avg. 6.8%) (Table 2). Coral cover ranged from 7.8% to 83.3% (avg.= 35.3%), an average higher than that reported during earlier surveys (27%, range 5-48% based on 10 sites surveyed in 2008; Wilkinson 2008). In those surveys, Wilkinson

(2008) recorded coral cover ranging from 20% to 40% in 2007 in Noumea, but location of surveyed sites was not indicated. In contrast, in our surveys, coral cover ranged between 9% and 33% in 2010 if we include data from Baie des Citrons and Mbere reef (Dumbea pass). This is in the range of previous surveys and suggests that coral reefs in the lagoon are recovering because in 2003, cyclone Erica destroyed between 10-80% of live coral cover in that region (Wilkinson 2008).

Overall coral cover did not differ significantly between offshore and inshore reefs (Fig. 3), however, offshore reefs had a higher number of coral genera (avg. = 26) as compared to inshore reefs (avg. =16) and there was a shift in the coral genera found in the different habitats. Sediment-tolerant corals such as *Porites* comprised an average of 21.4% of the coral community on inshore reefs as compared to 5.1% on offshore reefs. Many of the inshore reefs also had evidence of fish grazing (probably parrotfishes) and extreme sediment stress (Fig. 2 F, H, J, L, N) that never occurred on offshore reefs (Fig. 2 A, C, E, G, I, K, M). For example, the site in front of the nickel mine, Banc des Japonais, was a sediment filled area with few live corals remaining (Fig. 2F). Crustose coralline algae cover was significantly higher on offshore (avg. cover =17.8% SE$\pm$6.1%) compared to inshore reefs (avg. cover =2.3% SE$\pm$1.4%) (t-test, $p < 0.01$; Fig. 3). Crustose coralline algae grow preferentially in areas of strong surge and water motion such as reef crests (Adey 1998). Genera of crustose coralline algae (CCA) are difficult to identify in the field, so we limited our identifications to the two easily recognized genera: *Neogoniolithon* and *Hydrolithon,* both of which are abundant on offshore New Caledonian reefs.

High sedimentation and turbidity reduce light intensity reaching zooxanthellae inside coral tissues and negatively impact coral colony metabolism and health (Riegl & Branch 1995; Garren et al. 2006; De'ath and Fabricius 2010). This is a problem for corals because zooxanthellae are the main symbionts of corals covering a large part of their energy needs

(Houlbreque & Ferrier-Pages 2009). Nevertheless, autotrophic microborers (cyanobacteria and algae; see Tribollet 2008a) can also cover part of the energy needs of corals, especially during bleaching events (Fine and Loya 2002) and are also affected by reduced light (Tribollet 2008b). In turbid environments, corals also spend a lot of energy in producing mucus to remove sediment on their tissues (Riegl & Branch 1995). Severe sedimentation results in abrasion of coral tissues and loss of tissues (pers. observ. at different inshore reefs including Banc des Japonais). However, not all nearshore reefs are impacted by sedimentation. For example, Sèche Croissant (Fig. 2E) which is a lagoonal reef located near Nouméa city was a healthy reef with 81.4% coral cover.

Coral and CCA lesions

Twenty three types of lesions/diseases were found for corals, and two for CCA (Table 3). Coral lesions/diseases affected 14 genera out of the 38 identified (*Porites*, *Acropora*, *Goniastrea*, *Montipora*, *Galaxea*, *Pachyseris*, *Leptoseris*, *Pavona*, *Favia*, *Cosinaria*, *Pectinia*, *Astreopora*, *Turbinaria*, *Platygyra*) and all coral morphotypes (branching, massive with small and large polyps, encrusting and tabular-foliose corals). The most common coral diseases (Fig. 4) were *Porites* growth anomaly (Fig. 5A), suspected *Porites* trematodiasis (Fig. 5B: multifocal discoloration that could be due to trematodiasis), and *Acropora* white syndrome (Fig. 5C, D). In Hawaii, multifocal discoloration in *Porites* is often associated with a parasitic infection (trematodiasis parasite) which can adversely affect coral growth (Aeby 1991) . Growth anomalies have also been reported on *Porites* in Hawaii (Domart-Coulon et al. 2006; Aeby 2007) but little is known about the effect of growth anomalies on coral health. Similarly, bleaching is a reversible process and does not always lead to death. In contrast, the white syndrome on *Acropora* kills coral tissues and potentially the entire colony. In the

Caribbean, a major event of white syndrome as well as white pox on acroporids had dramatic consequences on coral reef structure. Reefs lost their rugosity (3D dimension), diversity and thus habitat diversity and ultimately their economic role (tourism attraction, fishing; Gladfelter 1982; Patterson et al. 2002). White syndrome in acroporids may be induced by elevated sea surface temperature above the maximum usually encountered in the studied reef (Harvell et al. 2001, 2002; Bruno et al. 2007). No single etiological agent has so far been found for *Acropora* growth anomalies (Work et al., 2008a).

Prevalence of diseases/lesions varied among coral genera; the most susceptible to disease was the tabular coral *Turbinaria*, followed by the massive corals *Goniastrea*, *Porites*, *Coscinaria* and *Astreopora* (Fig. 6). This prevalence was however low with less than 3% of the studied colonies of *Turbinaria* affected by diseases and less than 1% for the other corals. Thus surveyed reefs of NC, especially offshore reefs appear relatively healthy although all characteristics of reef health status were not recorded (species richness, habitat diversity, etc). Crustose coralline algae were affected by white band disease and coralline lethal orange disease (CLOD) (Fig. 7B) which is due to infection by unknown bacteria (Littler & Littler 1995). CLOD has been known in the Indo-Pacific since 1994 and has been reported in many U.S. reefs since then (Vargas-Angel 2010). However, this is the first time that CLOD and the white band disease of CCA are reported from the very south-west of the Pacific Ocean. These diseases were found at 6 sites out of the 14 surveyed, and all were offshore sites where CCA cover averaged 18 ± 6% (Fig. 3). These findings highlight the global distribution of CCA diseases and the need for a better understanding of disease dynamics, pathogen identification, and implications in maintenance of coral reefs in the context of climate change. CCA are indeed the second major reef framebuilders, contributing to reef accretion, cementation, sedimentation, primary production and coral settlement (Adey 1998; Harrington et al. 2004).

Coral disease prevalence was significantly higher at inshore reefs than at offshore reefs (Fig. 9) (0.3 ± 0.09 % and 0.1± 0.03 % respectively; t-test, $p < 0.01$) with the NE inshore reef Neangaon having the highest prevalence (Fig. 8). . Gué was the only offshore reef with a higher prevalence of coral disease than at the inshore reef, Casy. This probably results from the fact that the surveyed reef around Casy Island was located on the leeward side of the island, harbouring almost 100% of coral cover dominated by *Acropora* colonies (Fig. 2B). Aside from tissue loss resulting from fish predation (corallivorous fishes) seen on *Acropora*, very few diseases were observed at Casy reef. The higher number of lesions and diseases found at inshore reefs confirms trends observed by others. Haapkylä et al. (2010) showed that seasonal rainfall and runoffs promote coral diseases at inshore reefs such as growth anomalies. In our study, inshore reefs in New Caledonia had more *Porites* growth anomalies than offshore reefs (Fig. 9C, D) confirming this trend. Sedimentation is a physical cause of stress to corals and may favor proliferation of coral pathogens (Haapkylä et al. 2010). Thus, a trend exists whereby coral cover between offshore and inshore reefs is similar, yet disease plays a disproportionate role in inshore reefs. Future studies might consider measuring impacts of sediments on nearshore reefs in a more systematic manner (see recommendations at end of report).

Microscopic observations of live tissues

One hundred and four colonies comprising 37 species of coralline algae, scleractinian, and soft corals were photographed and sampled for histopathology (Table 4) from 14 locations (Table 5). Fragments manifesting discoloration were most often collected followed by tissue loss and growth anomaly (Table 6). For discoloration, bleaching was the most commonly sampled lesion followed by multifocal discoloration, localized discoloration, dark spot or mottling, CLOD or other (Table 6; Fig. 7). For tissue loss, acute comprised the majority of samples followed by subacute and chronic tissue loss (Table 6; Fig. 9). Nodular growth anomalies (n=8) predominated in samples followed by umbonate (n=5), and one each exophytic and crateriform (Fig. 9E, F).

For invasives, fungi and crustacea were the most commonly encountered organisms followed by algae or unidentified metazoa, molluscs, cnidaria or sponges, and cyanobacteria. Invasives were more often associated with discoloration (30%) followed by growth anomalies (21%) and tissue loss (10%). The crustacea of the genus *Balanus* are very commonly seen colonizing the surface of massive corals such as *Porites* cause a localized pink swollen discoloration (Benzoni et al. 2010) that could be confounded with *Trematodiasis*. Confirming *Trematodiasis* in corals requires documenting the characteristic trematode cercaria in affected corals under light compound or dissection microscopy (Aeby 2007). In this study, we did not see evidence of trematodes on histology. Future efforts to confirm trematodiasis should include examining affected coral tissues under the dissecting scope; a method used successfully to diagnosis trematodiasis in Hawaii.

Tissue changes were seen in 85% of tissue loss cases followed by 64% of growth anomalies and 47% of discoloration cases. The most common tissue change was necrosis followed by fragmentation or polyp malformation, cellular infiltrates or wound repair, and hypertorphy or cellular infiltrates. Zooxanthella changes were seen most often in discoloration (23%) versus growth anomaly (9%) with no such changes seen in tissue loss. Depletion of zooxanthellae was the most common zooxanthellar change (Table 7).

Microscopic observations of coral skeletons

Endolithic organisms were studied in five types of lesions/diseases: abnormal growth in *Turbinaria*, *Pavona* dark spot, *Acropora* white syndrome (it will be called here *Acropora* sp1), *Acropora* tissue loss because of fish grazing (corallivorous fishes) called here *Acropora* sp2, and *Pachyseris* white syndrome. These corals were collected at Gué and Casy along the inshore-offshore profile located in the southern part of the lagoon of New Caledonia. Diseased and healthy pieces for each coral were compared to highlight differences in boring microflora diversity and abundance, as well as possible interactions between boring filaments and coral tissues. In all corals, the chlorophyte of the genus *Ostreobium* dominated microboring communities (Fig. 10). Filaments of fungi were sometimes observed. Abundance of *Ostreobium* filaments varied greatly between coral samples, and between healthy and diseased skeletons.

In healthy parts of *Turbinaria,* which is a tabular coral fully covered by live tissues on both its faces, filaments of *Ostreobium* were present in low abundance and evenly distributed between the upper face of the coral exposed to light, and the bottom face. In the abnormal growth area, coral tissues appeared intact although they were pale (depletion of zooxanthellae). *Ostreobium* filaments were rarely observed, and only in the center of the coral skeleton. No filament of fungi was observed in the protuberance. This suggests that the protuberance growth was fast and that microborers could not keep up with it. The abnormal growth in *Turbinaria* appears to behave differently from that observed on *Porites compressa* in Kaneohe Bay reefs. Protuberances on *P. compressa* are heavily colonized by boring fungi (Domart-Coulon et al. 2004, 2006). It has been suggested that boring fungi in this case may be responsible for the abnormal growth on *P. compressa* but to date no proofs have been provided. Endolithic algae in corals have been considered neutral or even beneficial to coral hosts, whereas fungi were considered parasitic and associated with coral diseases (Raghukumar & Raghukumar 1991; Alker et al. 2001; see Review by Tribollet 2008a).

Boring fungi colonize live corals for food, parasitizing both coral organic matrix inside skeletons, polyps and other microborers (especially *Ostreobium*) (Golubic et al. 2005; Tribollet 2008a). Such attacks are accompanied by the release of a dark tannin-like substance that stains fungal filaments, algal filaments and to some extent coral skeleton (aragonite). Concentrations of endolithic fungi associated with black bands in the interior of the coral skeleton were observed earlier by Bak and Laane (1987) and considered to be annual. It is now known that extensive parasitism of fungi on algae in coral skeletons converts green bands produced by algae into black bands (Priess et al. 2000).

In healthy parts of *Pavona* which is a foliose coral with a live upper surface and a dead bottom face, boring filaments of *Ostreobium* were abundant throughout the skeleton, but decreased slightly from the bottom face to the upper face. In the dark spot area, fungal filaments were expected to be in abundance to provide the dark colour (Work et al. 2008b). Instead, *Ostreobium* filaments were extremely abundant, much more than in healthy parts, and very rare filaments of fungi were observed. Live coral tissues on the upper face in the dark spot area were discontinuous (damaged). Thus, the high abundance of *Ostreobium* filaments may have caused the dark appearance of *Pavona* in this area of the colony.

In the healthy parts of *Acropora* sp1 which is a fast growing branching coral, *Ostreobium* was in low abundance and evenly distributed in skeletons. In the area of white syndrome, *Ostreobium* filaments were significantly more abundant (twice the amount in healthy parts) and evenly distributed in the skeleton. Fine and Loya (2002) showed that during slow bleaching, microborer communities bloom as they receive more light intensity and the coral growth slows down.

In the healthy parts of *Acropora* sp2, *Ostreobium* was in very low abundance and mostly observed in the center of the studied branch. In contrast, in the tissue loss area, *Ostreobium* filaments were abundant and present across the skeleton. Abundance of filaments decreased from the center of skeletons to the coral tissue layer. Tissue loss here, probably due to corallivorous predation, induced probably a bloom of microborers, similarly to the case of Acropora white syndrome (*Acropora* sp 1).

In the healthy parts of *Pachyseris*, which is a tabular coral alive on the upper face and dead on the bottom face, abundance of *Ostreobium* filaments was relatively high and decreased from the bottom face to the upper face. In the parts of the coral affected by white band disease, abundance of *Ostreobium* increased a lot on the bottom face but did not change on the upper face. No particular interactions between filaments of microborers and coral tissues were observed.

Under the microscope, *Ostreobium* presents very polymorphic filaments (Fig. 10), which can not be attributed to different species or sub-species. Some are narrow and straight (diameter of 1-4 µm), others are large and straight or ramifying and wandering (diameter > 5 µm). To date, all filaments are identified as *Ostreobium quekettii*, Bornet and Flahault (1889). The preliminary molecular analysis (PCR method and sequencing using Rbcl gene) carried out as part of this project on *Porites* samples collected across the lagoon of New Caledonia revealed an important diversity within the genus of *Ostreobium*. At least four major "clades" can be distinguished at this stage but this trend needs to be confirmed by further analyses.

Conclusions/Recommandations

- These baseline surveys represent an important first step in conserving the reefs of New Caledonia.
- Surveys should be expanded to encompass all regions around the island and a monitoring program initiated. Anthropogenic stressors combined with global climate

change are placing all coral reefs at risk. It's important to take a pro-active approach if coral reefs are to be maintained.

- The inshore sites appear to be severely impacted by land-based pollution possibly influencing the prevalence of *Porites* growth anomalies.
- Data on environmental conditions (temperature, salinity, sedimentation, etc) should be documented and compared between inshore and offshore reefs to identify which of the main environmental factors induce diseases in corals and crustose coralline algae.
- The coral genera most susceptible to disease include *Turbinaria, Porites*, *Goniastrea* and *Acropora*.
- Diseases of concern include *Porites* growth anomalies and *Acropora* white syndrome. Suspect *Porites* trematodiasis is also very common but causes limited pathology to coral colonies. Trematodiasis still needs to be confirmed through identification of parasitic metacercariae.
- *Acropora* white syndrome has caused the highest mortality on other Indo-Pacific reefs (e.g. on the Great Barrier Reef; Willis et al. 2004) and is present on the reefs of New Caledonia so should be monitored closely.
- Studies should be initiated on the effect of *Porites* growth anomalies on the health and resilience of coral colonies.

Communication/popularization

As part of this project, a scientific meeting was organized at the end of field work in 2010 (6th of February) to report first observations to the scientific community at IRD. A large public event was then organized in July 2010 to popularize coral reef health and functioning in the context of climate change at the auditorium of IRD in Nouméa (Province Sud).

Authorities including persons working at the Environmental Department of the South and North Provinces, Aquarium of Nouméa, and NOGs were invited at this large meeting. As part of the workshop organized by OEIL (Observatoire de l'Environnment en Nouvelle-Calédonie) on potential indicators that could be used to better monitor coral reefs, held in Nouméa in October 2010, the topic of coral diseases and coral reef health received much more attention. All partners including governmental agencies-authorities, NGOs, private companies including the mining industry GORO-Nickel, and the scientific community working in New Caledonia (IRD, IFREMER, SPC, etc) were present at this workshop and showed their interest. Coral diseases, especially white syndrome of *Acropora* appeared as a potential good indicator of reef health which could be monitored in a close future. Aline Tribollet, the coordinator of the present project, highlighted the necessity of finalizing the first step of the monitoring programme of coral diseases in New Caledonia, i.e. the necessity of visiting the same 14 sites one year later. This is in order to consolidate the first baseline obtained in 2010. This baseline will serve as the "reference point" for future monitoring programmes of coral reef health and coral diseases in New Caledonia. Thus, A. Tribollet issued a call for funding to return on the field in 2011 to the assembly of OEIL. A proposal was submitted to Fonds Pacifique in December 2010 for this purpose. Results should be provided around April 2011. If funding is obtained, field work should occur in May 2011, i.e. 15 months after the first survey.

In addition, outreach cards were produced, both in French and English, to report basic knowledge about coral and CCA lesions/diseases in the lagoon of New Caledonia. A set of cards will be given to Mina Vilayleck, the head of the communication office at the Center of IRD in Nouméa, technicians of the Department of Environment in South and North Provinces, BIOCENOSE and CRISP (SPC). Basic knowledge in order to identify coral lesions versus coral diseases underwater was taught to Gregory Lasne, director of

BIOCENOSE, during the field work in 2010. This should promote surveys of coral diseases in New Caledonia.

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Tables

Table 1. Site names, location, date of sample collect and surveys, and brief description of reefs.

Date	Site	Location	Depth (m)	Latitude (S)	Longitude (E)	Brief description of reefs
1.25.10	Passe de Ourai (Ouano 1)	offshore	10-12	21 50.812	165 42.854	Good visibility, high coral cover ~60%, one Crown of Thorn starfish seen on transect
1.25.10	Chenal de Teremba (Ouano2)	inshore	3-5	21 50.187	165 45.063	Visibility about 3m, sediment, surge, lots of large *Porites* mounds, dead *Acropora* skeletons
1.26.10	Kone Pass	offshore	10-15	21 07.889	164 42.190	Coral cover ~45%, drupellids
1.26.10	Krefiat reef	inshore	2-4	21 07.329	164 43.010	Surge, murky, tape laid on top of patch reef, a lot large porites mounds
1.27.10	Gazelle pass	Offshore	9-10	20 23.046	164 56 223	Visibility of 15-20m, spur & groove, soft corals, coral cover very high
1.27.10	Pouerabate pointe	inshore	1-2	20 17.999	164 04.643	Murky, surge, visibility of 1m, high sediment stress, a lot of bleached *Galaxea*
1.28.10	Amos pass	offshore	10-12	20 12.439	164 27.189	Visibility of 20m, spur & groove
1.28.10	Neangaon	inshore	1-2	20 15.644	164 24.822	Visibility of 3-5m, sediment stress, lots of butterfly fishes, lots of boring organisms in coral, coral growing over tubes into weird shapes
2.1.10	Gue	offshore almost	8-9	22 21.585	166 57.519	Just on the inside of the barrier reef; high coral cover; visibility of 15m, gentle slope; Cowrie (Ovuela ovum) eating soft coral
2.1.10	Casy	inshore	6-7	22 21.155	166 50.305	Solid stands of fine branching *Acropora* (almost 100% of cover); visibility of 10m; calm water
2.2.10	Mbere reef (Dumbea pass)	offshore	6-7	22 31.585	166 57.519	Visibility of 10 m, surgy, outerslope with spur and grooves
2.2.10	Baie des Citrons	inshore	1-2	22 17.730	166 26.100	Area just in front Nouméa city, beach with hotels, bars and restaurants
2.3.10	Banc des Japonais	Inshore	11-13	22 15.541	166 24.808	In the lagoon in front of nickel industry; dead reef, lots of sediment, visibility <1m;patchy corals hanging onto life
2.3.10	Sèche Croissant	Lagoonal	3-4	22 19.589	166 22.712	Patch reef, visibility of 15m, staghorn *Acropora* beds, lots of fishes

Table 2. Coral community structure on the 14 reefs surveyed in January-February 2010 in the New Caledonian lagoon. Data represent the proportion of coral colonies belonging to each of the coral genera identified within belt transects. Dominant coral genera for each site in bold. # col /m^2: coral colony density per square meter.

Offshore reefs	Ouano pass	Kone Pass	Gazelle Pass	Amos Pass	Gue	Mbere reef
Acanthastrea	0	0,6088	0,0954	0,432	0,59	0,9777
Acropora	**41,79**	**31,35**	**57,63**	**48,1**	**15,04**	**25**
Anacropora	0	0	0	0	0	0
Archrelia	0	0	0	0	0	0
Astreopora	0	0,6088	0	0,288	0,295	0,6983
Barabattoia	0	0,6088	0	0,288	0	0
Coscinaraea	0,319	0,3044	0,5725	0,144	1,1799	0,2793
Cyphastrea	0,638	0,4566	0,5725	0,432	7,3746	0,9777
Diploastrea	0	0	0	0,576	0	0
Echinophyllia	0	0,3044	0,3817	1,441	0,59	0,6983
Echinopora	0,7974	1,6743	1,0496	0,72	0	0,1397
Favia/Favites	**5,582**	**8,524**	4,2939	6,196	**10,47**	**7,682**
fungiiadae	0	2,4353	0,0954	2,017	5,0147	0,6983
Gardinoseros	0,1595	0,3044	0,0954	0	0	0
Goniastrea	0,1595	0,4566	0,6679	0,865	0,7375	0,1397
Goniopora/Alveo	0,638	0	0	0	0,59	0,5587
Galaxea	5,2632	3,3486	1,4313	1,585	2,2124	5,8659
Hydnophora	2,0734	3,8052	0,4771	1,153	0	2,3743
Leptastrea	0	0,3044	0	0,288	1,9174	0,838
Lepto/Pachyseris	0	0	0	0,144	1,1799	0
Lobophyllia/Symphillia	2,3923	1,6743	0	1,441	3,2448	0,5587
Merulina	0	3,5008	0,3817	0,432	1,0324	0,2793
Millepora	1,9139	1,3699	0,6679	0,865	0,1475	2,6536
Montastrea	1,4354	1,6743	0,6679	0,288	2,5074	5,3073
Montipora	**15,63**	**8,828**	**5,344**	**7,2**	**14,31**	**11,59**
Mycedium	0	0	0	0	0,295	0
Oxypora	0,319	0	0	0,144	1,1799	0
Pavona	1,5949	5,6317	3,0534	1,585	5,0147	2,095
Pectinia	0	0	0	0	0	0
Platygyra/Leptoria	3,5088	4,2618	0,5725	2,594	2,8024	2,3743
Pocillopora	11,005	7,7626	**14,12**	**10,4**	5,6047	6,2849
Porites	0,9569	1,0654	2,8626	4,323	4,7198	16,899
Pssamocora	0,4785	0,3044	0,6679	0,576	1,4749	0,5587
Seriatopora	0,1595	0,4566	0	0	2,2124	0
Stylocoeniella	0	0	0	0	0,59	0
Stylophora	2,8708	7,7626	4,2939	4,467	5,3097	3,352
Scolymia	0,1595	0	0	0	2,2124	0,2793
Scapophyllia	0	0	0	0	0	0,2793
Turbinaria	0,1595	0,6088	0	1,009	0,1475	0,5587
Sinularia/soft coral	0	2,3774	0	0	0	0
Palythoa	0	0	0,1905	0	0	0
tot # genera	24	28	21	27	29	27
# col / m2	12,54	13,14	20,96	13,88	13,56	14,32
coral cover (%)	46,1	46,1	46,1	27,5	48	8,8
CCA cover (%)	19,6	31,4	38,2	13,7	1	2,9

Inshore reefs	Ouano inshore	Krefiat reef	Pouerabate	Neangaon	Casy	Citrons Bay
Acanthastrea	0	0,7782	0	0	0,2	0
Acropora	**23,585**	**37,35**	**59,77**	**32,36**	**57,6**	**32,3**
Anacropora	0	0	0	0	4	0
Archrelia	0	0	0	0	0,2	0
Astreopora	0	0,3891	0	0,2653	3,6	0,1946
Barabattoia	0	0,3891	0,3831	0,2653	0	0
Coscinaraea	0	1,1673	0	0,5305	0	0,1946
Cyphastrea	0,9434	1,1673	0	0	3,4	0,5837
Diploastrea	0	0	0	0	0	0
Echinophyllia	0	0	0	0	1,8	0,7782
Echinopora	0	0	0,3831	0,2653	0,4	3,1128
Favia/Favites	2,83019	1,9455	3,8314	6,1008	1,6	5,4475
fungiiadae	0	0	1,9157	0,7958	**4,2**	0,5837
Gardinoseros	0	0	0	0	0	0
Goniastrea	0	0	**7,28**	0	0	0,5837
Goniopora/Alveo	0	0	0	0	0,2	0
Galaxea	1,88679	0,3891	2,2989	3,183	3	0,9728
Hydnophora	0	0	0,7663	0	0	0,1946
Leptastrea	0	0,7782	0	0	0	0,1946
Lepto/Pachyseris	0	0	0	0	2,4	0
Lobophyllia/Symphillia	0	0	0,7663	0	0,8	0,9728
Merulina	0	0	0	0	0	0,3891
Millepora	0	0	0	0,2653	0	0,9728
Montastrea	0	0	0,7663	0,7958	0	0,7782
Montipora	2,83019	12,84	**13,03**	**24,14**	8	**14,98**
Mycedium	0	0	0	0	0	0
Oxypora	0	0	0	0	0	0
Pavona	0	0	0	0,5305	**3,8**	2,9183
Pectinia	0	0	0	0,2653	0	0,1946
Platygyra/Leptoria	0,9434	0,3891	2,2989	1,061	0	0,3891
Pocillopora	**5,6604**	**20,62**	2,682	3,183	0,2	6,2257
Porites	**61,321**	**21,01**	3,0651	**15,65**	3,2	**24,12**
Pssamocora	0	0,7782	0,3831	2,6525	0,8	1,9455
Seriatopora	0	0	0	0	0,2	0
Stylocoeniella	0	0	0	0	0	0
Stylophora	0	0	0	6,8966	0	0,9728
Scolymia	0	0	0	0	0,4	0
Scapophyllia	0	0	0	0	0	0
Turbinaria	0	0	0,3831	0,7958	0	0
Sinularia/soft coral	6,19469	6,2044	12,121	0	0	0
Palythoa	0	0	0	0	0	0
tot # genera	8	14	14	17	19	23
# col/m2	2,12	5,14	5,22	7,54	10	10,28
coral cover (%)	17,6	11,8	7,8	47,1	83,3	33,3
CCA cover (%)	8,8	2,9	0	2	0	0

Table 3. List of coral and crustose coralline algal diseases and acronymes.

Full name	**Acronyme of coral disease**
Porites growth anomaly	Por GA
Porites trematodiasis	Por TRM
Porites multi-focal bleached spots	Por MFBLS
Acropora white syndrome	Acro WS
Acropora white band disease	Acro WB
Acropora growth anomaly	Acro GA
Pavona white syndrome	Pav WS
Pavona discoloration	Pav DS
Favia discoloration	Fav DS
Favia growth anomaly	Fav GA
Montipora white syndrome	Mont WS
Montipora growth anomaly	Mont GA
Turbinaria white syndrome	Turb WS
Turbinaria growth anomaly	Turb GA
Platygyra discoloration	Platy DS
Goniastrea growth anomaly	Goni GA
Goniastrea discoloration	Goni DS
Pectinia white syndrome	Pec WS
Pachyseris white syndrome	Pach WS
Galaxea white syndrome	Galax WS
Leptoseris discoloration	Lept DS
Cosinaria white syndrome	Cosin WS
Astreopora white syndrome	Astreop WS
Crustose coralline algae white band disease	CCA WD
Coralline lethal orange disease	CLOD

Table 4. Number of samples and colonies sampled for gross and microscopic examination from 24 January 2010 to 2 February 2010.

Organism	**Coralline algae**	**Scleractinia**	**Soft Coral**	**Samples**	**Colonies**
Algae Coralline	5			5	5
Acanthastrea hemprichii		1		1	1
Acropora branching		16		16	8
Acropora florida		6		6	3
Acropora formosa		2		2	1
Acropora kyrstiae		2		2	1
Acropora mirabilis		2		2	1
Acropora paniculata		2		2	1
Acropora plating		5		5	3
Acropora seriata		2		2	1
Astreopora listeri		1		1	1
Astreopora myriophthalma		4		4	3
Coscinaraea columna		1		1	1
Echinopora sp.		2		2	1
Favia sp.		4		4	3
Favia truncatus		1		1	1
Favites pentagona		1		1	1
Favites sp.		4		4	4
Favites stylifera		1		1	1
Fungia concinna		2		2	2
Galaxea paucisepta		2		2	1
Goniastrea sp.		1		1	1
Leptoria phrygia		4		4	2
Merulina scabricula		4		4	2
Montipora malampaya		2		2	1
Montipora millepora		3		3	2
Montipora sp.		14		14	9
Pachyseris speciosa		4		4	2
Pavona varians		4		4	4
Platygyra daedala		1		1	1
Pocillopora damicornis		2		2	1
Pocillopora verrucosa		1		1	1
Porites annae		2		2	1
Porites massive		32		32	23
Sinularia sp.			12	12	5
Stylophora pistillata		2		2	1
Symphyllia recta		2		2	1
Turbinaria mesenterina		2		2	1
Turbinaria retiformis		4		4	2
Total	5	145	12	162	104

Table 5. Number of colonies of marine organisms sampled for gross and microscopic examination from 24 January 2010 to 2 February 2010 partitioned by location and group.

Location	**Coralline algae**	**Scleractinia**	**Soft Coral**	**Total**
Baie Des Citrons		7		7
Banc Des Japonais		9		9
Casy		7		7
Dumbea Pass - Mbere		8		7
Gue		14		14
Kabris			2	2
Krefiat		7	1	8
Neangaon		8		8
Passe D'Amos	2	8		10
Passe De Kone	1	8		9
Passe De La Gazelle	2	6	1	9
Passe De Ourais		1		1
Point Pouerabate		7	1	8
Seche Croissant		5		5
Total	5	95	5	104

Table 6. Number of samples examined for histology partitioned by gross lesions and species of coral.

	Discoloration								**Growth anomaly**	**Normal**	**Tissue loss**			
Organism	**Bleaching**	**CLOD**	**Dark Spots**	**Localized**	**Mottling**	**Multifocal**	**Other**	**Total**		**Normal**	**Acute**	**Chronic**	**Subacute**	**Total**
Algae: CCA	1	3					1	5						
Acanthastrea hemprichii					1			1						
Acropora branching										8	3		5	8
Acropora florida	1							1		3	2			2
Acropora formosa										1	1			1
Acropora kyrstiae										1			1	1
Acropora mirabilis	1							1		1				
Acropora paniculata										1			1	1
Acropora plating									1	2	2			2
Acropora seriata										1			1	1
Astreopora listeri	1							1						
Astreopora myriophthalma						1		1	1	1			1	1
Coscinaraea columna													1	1
Echinopora sp.	1							1		1				
Favia sp.	1				2			3		1				
Favia truncatus					1			1						
Favites pentagona				1				1						
Favites sp.	2		1					3	1					
Favites stylifera					1			1						
Fungia concinna						2		2						
Galaxea paucisepta	1							1		1				
Goniastrea sp.	1							1						
Leptoria phrygia	1		1					2		2				
Merulina scabricula										2	2			2
Montipora malampaya										1			1	1
Montipora millepora				2				2		1				
Montipora sp.									1	5	7		1	8
Pachyseris speciosa										2	1		1	2
Pavona varians			3					3					1	1
Platygyra daedala	1							1						
Pocillopora damicornis										1	1			1
Pocillopora verrucosa												1		1
Porites annae									1	1				
Porites massive	6			1		8	2	17	5	9	1			1
Sinularia sp.				2				2	3	6	1			1
Stylophora pistillata										1	1			1
Symphyllia recta										1	1			1
Turbinaria mesenterina										1			1	1
Turbinaria retiformis									1	2	1			1
Total	18	3	5	6	5	11	3	51	14	57	24	1	15	40

Table 7. Microscopic findings partitioned by gross lesion and microscopic lesion.

	Discoloration								**Growth anomaly**	**Tissue loss**				**Normal**	**Grand Total**
Histological Categories	Bleaching	CLOD	Dark Spots	Localized	Mottling	Multifocal	Other	Total		Acute	Chronic	Subacute	Total		
Invasives															
Algae				2				2		1			1		3
Cnidaria										1			1	1	2
Crustacea									1	1			1	2	4
Cyanobacteria		1						1							1
Hypermycosis			4		3			7							7
Metazoa	1	1		1				3							3
Mollusc												1	1	1	2
Sponge	1						1	2							2
Tissue															
Cell infiltrates-Granular				1				1							1
Cell infiltrates-pigment				1				1	2	1			1	2	6
Coenosarc hypertrophy									1						1
Fragmentation										3		5	8		8
Healing										2		3	5	1	6
Mucus sheathing					2			2							2
Necrosis	1					7	2	10		11		3	14	2	26
No lesions	4	1		1		3		9	4	1	1	3	5	46	64
Pigment deposition						1		1							1
Polyp malformation									5	1			1	2	8
Zoox															
Zooxanthellar vacuolation			1					1							1
ZooxDepletion	11							11	1	2			2		14
Grand Total	18	3	5	6	5	11	3	51	14	24	1	15	40	57	162

Figures

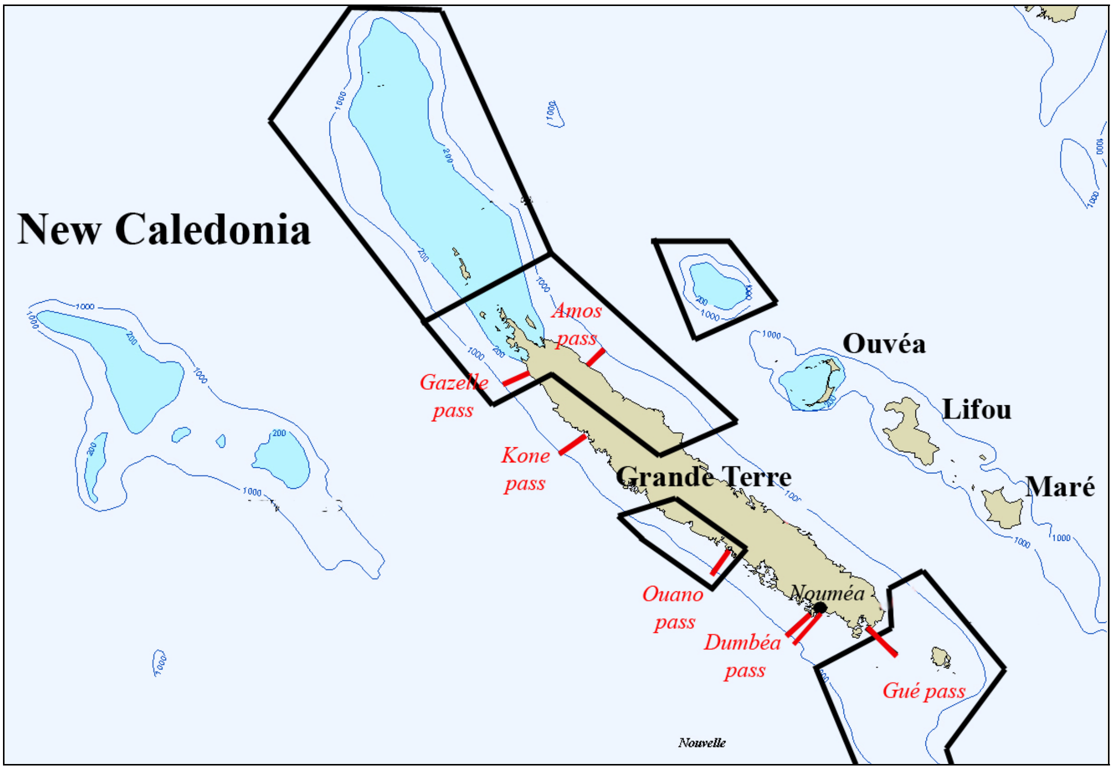


Figure 1. Map of New Caledonian Islands and location of studied inshore-offshore profiles (red bars) across the lagoon of Grande Terre. The name of the offshore reefs of each profile is indicated (the same one is used for both profiles in front of the city of Nouméa: Dumbéa pass). Black rectangles represent UNESCO reefs.


A
B
C
D
E
F
G
H
I
J
K
L
M
N

Figure 2. General views of surveyed coral reefs; offshore reefs are on the left side while inshore reefs are on the right side of the figure. Note turbidity at inshore reefs, especially on F. **A**. Gué. **B**. Casy. **C**. Dumbea pass (Mbere reef). **D**. Baie des Citrons. **E**. Sèche croissant. **F**. Banc des Japonais. **G**. Passe de Ouarai (Ouano 1). **H**. Chenal de Teremba (Ouano 2). **I**. Kone pass. **J**. Krefiat reef. **K**. Gazelle pass. **L**. Pouerabate pointe. **M**. Amos pass. **N**. Neangaon

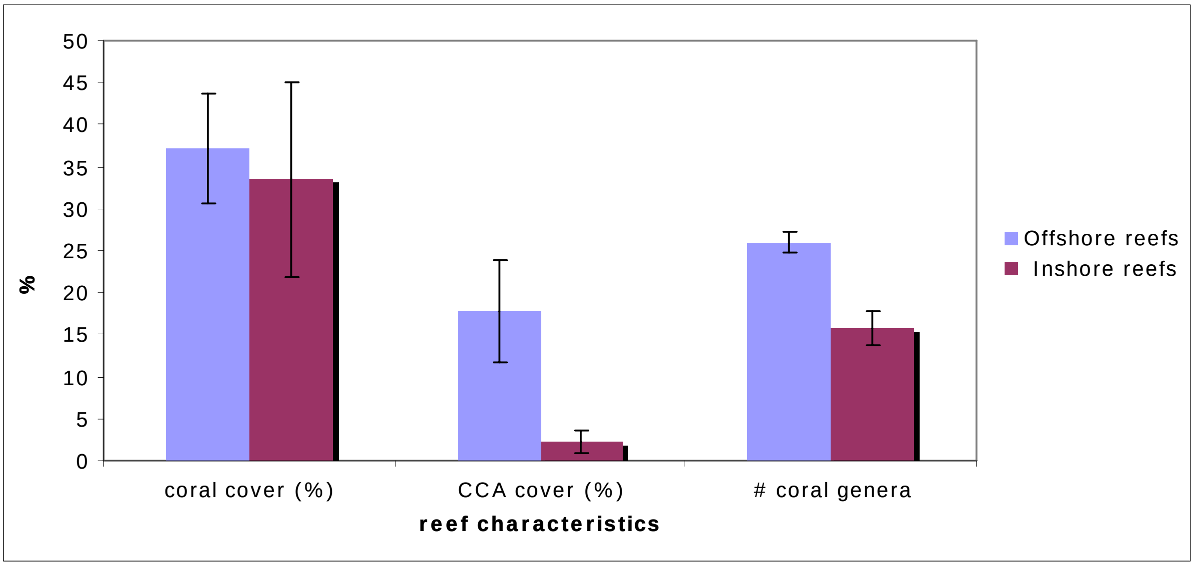


Figure 3. Comparison of coral cover, crustose coralline algae cover and number of coral genera between offshore and inshore reefs studied in the lagoon of New Caledonia.

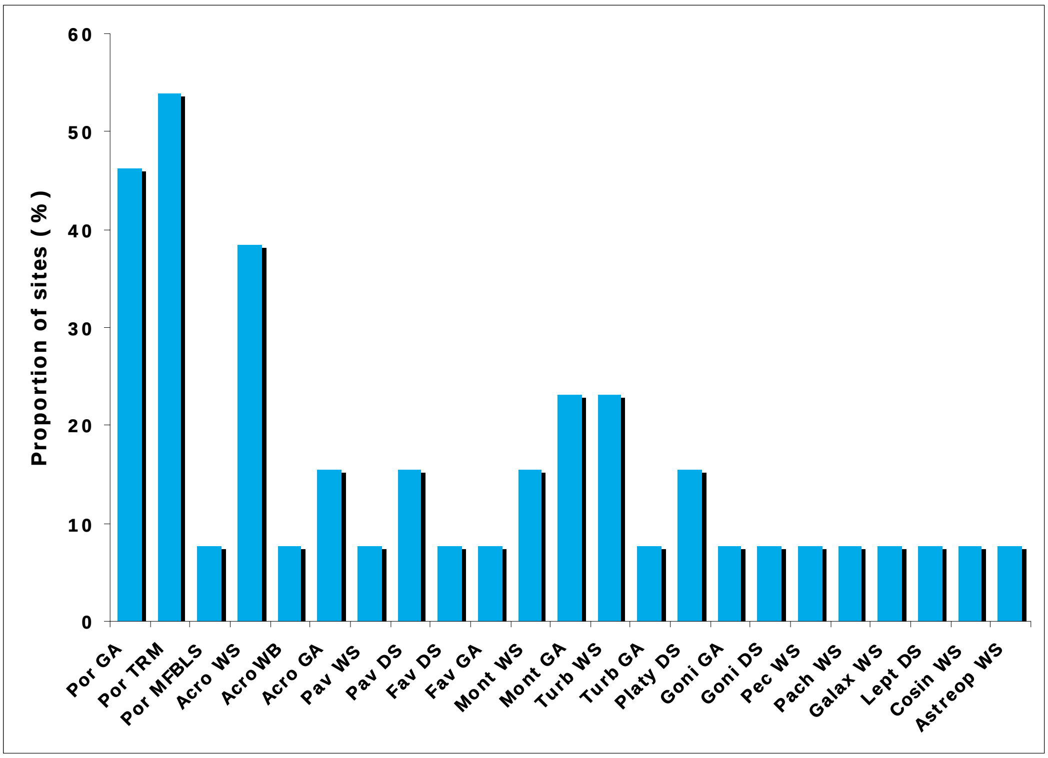


Figure 4. Proportion of sites where the different types of lesions/diseases were found. Legend of coral diseases is given in Table 3.

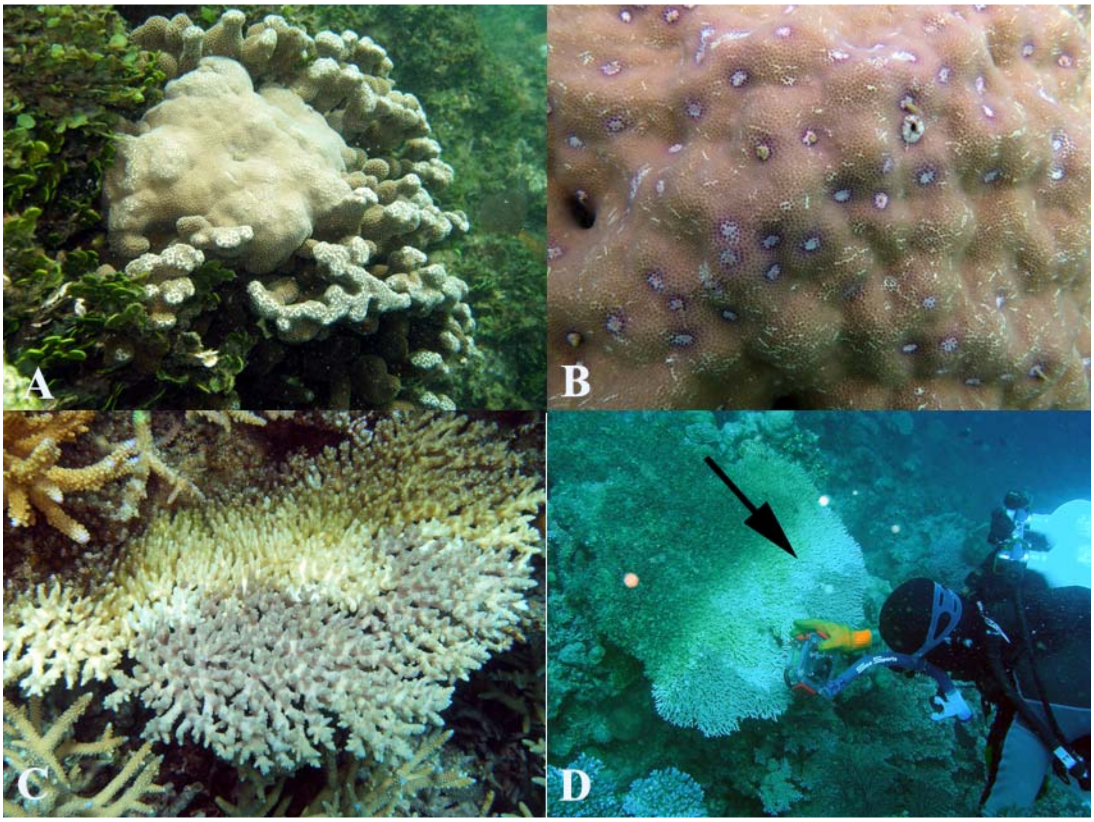


Figure 5. Main coral diseases observed in New Caledonia. **A**. *Porites* abnormal growth. **B**. *Porites* multifocal discoloration (some pink spots may be due to *Trematodiasis* and others to balanus). **C**. and **D**. *Acropora* white syndrome. Note on D that the white band is important (arrow) and is killing a large colony of *Acropora*. Above the arrow, coral tissues are dead and colonized by epilithic organisms (dark green). Below the arrow (toward the diver), the coral colony is still alive and appears in light grey.

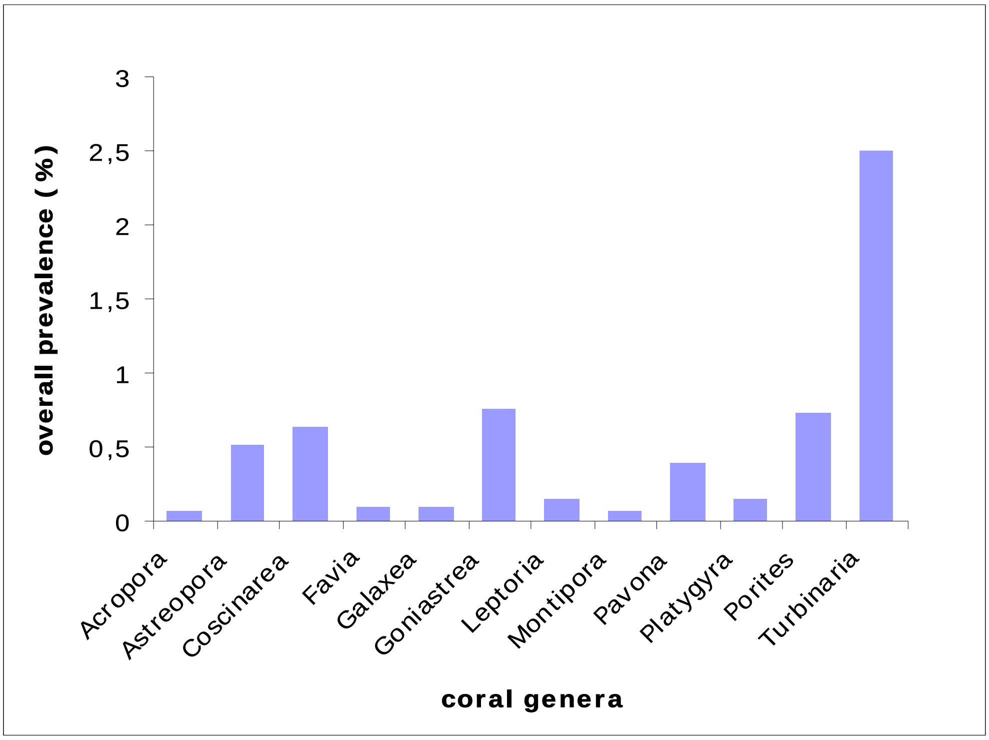


Figure 6. Prevalence of disease/lesion within the 12 most common genera affected.

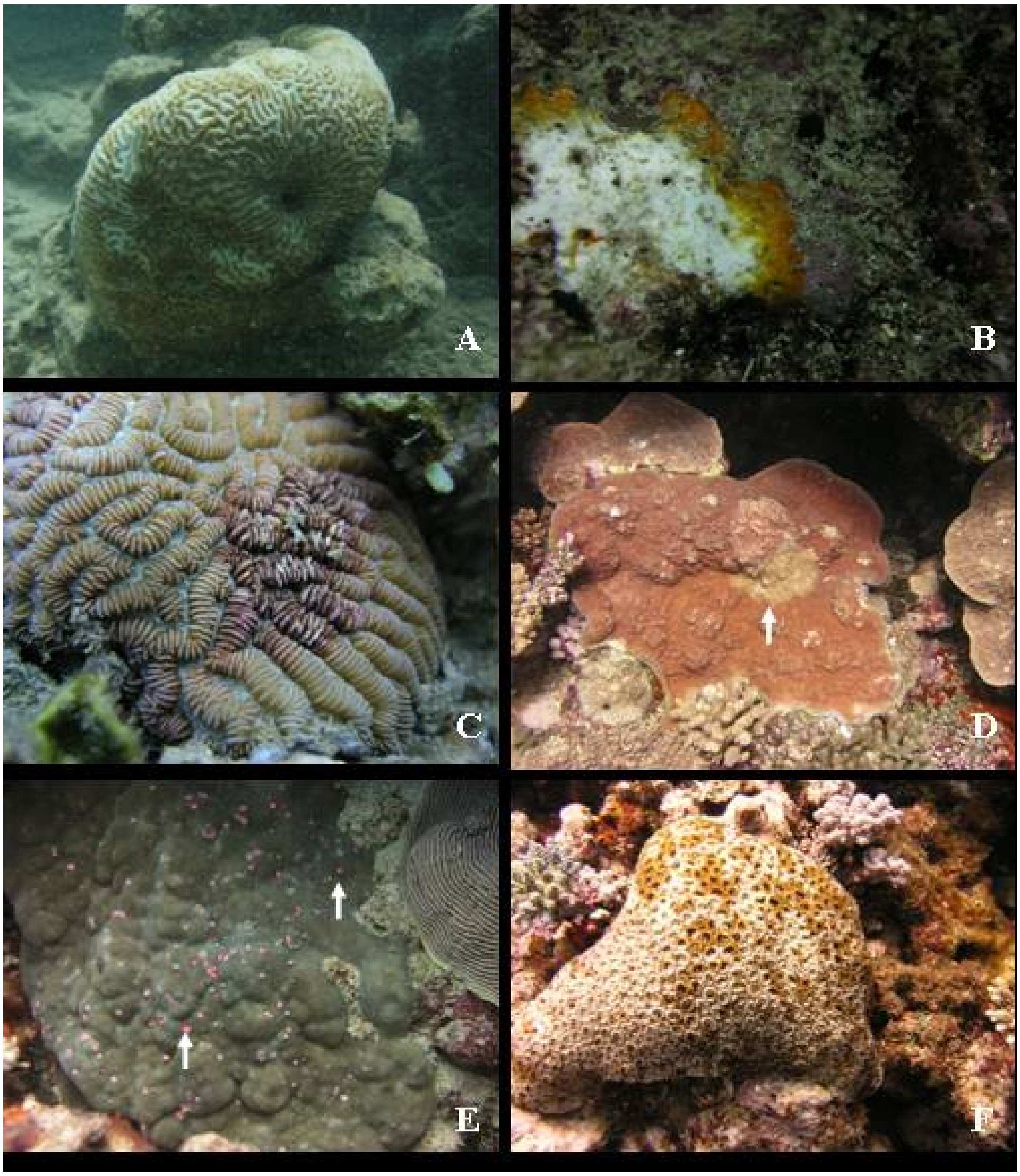


Figure 7. **A.** *Platygyra daedala* with multifocal to diffuse bleaching. **B.** Coralline lethal orange disease. Note the characteristic white central portion bordered by an irregular meandering orange band separating normal thallus from lesion. **C.** *Leptoria phrygia* with dark spots. **D.** *Montipora* sp. with localized discoloration (arrow). **E.** Massive *Porites* with multifocal discoloration (arrows). **F.** *Favia* sp. with diffuse mottling.

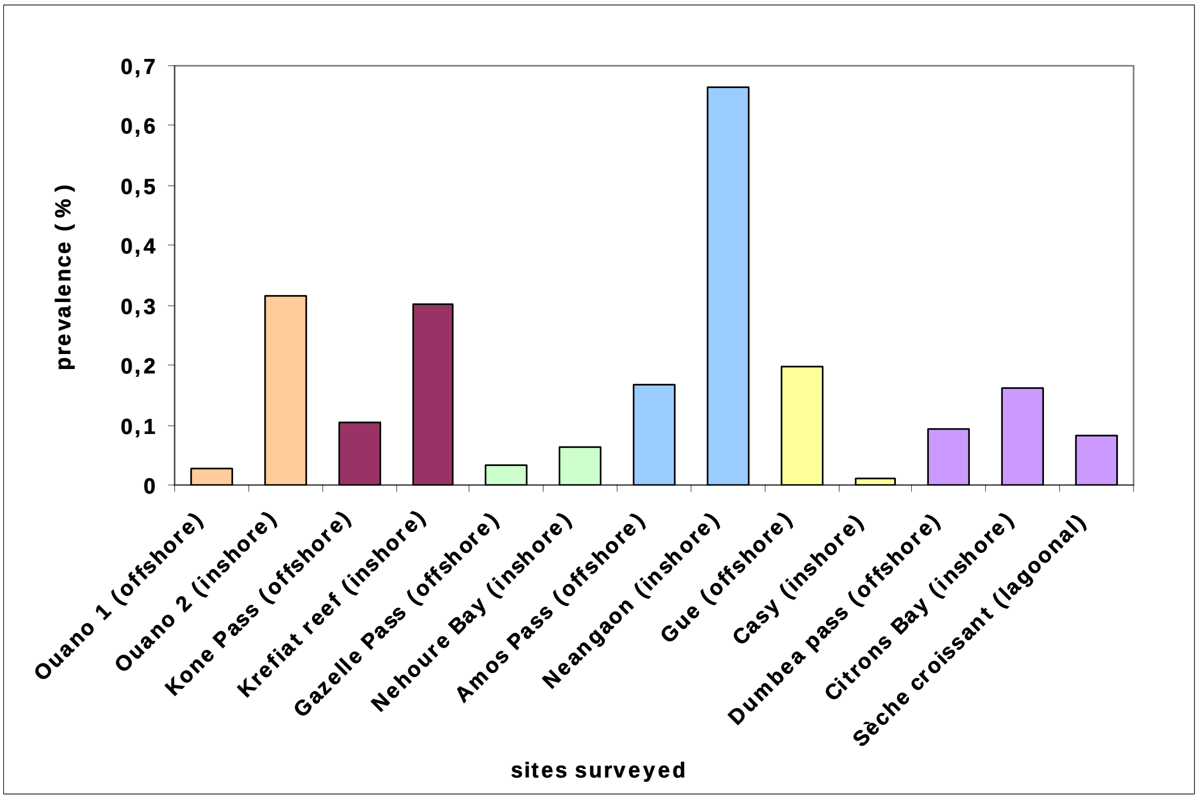


Figure 8. Prevalence of coral diseases at the different studied sites. Colours indicate pairs of sites per inshore-offshore transect. Ouano reefs are located on the west coast of Grande Terre. Kone and Krefiat reefs are located on the west coast of Grande Terre, north of Ouano. Gazelle and Nehoure reefs are located at the very north-west coast of Grande Terre, while Amos and Neangaon are located on the very north-east coast of Grande Terre. Gue and Casy reefs are located at the southern point of Grande Terre, in front Prony Bay. Dumbea, Citrons Bay and Sèche Croissant are located in front of the city of Nouméa.

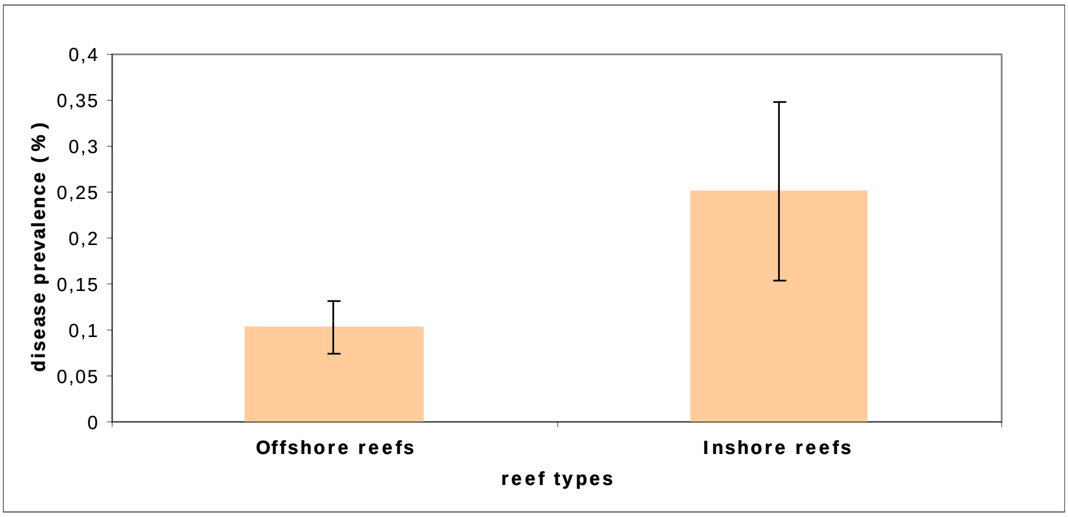


Figure 9. Disease prevalence per type of reef (offshore versus inshore).

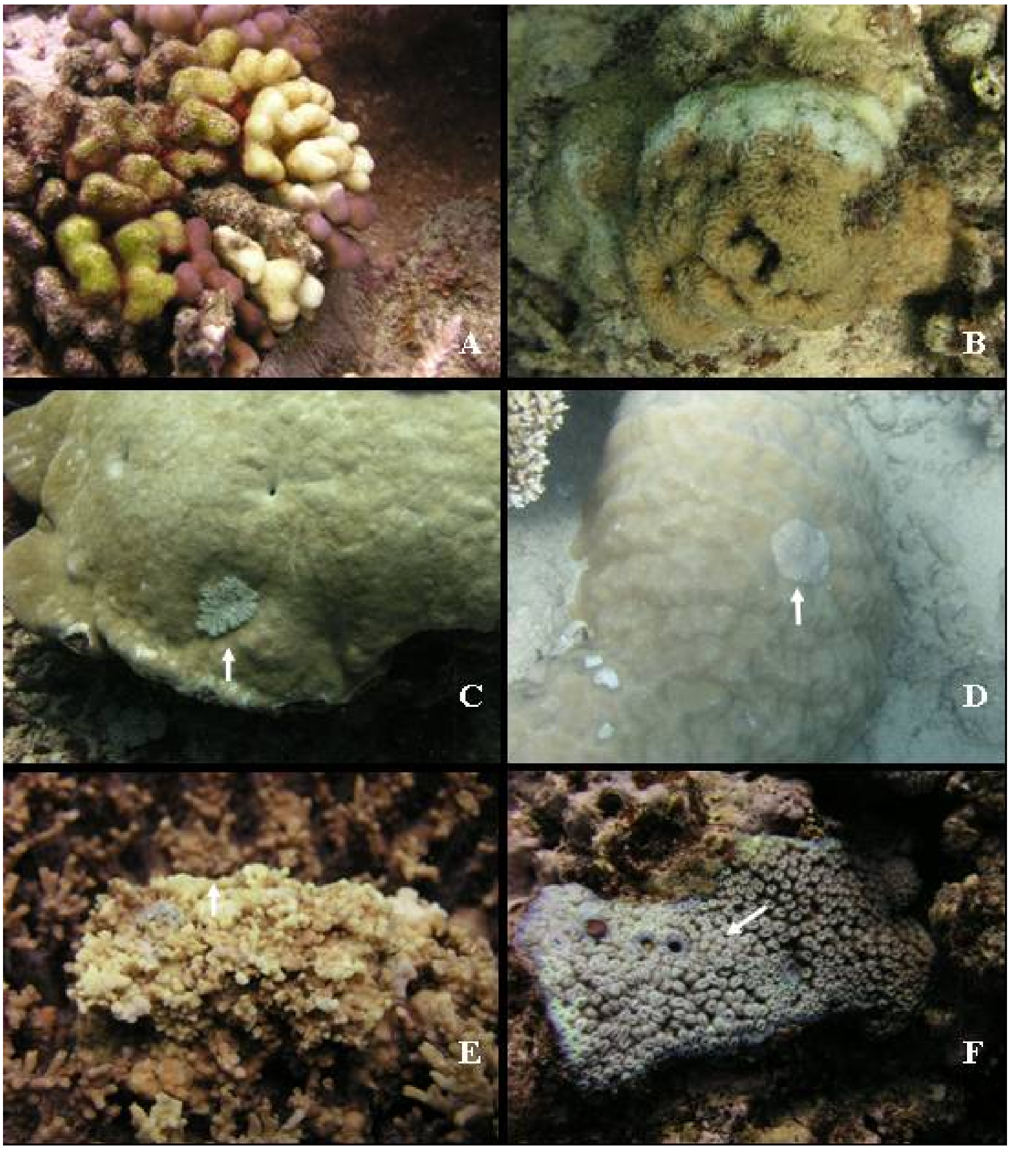


Figure 9. A. *Stylophora pistillata* with acute diffuse tissue loss. **B.** *Pavona varians* manifesting diffuse subacute tissue loss. Note the characteristic white central portion bordered by an irregular meandering orange band separating normal thallus from lesion. **C.** *Porites* with nodular growth anomaly (arrow). **D.** *Porites* with umbonate growth anomaly (arrow). sp. with localized discoloration (arrow). **E.** Plating *Acropora* with exophytic growth anomaly. **F.** *Astreopora myriophthalma* with crateriform growth anomaly.

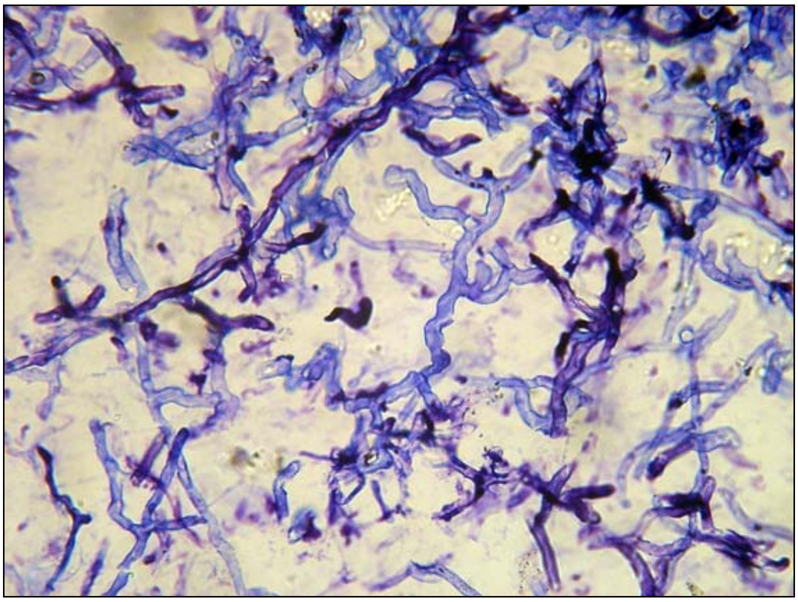
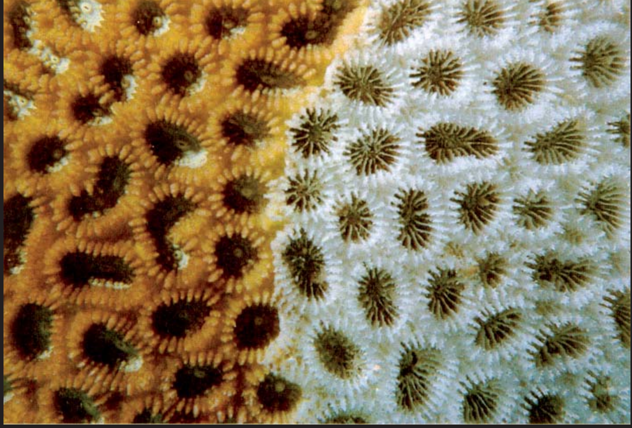


Figure 10. Very polymorphic filaments of the chlorophyte *Ostreobium* coloured by Toluidine blue, and present in coral skeletons (here of *Porites*).



Survey and determination of coral and coralline algae diseases/lesionstlagoon of New Caledonia

ABSTRACT

Coral reefs are increasingly threatened by various factors such as rising sea surface temperature, ocean acidification, pollutants, and terrigenous inputs resulting from climate change and human activities. Sediment stress on corals can lead mortality or morbidity with attendant loss of the substratum upon which many fish and invertebrates depend. The lagoon of New Caledonia is the largest in the world, and this unique ecosystem with high diversity of marine life and high rate of species endemism has merited its classification as a UNESCO World Heritage Site. To date no study has been carried out on the state of health of corals and crustose coralline algae. Such information is critical as New Caledonia has land use patterns such as mining and agriculture that can directly impact nearshore reefs in the form of runoff and landbased pollution A good indicator of the health status of a coral reef is the health of the corals that comprise that reef. We thus surveyed 14 nearshore and offshore reefs throughout the northern and western lagoon and documented prevalence of lesions on corals and crustose. Twenty three types of lesions and diseases were found in 92% of surveyed reefs in low abundance. They affected 12 genera of corals including the main reef framebuilders such as massive Porites and Acropora. The most common coral diseases encountered were Porites growth anomalies and Acropora white syndrome. Two crustose coralline algae diseases were observed, CCA white band disease and CLOD. Based on this first survey, the reefs of the lagoon of New Caledonia have uniformly low (< 3%) prevalence of lesions. However diseases such as white syndrome in acroporid corals should be monitored closely as such diseases have the potential to cause widespread and rapid loss of coral cover as seen in other regions of the Pacific and Western Atlantic. Results of this survey are a valuable first step to developing our understanding of coral reef health in the Lagoon of NC and provide a basis for more focused and comprehensive studies of this topic in the region.