OCEANO MONACO
INSTITUT OCÉANOGRAPHIQUE

Handbook

Coral Pathology: Identification and Management in Aquarium

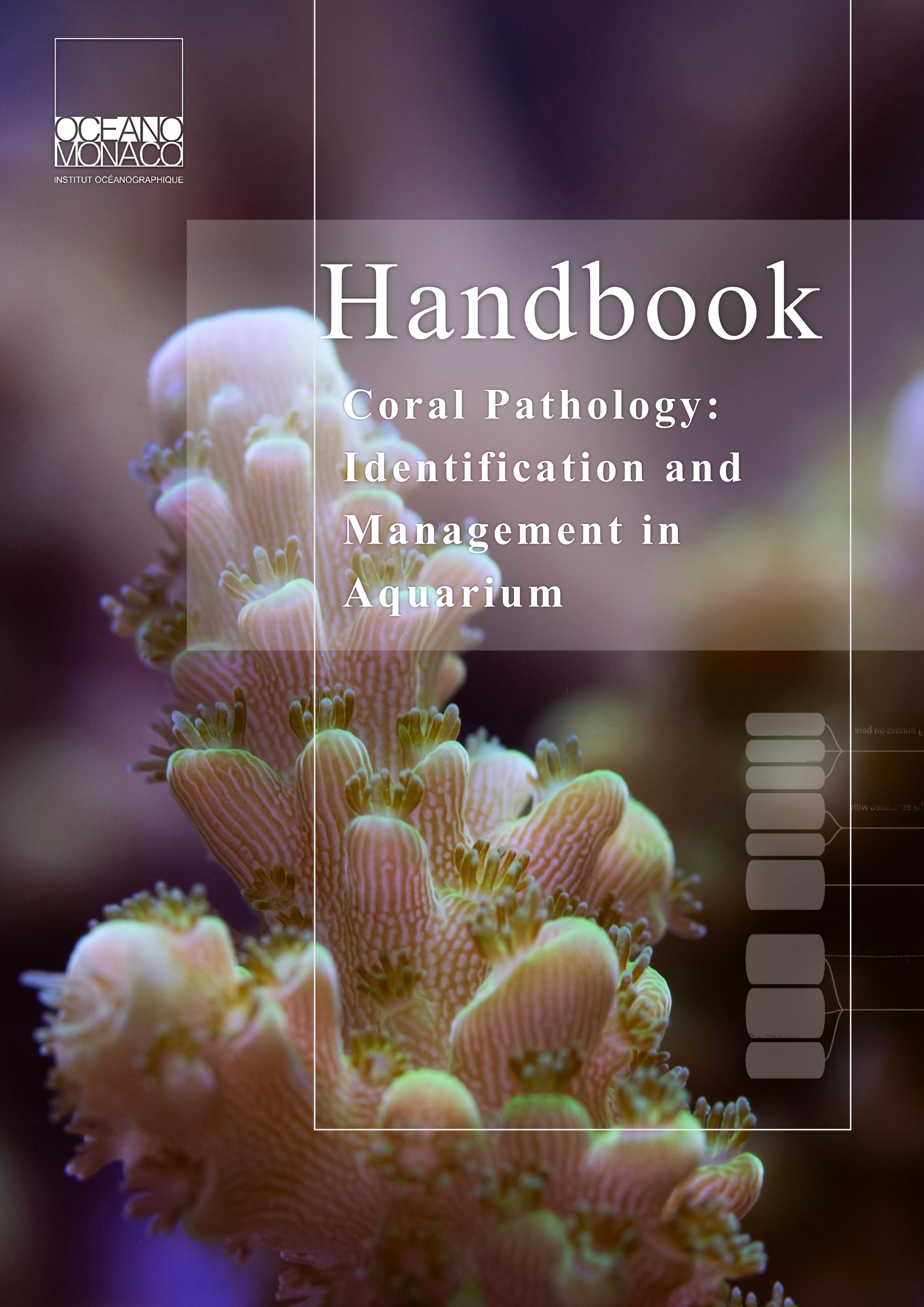

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Image in the front page: *Acropora* sp.

Acknowledgments

Coral pathology is an extremely vast subject. Even if numerous publications and practical guides exist, it was a real challenge to produce a synthesis for aquarists.

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Finally, the aquarists at the Oceanographic Institute agreed to share their knowledge and experience, giving this guide its highly practical and field-oriented character. We would like to express our warmest thanks to them.

Contents

Introduction

Coral reefs are biodiverse ecosystems where corals form intricate relationships with their surroundings, including bacteria, archeae, viruses, eukaryotic microorganisms, invertebrates, and fish. Ultimately, maintaining corals in aquaria requires both scientific knowledge and hands-on experience, reflecting the intricate complexity of their natural habitats. By fostering these miniature reef ecosystems, aquarists contribute to coral conservation efforts while gaining insights into the beauty and fragility of marine life.

Keeping corals alive in an aquarium requires specific skills and knowledge to meet the various challenges involved. Among these, controlling any disease or infestation by parasites or pathogens is one of the main keys to long-term success. Yet aquarists often find themselves at a loss when it comes to dealing with the pathologies they may encounter, due to a lack of experience and a lack of practical guides.

This guide aims to summarize current knowledge on coral pathologies, particularly in *ex-situ* cultures, and provide essential tools to identify, prevent, manage, and mitigate the spread of coral diseases.

Reef aquarium at the Oceanographic Institute of Monaco © Oceanographic Institute of Monaco, F. Pacorel

I. Reminder of the good practices

Coral holobiont

Corals are the primary contributors to the structural complexity in coral reef ecosystems (Ferrari, 2017; Graham & Nash, 2013). They are broadly categorized into two main groups: *stony corals* (order Scleractinia), also known as reef-building corals due to the secretion of a calcium carbonate skeleton and *soft corals* (subclass Octocorallia) which typically do not develop a calcium carbonate skeletal structure. Both coral groups are mostly colonial, consisting of many interconnected polyps and engage in a multitude of symbioses with microorganisms, collectively forming a metaorganism, referred to as the holobiont (Rosenberg et al., 2007).

The most well-known symbiotic relationship involves Symbiodiniaceae, unicellular dinoflagellates residing inside the coral tissues, which produce photosynthates that supply energy to the coral host (Burriesci et al., 2012). These symbiotic microorganisms contribute to the coral holobiont's remarkable nutrient cycling and recycling efficiency (Rädecker et al., 2015), enabling corals to thrive in nutrient-poor environments (Muscatine & Porter, 1977). However, environmental stressors such as temperature extremes, hypoxia or elevated nutrient levels can disrupt the microbiome, potentially leading to an increase in opportunistic pathogens (McDevitt-Irwin et al., 2017). Mitigating these stressors can help to preserve or restore the balance of symbiotic relationships (Voolstra et al., 2024). In aquaria, maintaining coral health is primarily based on environmental management particularly on the adjustment of abiotic and biotic culture conditions. Factors such as water composition and quality, nutrient supply and physical trauma appear to be the largest contributors to morbidity and mortality in these organisms (Stoskopf et al., 2022).

Detailed view of the cellular and structural diversity of coral holobiont. The coloured band on the left highlight the different cellular layers and compartments: seawater (dark blue); coral mucus (light blue); ectodermis, the outermost layer (peach); mesoglea, acellular layer (red); gastrodermis, the inner cell layer (orange); gastrovascular cavity, (yellow); calicodermis, cell layer responsible of skeleton calcification (pink); skeleton (beige); filamentous algae with fungi and prokaryotes (green). Circled numbers identify specific cellular structures: **1**. epidermal cilia; **2**. mucus layer and associated procaryotes; **3**. cnidocytes: stinging cells embedded in the epidermis; **4**. mucocyte, cell secreting mucus; **5**. cell-associated microbial aggregates; **6**. granular cells: involved in immune defence; **7**. Symbiodiniaceae hosted in the coral endoderm. Scale bar: 50 µm. © Philippe Plateaux, from van Oppen and Raina, 2023.

Following sections provide an overview of the foundational knowledge on coral ecology and physiology that are critical for providing essential environmental parameters to maintain corals in closed systems. Additionally, this chapter highlights key considerations for optimizing the reef tank environment and minimize the risk of coral pathology onset.

Light

Light is an essential parameter for corals as it supports the photosynthetic activity of dinoflagellates endosymbionts inhabiting the coral tissue, and therefore contribute to the nutrient needs of the host. As a result, light enhances coral growth and calcification (Falkowski et al., 1984; Holcomb et al., 2014; Wijgerde et al., 2012), but also affects physiological condition, shape, colour and metabolite content (Khalesi et al., 2009; Titlyanov & Titlyanova, 2002; Todd, 2008). Consideration must be taken to both qualitative (light spectrum) and quantitative (irradiance) aspects to achieve proper lightning. Although the photosynthetic optimum is species-specific, the symbiotic corals tend to adapt to different light environment (Titlyanov & Titlyanova, 2002).

For coral hosting dinoflagellates symbionts, photosynthetically active radiation (PAR) within the 400-700 nm is required, with a preference for higher irradiance in the 400-500 nm range and lower irradiance between 650 and 700 nm (Stoskopf et al., 2022). In aquariums, irradiance levels ranging from 150 to 300 µmol photons m^{-2} s^{-1} are a suitable starting point, considering that values up to 2000 µmol photons m^{-2} s^{-1} are generally acceptable (Borneman, 2008; Riddle, 2007). Irradiance values should be adjusted based on the specific needs of the coral species, as well as other factors such as heterotrophic feeding, water flow, or filtration systems.

Temperature

Coral reefs consist of heterogeneous environments where colonies are exposed to varying temperature regimes. However, each coral species can only tolerate a narrow temperature range. Water temperature influences numerous enzymatic processes essential for digestion, tissue maintenance, and detoxification pathways. Elevated temperatures are particularly harmful as they increase metabolic rates, leading to higher oxygen demands while simultaneously reducing the oxygen saturation of water (Stoskopf et al., 2022). Furthermore, high temperatures weaken coral immunity, making them more susceptible to diseases, and promote the growth of pathogens (Alker et al., 2001; Bruno et al., 2007; Gil-Agudelo et al., 2004).

Although very diverse temperature conditions exist in natural environments and corals can face various temperature range, most of the tropical corals prosper in aquarium within an optimal temperature range of 25°C to 28°C but can tolerate lower temperatures down to 22°C for limited periods. In contrast, temperate coral species can generally survive at a wide temperature range, an average of 20 °C provides a good foundation for their growth (Borneman, 2008; Sprung & Delbeek, 1997).

Nutrition

While the algal symbionts can provide up to 90% of a coral's nutritional requirements (Muscatine & Porter, 1977), corals without algal symbionts depend entirely on heterotrophy, that is, source of feeding in the water column such as sugars, amino acids, detrital organic matter and planktonic organisms. For symbiotic corals, both nutrition modes are important for coral fitness as photosynthates are often deficient in some elemental molecules like nitrogen and phosphorus (Houlbrèque & Ferrier-Pagès, 2009). Heterotrophic feeding also increases the photosynthetic capacity and growth of corals (Houlbrèque et al., 2004), maximize resilience to stress and potential for recovery (Grottoli et al., 2006). Micronutrients (i.e. iodine, trace metals) availability is also essential for coral photosynthesis and health (Ferrier-Pagès et al., 2018). It is also important to note that large polyp corals can easily get energy directly from plankton, whereas species with smaller polyps rely more on nutritional elements they catch in the water or in the sediments that land on them. However, heavy feeding may deteriorate water quality in the tank and the system's ability to remove the unconsumed portion effectively is essential. In contrast, excessive ozone filtration or activated carbon may rapidly remove organic matter in the water and lead to an increase of light exposure, requiring adjustments to the light settings to maintain adequate light penetration in the water (Sprung & Delbeek, 1997).

Water quality

In their natural environment, coral reefs thrive in clear, nutrient-poor waters. Symbiotic corals rely on their association with Symbiodiniaceae to absorb inorganic nutrients, such as nitrate and ammonia, which are essential for coral growth but naturally scarce (Atkinson et al., 1995).

Inorganic nitrogen can be benefit corals by stimulating proliferation of symbionts and maintaining their photosynthetic capacity under stress condition such as thermal stress (Béraud et al., 2013; Houlbrèque & Ferrier-Pagès, 2009). However, excessive concentrations of ammonia and nitrate are also toxic to corals (Grover et al., 2003; Muller-Parker et al., 1994), can block the photosynthesis (Borneman, 2001), and should be avoided. In artificial reef systems nitrate levels should be kept below 10 ppm, and ammonia should remain undetectable with routine testing equipment (Stoskopf et al., 2022).

Phosphate concentrations are typically very low in natural reef environment but tend to accumulate in aquaria due to food addition. Elevated phosphate levels can have deleterious effects on coral skeleton growth (Borneman, 2008) and levels should be controlled below detection limits or at least under 0.3 ppm. High concentrations of dissolved organic matter can also hinder coral growth, hence the levels should be held in the range of 0.5-3 ppm (Stoskopf et al., 2022).

The nitrogen-to-phosphorus (N:P) ratio is a critical factor influencing coral physiology and the stability of coral-Symbiodiniaceae symbioses. Elevated nitrogen levels, especially when not accompanied by proportional increases in phosphorus, can lead to several physiological challenges for the coral holobiont like reducing the coral skeletal growth (J. C. Delbeek, pers. com.) or causing the breakdown of symbiosis (Morris et al., 2019).

Calcium is vital for managing hard corals, as it supports calcification. Levels should be maintained at 400–450 ppm, with 450 ppm being preferable. A lack of bioavailable calcium can lead to decalcification syndrome, where coral skeletons become fragile and collapse despite healthy tissue and polyp expansion. In the wild, this syndrome is mostly due a global pH decrease related to ocean acidification. This drop in pH compromises the calcification mechanisms, necessary to the skeleton development. Decalcification is also thought to be associated with boring sponges, worms, and encrusting algae (Stoskopf et al., 2022). Magnesium is important to maintain a stable balance between calcium levels and alkalinity. The optimal magnesium concentration for biomineralization of aragonite in seawater is between 1200–1350 ppm, with the Mg:Ca molar ratio maintained around 5, similar to natural seawater conditions (Laipnik et al., 2020). This balance is essential for coral skeleton calcification and stabilization processes.

Small diurnal pH fluctuations of up to 0.2 points are not uncommon, with pH slightly lower at night. For coral husbandry, the ideal pH range is 8.2–8.6, though values between 7.8 and 8.8 are acceptable (Borneman, 2008). Alkalinity is another important parameter to consider and is generally maintained higher in aquaria than in the reef environment, between 3.5 and 4.0 mEq L^{-1}), to enhance buffering capacity and stabilize pH values. Salinity, which can vary significantly in natural reef environments, should be controlled within 33–38 ppt in artificial systems, with an ideal range of 34–36 ppt (Borneman, 2008).

Parameter	Acceptable range	Optimal range
PAR (µmol photons m^{-2} s^{-1})	0-2000	250-1000
Temperature (°C)	24-28	26-28
NH^{4+} NH^{3+} NO_2 (mg L^{-1})	Undectectable	Undectectable
NO_3^- (mg L^{-1})	0-10	0-1.0
PO_4^{3-} (mg L^{-1})	0-1.0	0-0.03
Calcium (mg L^{-1})	350-500	425-450
Magnesium (mg L^{-1})	1200-1350	1200-1350

pH	7.8-8.8	8.2-8.6
Alkalinity (mEq L^{-1})	2.5-4.5	3.5-4.4
Salinity (ppt)	33-38	34-36

Modified from Borneman, 2008

Water motion

Water movement in reef environments is created by tides, current, upwellings, internal waves and wind-driven waves, creating different conditions among reef areas. Coral species are adapted to their environment and therefore exhibit varying preferences for water flow. Coral morphology is influenced by light intensity and water current. Considering current, low flow areas typically support small and large-polyped corals with encrusting, plate-like, phaceloid structures, including branching species with widespaced thin branches. In contrast, high flow environments favour corals with upright branches, plates and ridges, and more robust branching species (Borneman, 2008). Adequate water flow in aquarium is crucial for coral growth, tissue oxygenation and flushing away debris. Corals have an optimal flow rate for maximizing prey within a range of 5 to 15 cm s^{-1} (Wijgerde et al., 2012). Enhanced water movement boosts photosynthesis, respiration, nutrient uptake and the calcification process (Mass et al., 2010; Sebens et al., 2003; Sebens et al., 1997). Additionally, higher flow rates can help alleviate coral stress and lessen their sensitivity to environmental stressors, such as intense light or high temperatures, by enhancing gas and nutrient exchange and dissipating heat. Increased water motion can also remove excess mucus produced under stress, which otherwise may impair tissue oxygenation, trap debris, and potentially cause localized tissue damage (Stoskopf et al., 2022). These conditions also help to prevent overgrowth of colonies by competing species and proliferation of disease-causing organisms.

Reef tank communities

Maintaining community balance in a reef tank is crucial for creating a stable and thriving ecosystem. A well-balanced aquarium ensures harmonious interactions between corals, fish, and other marine organisms, minimizing competition for resources and space preventing dominance by aggressive species. This balance directly influences coral health by reducing stress, enhancing nutrient availability, and maintaining water quality. Conversely, community balance shifts may occur and can lead to overgrowth by encrusting species, increased coral predation and competition for light and space, all of which can compromise coral health.

Intra- and interspecific competition among corals

Coral competition is common in reef tank systems. The most apparent, and least aggressive form of competition among corals is for space. Faster-growing coral species can shade the other ones, potentially weakening the underlying colony due to reduced light availability. Additionally, the growth of coral colonies can result in contact burns, either between different species or between colonies of the same species, causing localized tissue necrosis. To avoid such issues, fast-growing corals should be thoughtfully placed in the aquarium and, if necessary, relocated or fragmented.

A more subtle form of territorial competition involves the use of specialized tentacles to attack neighbouring corals. Many scleractinian corals, like *Favia, Euphyllia, Galaxea* or *Pavona* possess elongated tentacles at the outer-most part of the colonies, known as sweeper tentacles, that are specialized for territorial aggression. Several coral species are also capable to extend mesenterial filaments from their gastrovascular cavities to attack and digest tissue of other coral species. Some soft corals have also similar structures to compete for space (Sebens & Miles, 1988). These tentacles, which can be up to 30 times longer than feeding tentacles, typically contain a higher density of stinging cells and toxins (Yosef et al., 2020). Multiple stings on an adjacent coral can cause significant damage or even tissue death. These tentacles often emerge at night and can be cut off using sharp scissors, though they tend to regrow quickly. Relocating the threatening coral may be necessary to prevent reoccurence. Note that some corals (like *Euphyllia, Fungia* or *Catalaphyllia*) exhibit increased aggressiveness when hungry, so implementing a proper nutrition plan may help mitigate the issue (Stoskopf et al., 2022).

Sweeper tentacles of *Platygyra* sp. © Oceanographic

Soft corals compete for space with surrounding organisms by releasing toxic compounds in the water. These toxins are also emitted as a defence mechanism against predators or in response to stress conditions. In tank systems, these chemical interactions require active management, as the released compounds can harm or even kill other species. Regular water renewal and efficient carbon filtration are generally effective to counteract these undesirable effects.

In the following table are listed common coral species encountered in aquaria based on their level of aggressiveness:

Coral Species	Aggressiveness	Weapons
Euphyllia spp. (e.g. *E. ancora, E. fimbriata, E. glabrescens, E. cristata*		Long sweeper tentacles that can cause acute damage to adjacent corals. *Euphyllia* species generally tolerate each other, except for *E. glabrescens*)
Galaxea spp. (e.g. *Galaxea fascicularis*), *Catalaphyllia* spp.		Long sweeper tentacles that can sting neighbouring corals
Hydnophora spp.		Powerful stinging capabilities and extension of mesenterial filaments
Plerogyra sinuosa, Pectinia spp.		Can extend sweeper tentacles
Brain corals (e.g. *Trachyphyllia* spp., *Platygyra* spp., *Lobophyllia* spp., *Symphyllia* spp., *Cynarina* spp., *Favia* spp., *Favites* spp.)		Long sweeper tentacles that can sting neighbouring corals, extension of mesenteric filaments
Chalice corals (e.g. *Echinopora lamellosa, Echinophyllia* spp., *Oxypora* spp., *Mycedium* spp.)		Some species can extend long sweeper tentacles and/or mesenterial filaments
Zoanthids (e.g. *Zoanthus* spp., *Palythoa* spp.)		Can contain highly toxic compounds in their tissue
Leather corals (e.g. *Sarcophyton* spp., *Lobophyton* spp., *Sinularia* spp.)		Release of toxic compounds that may affect the surrounding organisms
Mushroom corals (e.g. *Discosoma* spp., *Rhodactis* spp.)		Nonaggressive but some can emit toxins affecting other corals. *Rhodactis* can strongly extend their tentacles at night

Modified from Stosktopf et al., 2022

Within the phylum of Cnidaria, the genus *Exaiptasia*, commonly known as *Aiptasia* or glass anemone, are particularly invasive in reef tanks. They multiply rapidly, outcompete coral colonies for space and have a powerful sting that can damage neighbouring coral tissue. Various methods are available for controlling and eliminating these anemones, each with varying levels of success. Physical removal can be effective if the affected rock can be isolated from the aquarium. Using a knife or other sharp tool, the anemone can be scraped away, including a few millimetres of the substrate to which it is attached (Carl, 2008). However, this method is often limited in effectiveness, as small fragments left behind can regenerate into new anemones, potentially exacerbating the problem. To resolve this, epoxy resin beads can be applied to the areas where the anemones where removed. Other approaches, such as commercial treatments or injections with boiling water, hydrogen peroxide, or vinegar, have shown moderate success rates (Bartlett, 2013). Biological controls and preventive measures generally yield the best results. Natural predators like Copperband butterflyfish (*Chelmon rostratus*), raccoon butterflyfish (*Chaetodon lunula*), peppermint shrimp (*Lysmata wurdemanni*) in significant numbers, or the nudibranch *Berghia verrucornis* can help reduce *Aiptasia* populations. However, some predators may not exclusively target undesirable anemones and might also feed on corals or other invertebrates. Among these, *Chelmon rostratus* is relatively reef-safe and effective at controlling glass anemone population. Nutrient-rich systems are particularly favourable to their reproduction. Therefore, maintaining proper water quality through strong skimming and reduced feeding can help to mitigate their proliferation.


Chelmon rostratus © Oceanographic Institute of Monaco, F. Pacorel

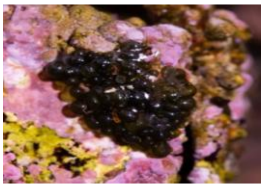

Exaiptasia pallida © A. Perrone

Another invasive anemone in aquarium is *Anemonia majano.* Manual removal is generally easier than with *Exaiptasia,* as these anemones tend to detach entirely from the substrate and respond better to chemical treatments (Carl, 2008). Predators like certain species of *Centropyge*, *Pomacanthus*, or peppermint shrimp may feed on *Anemonia majano*, but their efficiency is often limited.

Space competition with algae

Algal competition is a major challenge in reef tanks, as algae can outcompete corals for light, space, and nutrients, disrupting the delicate balance of the ecosystem. Although some species can be beneficial to corals if maintained in reasonable amount (for example Crustose Coralline Algae (CCA) promotes coral recruitment and stabilize the reef), excessive development of algae in aquarium must be avoided. It is often triggered by high nutrient concentrations in the water, such as nitrates, phosphates or silicic acid (Stoskopf et al., 2022). Algae can overtake coral surfaces, causing tissue irritation, blocking light, and disrupting photosynthesis in Symbiodiniaceae, which can ultimately weaken or kill the coral colony. Common detrimental algae in tropical aquariums include *Bryopsis* spp. (filamentous algae), *Derbesia* spp. (hair algae), *Valonia* spp. (bubble algae), diatoms and cyanobacteria (often referred to as "red slime algae"). Often confused with cyanobacteria, dinoflagellates are part of the phytoplankton but are not real algae. They may cause problems through mass propagation due to biological imbalance in the aquarium. These species can form dense mats, smothering coral colonies and reducing biodiversity. To manage algal competition, maintaining optimal water quality through proper filtration, regular water changes, and controlled feeding is essential. Adding herbivorous fish and invertebrates can also help control algae growth. Furthermore, ensuring adequate flow and reducing light intensity may deter algae proliferation while promoting coral health. A proactive approach combining biological, chemical, and mechanical controls is crucial for preventing algal dominance and supporting a thriving reef environment. Quarantining organisms on arrival is also crucial to avoid the introduction of algae (and other organisms).

The primary groups of algae that commonly pose challenges in reef tanks are outlined in the table below. Suggested solutions are provided, primarily drawing from Knop (2020), but there are also several commercial products available to eradicate these invasive species.



Bubble algae

Red slime algae

Dinoflagellates

Organisms	Possible causes	Solutions
Bryopsis spp.: filamentous algae with feathery structures that can penetrate coral skeleton and other substrates with their rhizoids. More commonly found in newly established tanks.	High light and nutrient levels (nitrate and phosphate)	Create a deficiency in essential elements for algal growth such as nitrates and phosphate, while maintaining alkalinity levels above 7 dKH. Simultaneously, regular manual removal through vigorous brushing limits the excessive algal expansion and strong filtration helps eliminate residual fragments.
Derbesia spp.: long and thin filamentous algae that can strongly attach to multiple surfaces in reef tank. More likely to occur in well matured reef tanks, rapid growth.		
Valonia spp.: bubble-like structures firmly attached to multiple surfaces in reef tank. Multiply rapidly by vegetative propagation.	Low water flow and elevated nutrient levels (nitrate and phosphate)	Regular maintenance and nutrient control are the key to keep these algae in check. Carefully scrape off bubbles without bursting them to prevent the spread of daughter cells in the tank, combined with strong filtration. Introduce herbivores like rabbitfish (*Siganus* spp.) or emerald crabs (*Mithrax sculptus*) may help to limit *Valonia* colonization on various surfaces within the tank.
Cladophoropsis spp.: Thick, hair-like filaments that form green carpet firmly attached to surfaces. They can outcompete and harm other invertebrates due to their rapid multiplication rate.	Elevated nutrient levels	To remove these algae, it will be necessary to act at the first signs of development by using sharp tweezers and digging into the substrate to extract as many fragments as possible, as it can regrow quickly. Some grazers, especially the sea urchin *Tripneustes gratilla,* can feed on *Cladophoropsis.* Several snail species such as *Strombus* spp. And *Turbo* spp. can also help a lot.
Diatoms: siliceous algae forming fine brownish deposits on diverse substrates of aquarium. Common in newer tanks but can reappear in mature systems under certain conditions. Microscopic observations may be necessary to differentiate them form dinoflagellates.	High silicate concentration and high nutrient levels	These algae will stop proliferating once there is no more silicate available. Common sources of silica include tap water and installation on new substrates. If diatoms become a persistent issue, measures such as reverse osmosis water or reducing evaporation may be necessary. Regularly siphon out the diatoms deposits to limit their growth.
Cyanobacteria: Red, black to blue-green coatings on all illuminated surfaces in the aquarium. Also commonly known as "Red Slime Algae".	High levels of organic nutrients, imbalance of N/P ratio, high Fe concentration or excessive yellow and red-light spectrum	To prevent the development of cyanobacteria, avoid the contamination of heavy metals by limiting the contact of water with metallic objects and using a proper filtration (i.e. activated carbon). Ensure the reduction of nitrate and phosphate, adjust the light spectrum to decrease yellow and red components. Regularly siphon out the cyano mats to limit their growth.
Dinoflagellates: unicellular organisms that form slimy, golden-brown mat on diverse surfaces and can generate air bubbles. They are toxic to other invertebrates in the tank. Microscopic observations may be necessary to differentiate them form diatoms.	Not well understand. High concentrations in Fe, CO_2 or silicate, imbalance of N/P ratio or too low nutrient levels	Manual removal daily by brushing and siphoning the substrates can slow down the colonization. Carefully increasing the pH with calcium hydroxide appears to be a suitable option in most cases. Reducing lightning may help to limit the growth of dinoflagellates.

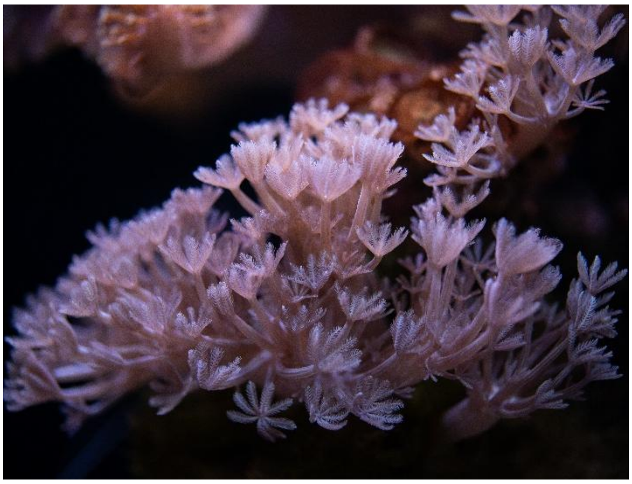
Space competition with other benthic invertebrates

In reef aquariums, spatial competition between corals and other benthic invertebrates is a common challenge that impacts the health and balance of the tank ecosystem. Corals may compete with many organisms like sponges (Porifera), hydroids (Hydrozoa), other coral species (Octocorallia), and even mobile invertebrates such as brittle stars (Ophiuridae).

Sponges like those in the genus *Collospongia* exemplify invasive growth potential, forming encrusting mats that smother corals and release allelopathic compounds. High phosphate levels often promote their proliferation. Sustainable management focuses on reducing phosphate concentrations, although manual removal or chemical treatments are also used. Note that they can release toxic secondary metabolites when the tissue integrity is compromised.

Colonial hydroids colonising a gorgonian axis © Oceanographic Institute of Monaco, F. Pacorel

Colonial hydroids may also pose a threat, as they are highly prolific and can irritate nearby corals, causing tissue recession if left unchecked. Localized application of hydrogen peroxide can kill them, but they can also be physically removed through scrubbing and brushing the substrate surfaces.



Xenia sp. © Oceanographic Institute of Monaco, F. Pacorel

Among soft corals, some like *Xenia* spp. (and other members of the Xeniidae) are particularly notorious in aquariums for their rapid growth and spreading behaviour. While their pulsing motion makes them a favourite among aquarists, *Xenia* can quickly overtake nearby hard corals, shading them and monopolizing space. Colonies must be regularly checked and prune to maintain a balance with the rest of the benthic organisms.

Brittle stars, or Ophiuridae, are less direct competitors but can influence coral dynamics. These mobile invertebrates, typically symbiotic, often settle in branching colonies and can sometimes disrupt corals by displacing polyps and potentially damaging tissues. Manual removal remains the best option for limiting their population in the aquarium.

Brittle stars entwined around branches of a *Sinularia* © Oceanographic Institute of Monaco, F. Pacorel

These examples highlight the diverse forms of spatial competition in aquariums, though many other interactions also occur. Small variations in parameters such as nutrient levels, lighting, or water flow can have significant effects, potentially causing shifts in species dominance or outbreaks of invasive organisms. Such disruptions can disrupt the balance of the tank, intensifying competition for space and resources and compromising coral health. Predation on corals by fish or invertebrates, may also increase if their dietary needs are not adequately met, causing further stress to the artificial reef systems. Ensuring appropriate feeding, consistent water quality, and regular monitoring helps mitigate these risks, fostering a stable and thriving tank environment.

Coral conditions

Corals are sensitive organisms that respond dynamically to environmental stressors such as temperature fluctuations, poor water quality, light variations, or nutrient imbalances. These stressors can disrupt their delicate symbiosis with Symbiodiniaceae, the photosynthetic algae living within their tissues. When stressed, corals may expel these algae, leading to **bleaching** - a condition that leaves the coral pale or white, nutrient-starved, and more susceptible to disease. Excessive mucus production is another stress response, where corals secrete mucus to shield against sedimentation, pathogens, or environmental changes. Clinical signs of stress may also include tissue recession, polyp retraction, or discoloration, such as patchy or uneven pigmentation. These signs often indicate that the coral is experiencing physiological stress and is at higher risk for disease or mortality.

Bleached colony of *Acropora humilis* © V. Chalias

Normal coral behaviours and clinical signs provide important cues about their health. For example, leather corals often shed a waxy layer as part of routine maintenance or in response to mild stress, which is usually not harmful. Similarly, some large polyped corals and anemones may purge remains of digested food, visible as small pellets expelled from their mouths. In some cases, corals expel excess or degraded symbionts, resulting in brownish strings around their oral cavities. While these signs can be normal under stable conditions, excessive or prolonged occurrences may indicate environmental stress or nutrient imbalances.

Lesions caused by predation or disease present additional challenges. Predators such as butterflyfish, fire worms, or coral-eating snails can leave visible damage, including bite marks or exposed skeleton. These injuries not only weaken the coral directly but can also serve as entry points for pathogens. Moreover, such predators can act as vectors for certain diseases (Nicolet et al., 2018). Other clinical signs of disease include rapid tissue loss, necrotic spots, or the presence of abnormal growths. Minimizing environmental stressors and promptly addressing signs of predation or disease are essential for coral health. Regular monitoring for clinical signs and swift intervention can mitigate damage, promote healing, and support recovery in both natural reefs and aquarium environments.

The following parts of this document aim to guide aquarists in diagnosing and addressing these issues to maintain healthy and thriving coral systems.

References

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II. Lesion terminology

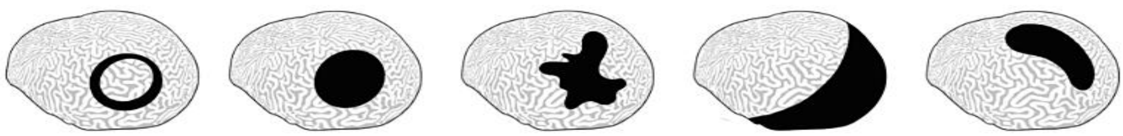
The lesion description and terminology in this guide will follow the guidelines of the CDHC (Coral Disease & Health Consortium; https://cdhc.noaa.gov/coral-disease/lesion-terminology/) to establish a diagnosis.

Lesion Descriptions

Colour Change · Growth Anomaly · Tissue Loss · Skeletal Damage

Colour change : include corals exhibiting change from their normal pigmentation (darker or lighter) or lack of pigmentation in tissue, typically exemplified by a white colour (discoloured areas)
Growth Anomaly : include corals exhibiting excessive or apparently uncontrolled growth of skeleton or soft tissues in relation to polyps on the same colony with intact corallite structure (hyperplasm) or abnormal polipar structure (neoplasm)
Tissue Loss : include corals manifesting absence of tissues with or without intact skeleton
Skeletal Damage : structural change to the skeleton caused by anthropogenic, biological agent or environmental events

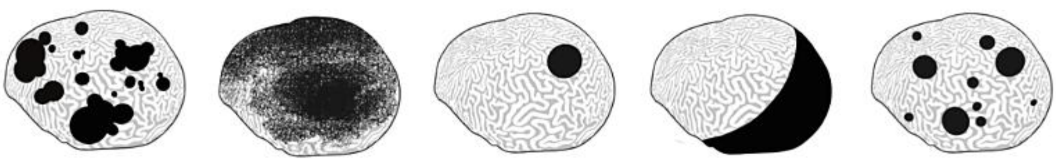
Lesion Shapes



Annular · Circular · Irregular · Linear · Oblong

Annular : of, relating to, or forming a ring
Circular : having the form of a circle
Irregular : lacking perfect symmetry of form; not straight, smooth, even, or regular
Linear : of, relating to, or resembling a line
Oblong : deviating from a square, circular, or spherical form by elongation in one dimension

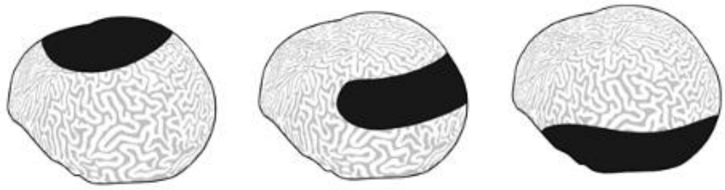
Lesion Distribution



Coalescing · Diffuse · Focal · Linear · Multifocal

Coalescing : to grow together
Diffuse : not concentrated or localized
Focal : of, relating to, being, or having a focus
Linear : of, relating to, or resembling a line
Multifocal : arising from or occurring in more than one focus or location

Lesion Location



Apical | Central / Medial | Basal / Peripheral

Apical : situated near the apex or tip of a structure, as in the apical portion of a cell, opposite to basal
Central / Medial : lying or extending in the middle
Basal / Peripheral : situated near the base of a structure in relation to a specific reference point, opposite to apical

Lesion Edges

Annular | Distinct | Indistinct

Annular : of, relating to, or forming a ring
Distinct : distinguishable to the eye or mind as discrete
Indistinct : not sharply outlined or separable

Lesion Margins

Serpiginous | Serrated | Smooth | Undulating

Serpiginous : having a wavy border
Serrated : having a sawlike edge or border
Smooth : having a continuous even surface
Undulating : wavelike in shape

III. Diagnostic trees

In order to determine the possible causes of coral **lesions** (morphologic abnormalities), different decision trees have been built following the scheme proposed by Raymundo et al., 2008[1]. Please note that the pathologies and diseases observed vary across geographical regions. Unlike the work of Raymundo and colleagues, the decision trees in this document compiles all pathologies encountered worldwide, and you will find the relevant geographical region indicated at the top of each technical sheet. Although very few studies have been conducted on coral diseases in aquaria, different sources of information online and in the literature highlight some pathologies that frequently occur in aquaria. Here are how the diagnostic trees were constructed:

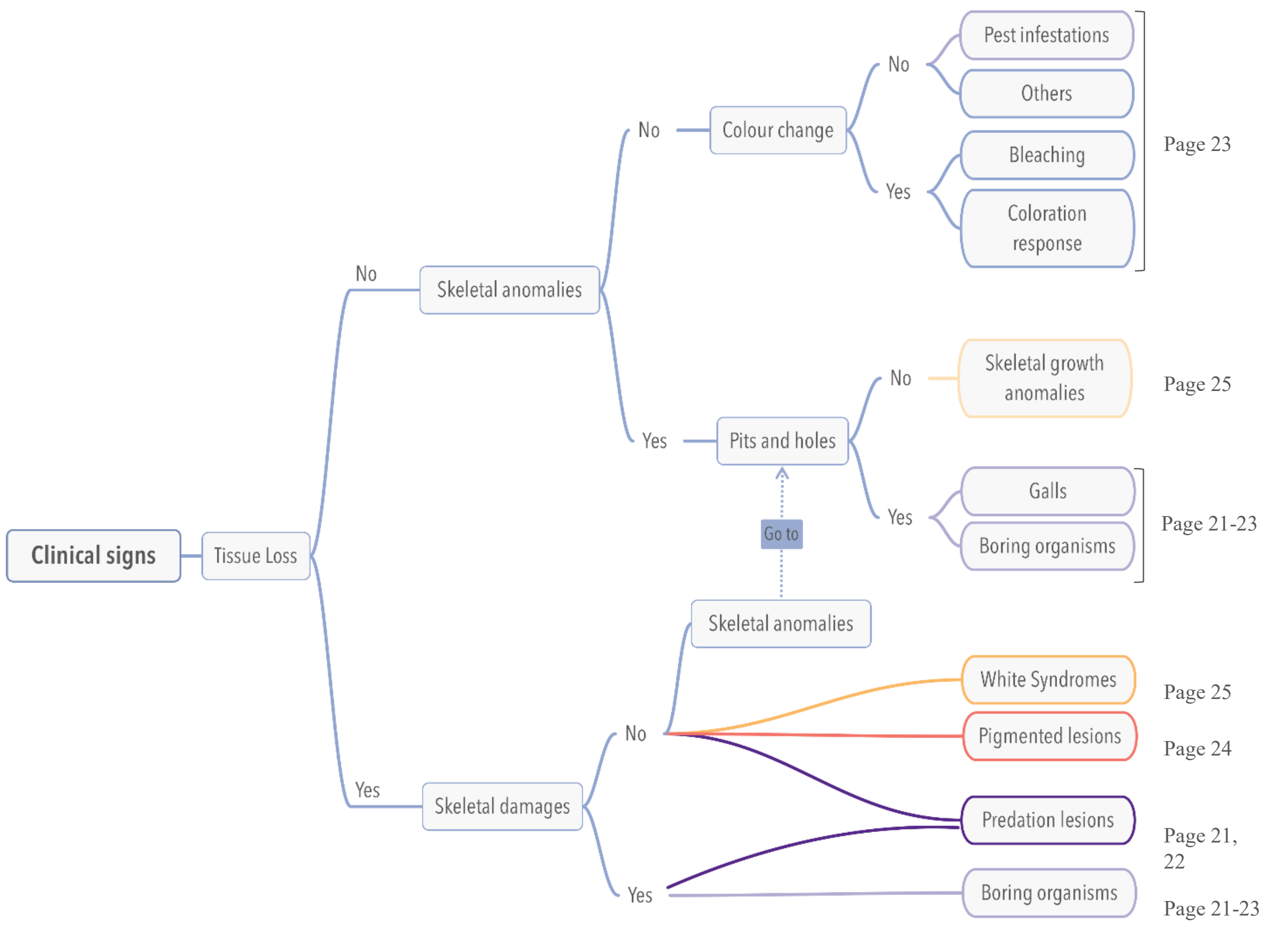
These decision trees are used to identify potential causes of lesions based on various discriminating criteria, which, step by step, guide the user towards one or more suggestions and the corresponding identification and management sheet. It can be used with any coral species as it is based on different criteria applicable to all types of coral. For more details, the description and terminology of lesions are described in the previous chapter.

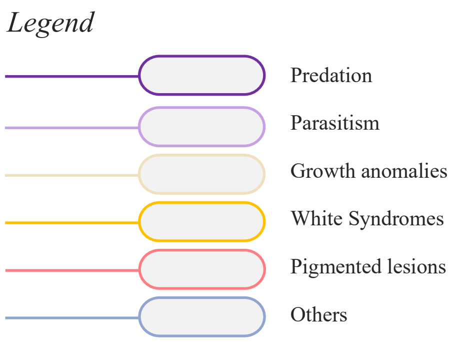
When a coral exhibits a lesion, we first consider causes that are not necessarily attributable to diseases. Indeed, in a captive environment, major causes of morbidity and mortality for these organisms can be due to unsuitable environmental conditions or trauma. In aquaria, traumatic lesions can be of human or animal origin, which are then predation lesions. It is also common to observe stress responses, whether related to unsuitable physicochemical parameters of the environment, the presence of parasites, or interspecific competition. Once these factors are ruled out, it is then recommended to look into the diagnostic trees for diseases. It is important to keep in mind that diseases can have multiple origins and it is often impossible to determine the causes without laboratory work.

- The **general diagnostic tree** provides an overview of potential causes of coral health disturbances in an aquarium (p.20).
- The following trees are dedicated to lesions frequently caused by **predation**, **parasitism**, or **stress responses** (p.21 to p.23), based on different clinical signs like **skeletal damages**, **tissue loss** and **others**.
- The final trees focus on lesions caused by **diseases** such as **White Syndromes** (broad term encompassing coral diseases characterized by severe tissue loss from the coral with a sharp demarcation between the apparently healthy tissue), **pigmented lesions**, and coral **growth anomalies** (p.24-25).

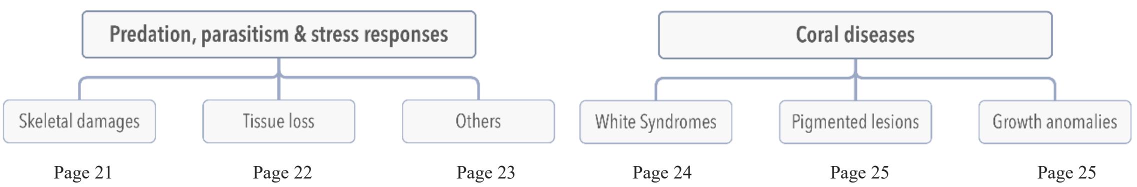
[1] Raymundo, L. J., C. A. Couch, & C. D. Harvell (Eds.). (2008). A coral disease handbook: Guidelines for assessment, monitoring, and management. Coral Reef Targeted Research and Capacity Building for Management Program; USGS Publications Warehouse. https://pubs.usgs.gov/publication/70197913

General Diagnostic Tree



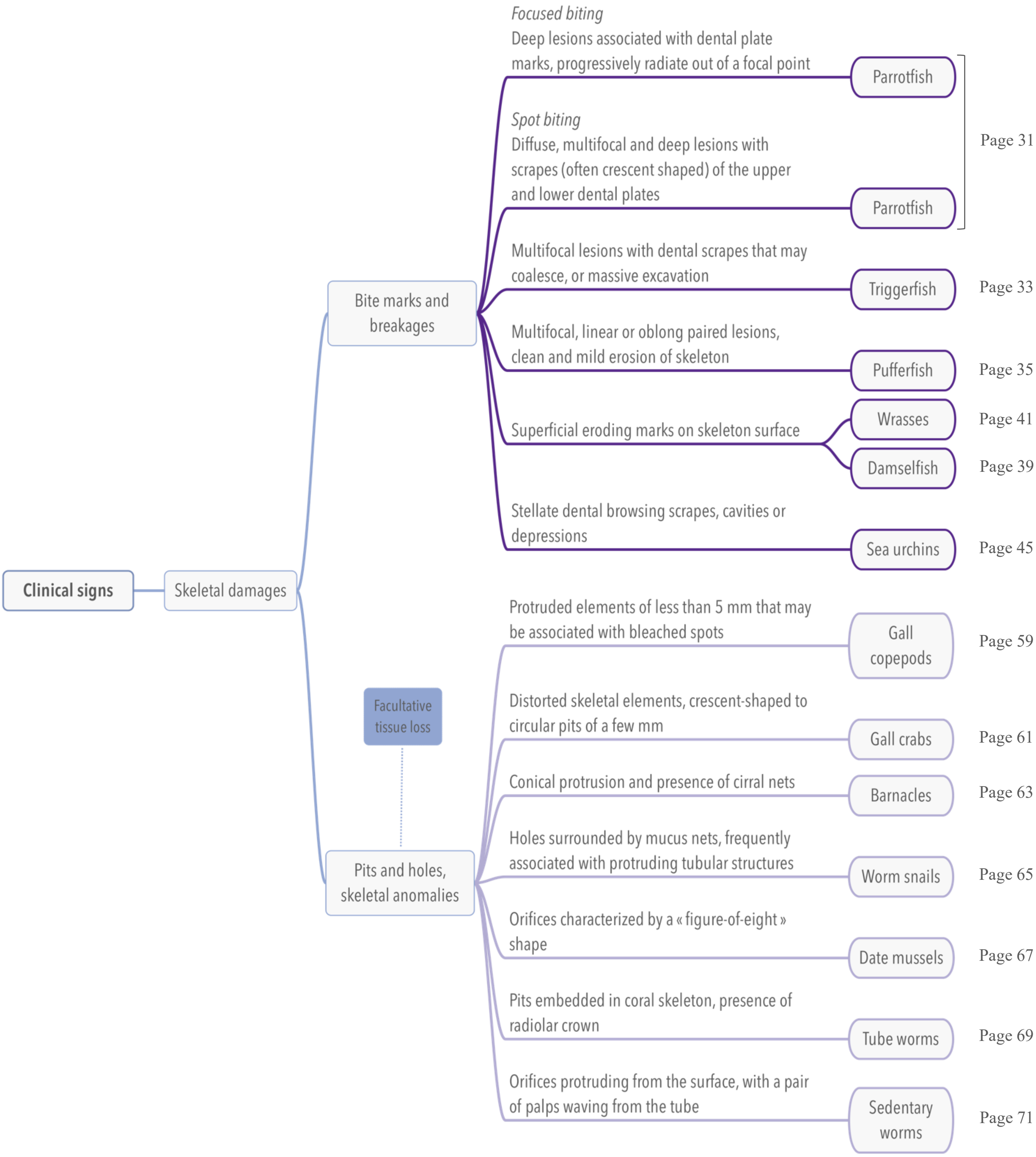


For clarity, the general diagnostic tree is subdivided in different parts depending on the causative agent types and the main discriminating criterion as followed:



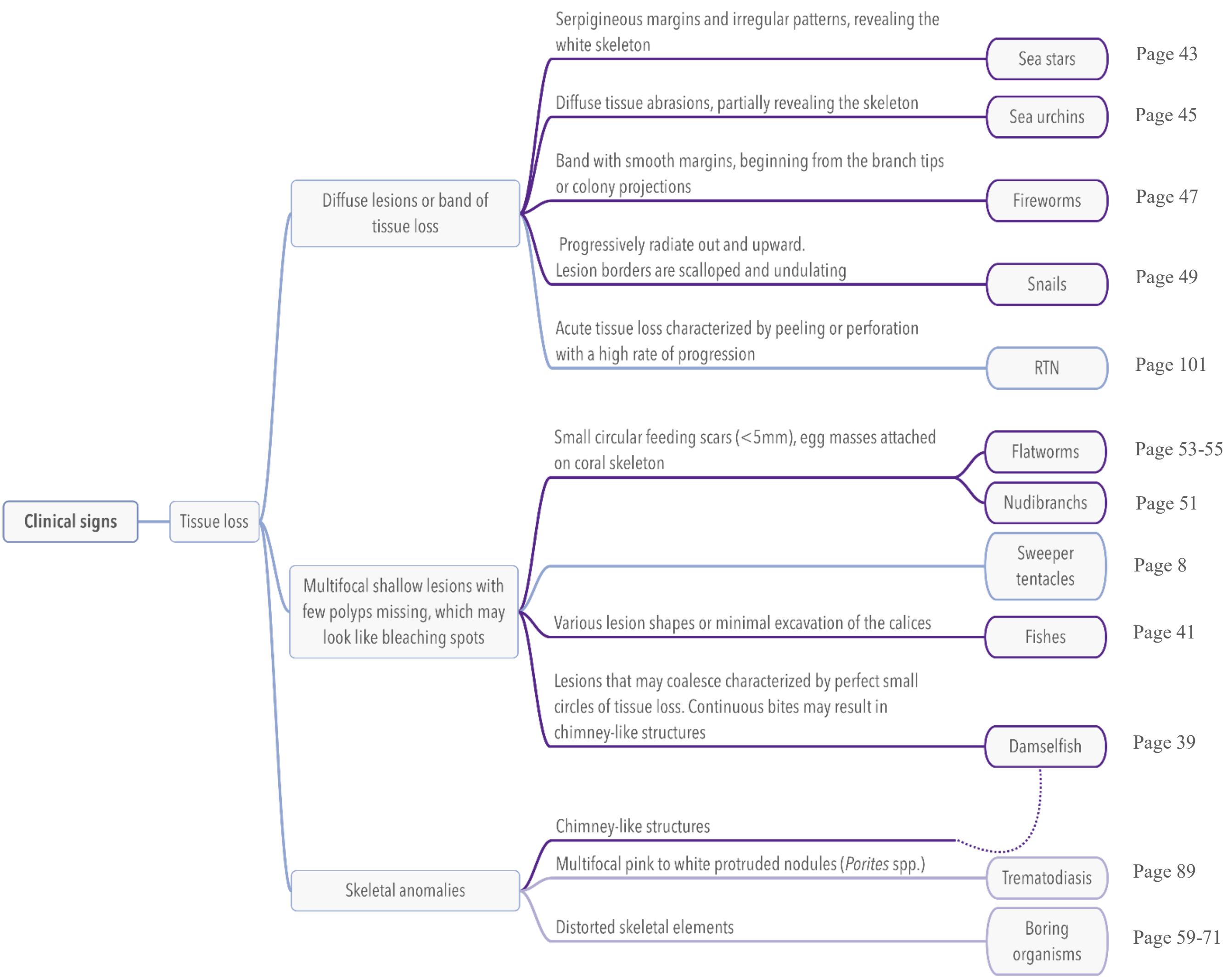
Predation, Parasitism and Stress Responses

Skeletal damages



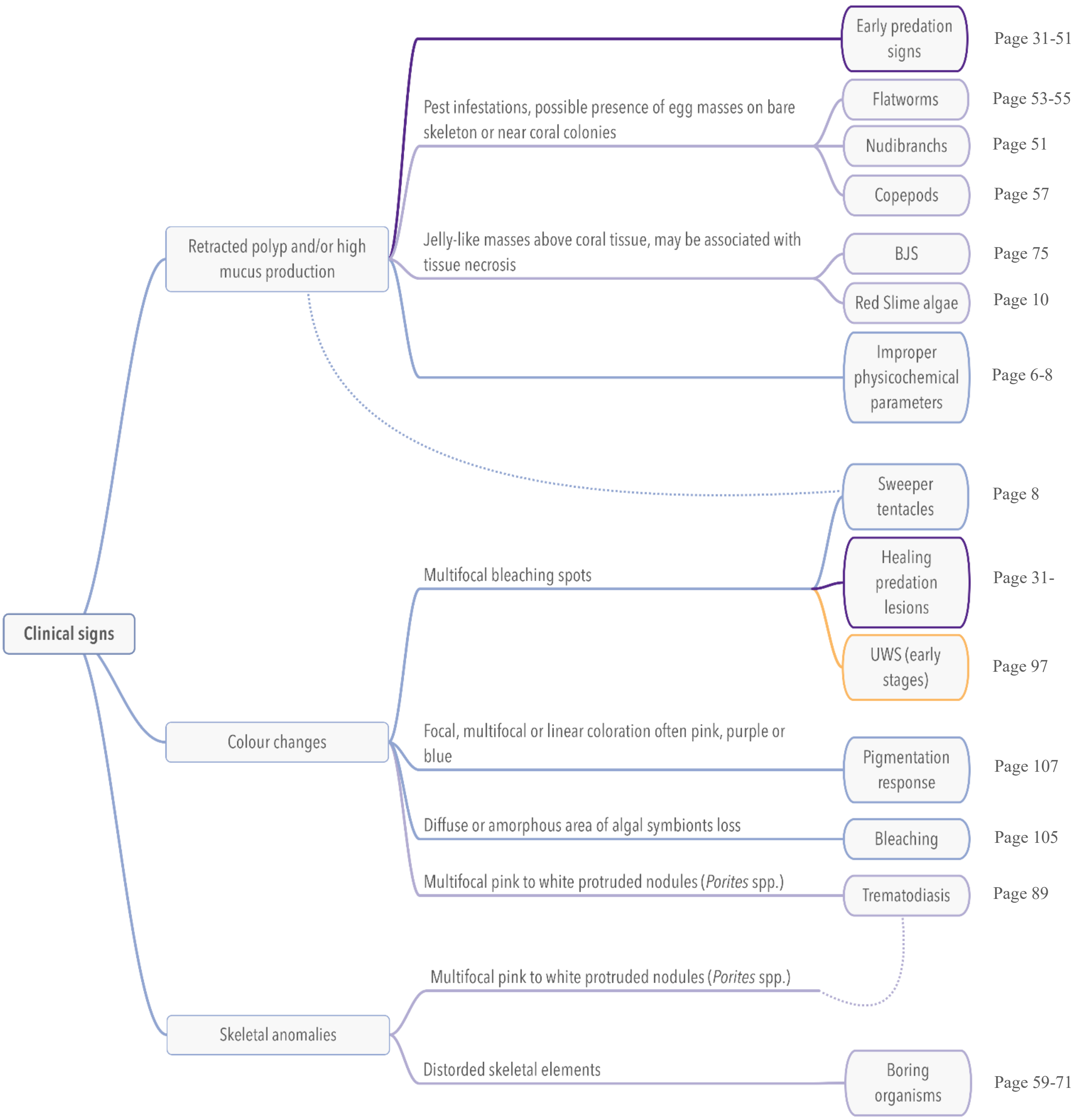
Predation, Parasitism and Stress Responses

Tissue loss



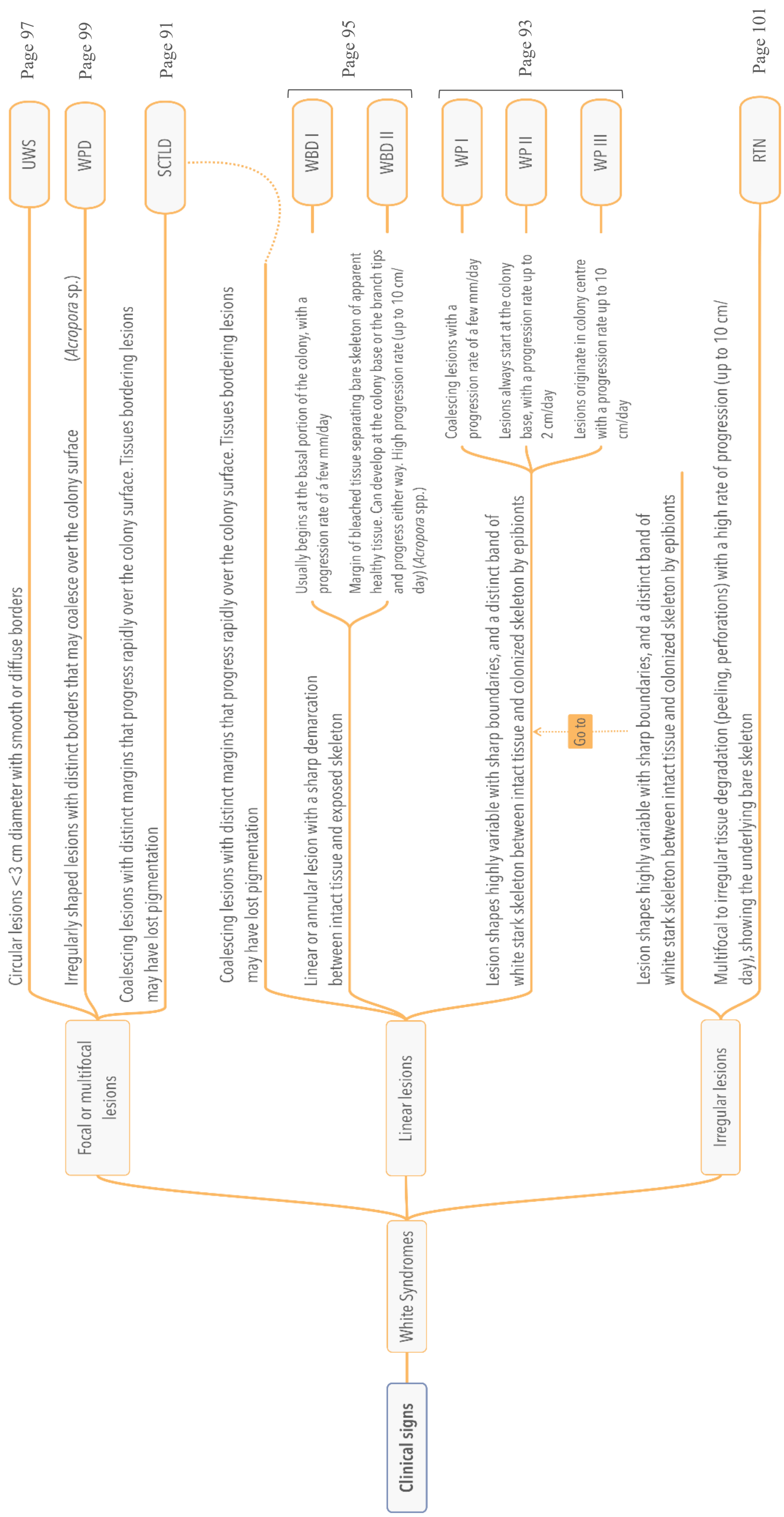
Predation, Parasitism and Stress Responses

Others



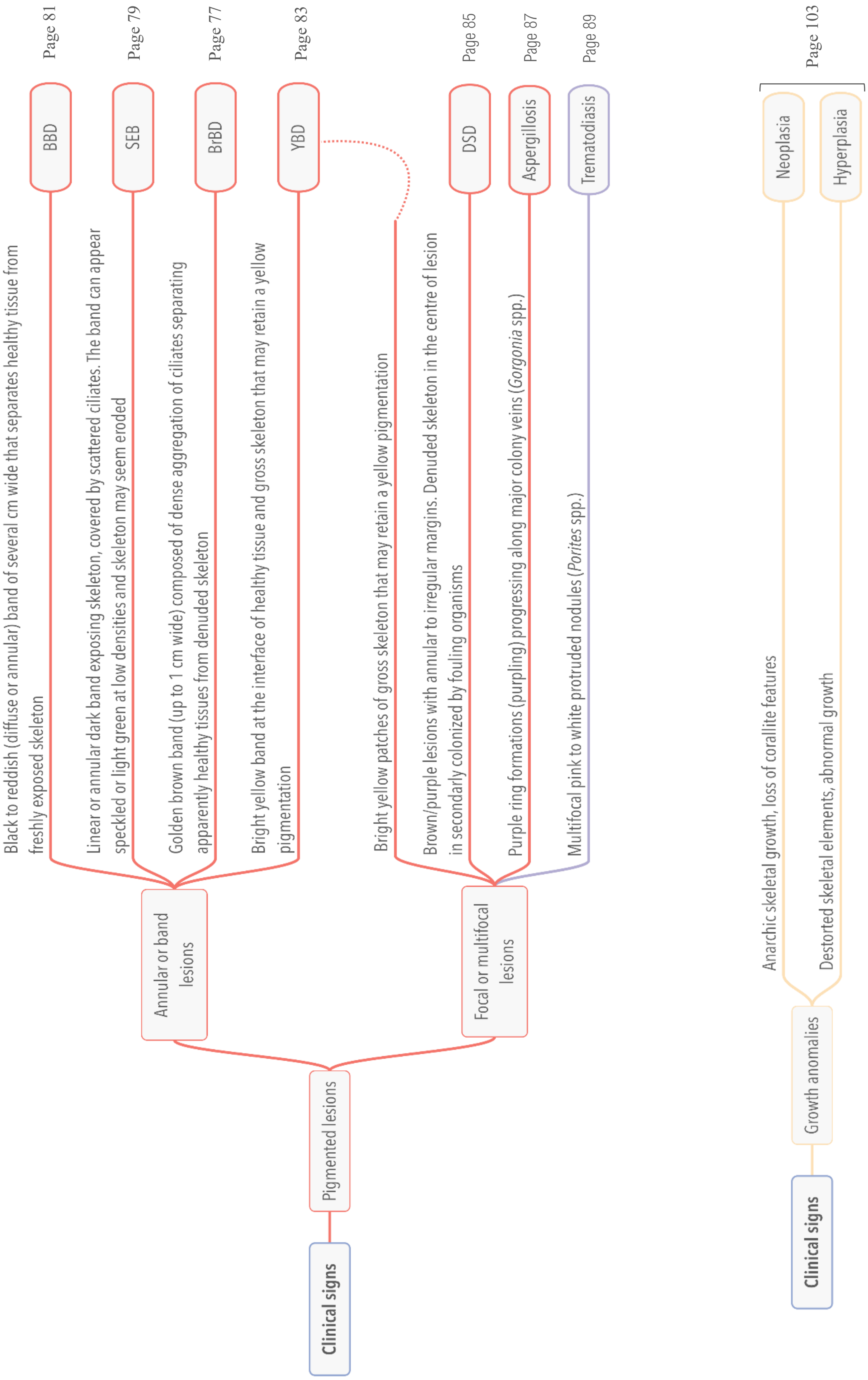
Diseases

White Syndromes



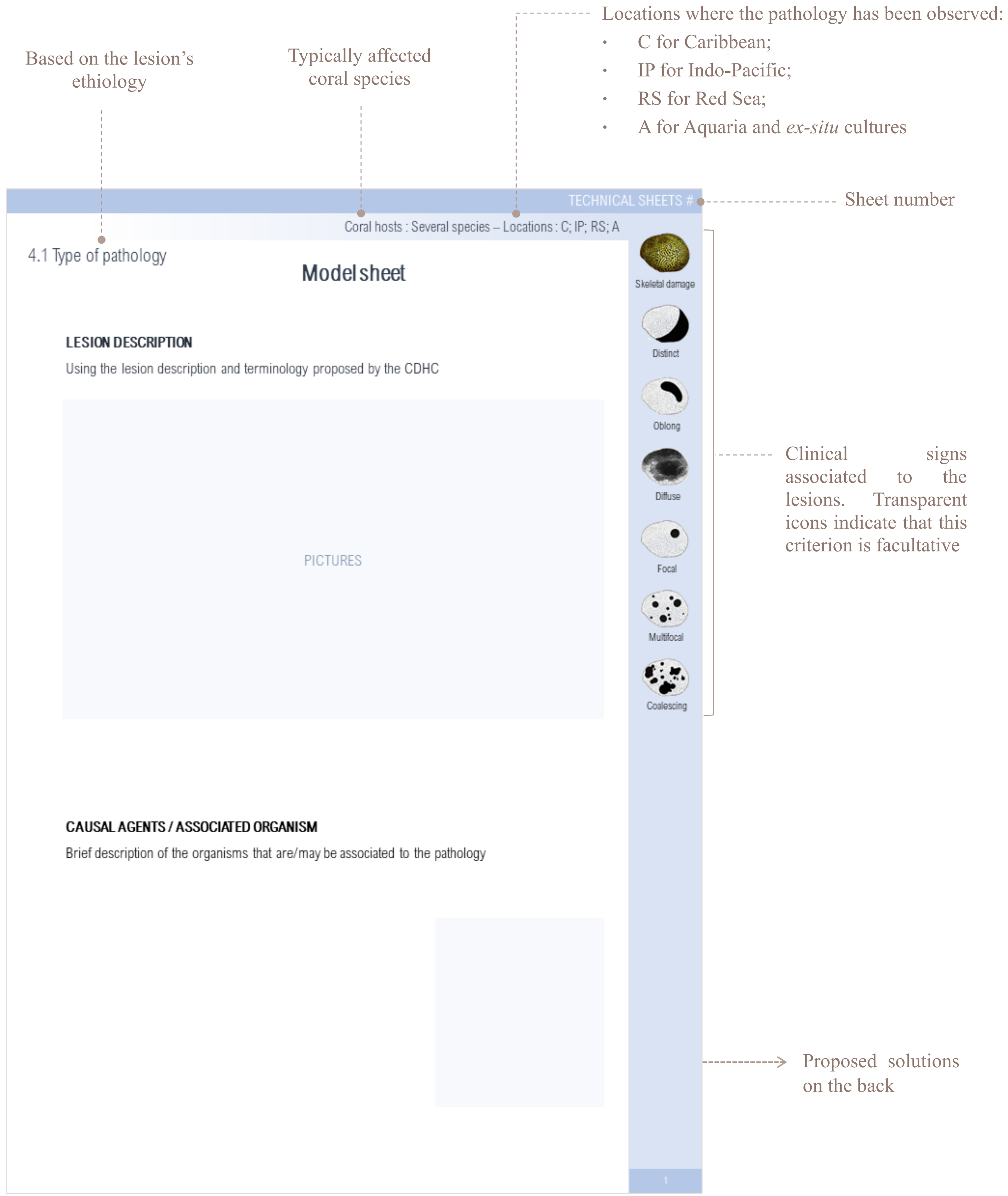
Diseases

Pigmented lesions & Growth anomalies



IV. Technical Sheets

The following figure illustrates the structure and organization of the technical sheets:



Sheet index numbers

Coral hosts : Several species – Locations : C; IP; RS; A

4.1 Predation and bioerosion

Parrotfish

LESION DESCRIPTION

Diffuse and deep lesions associated with loss of corallite and underlying skeleton. Bite marks are characterised by distinct edges and are often oblong or crescent-shaped, made by upper and lower dental plates. Lesions distribution may be multifocal (known as “Spot biting”), concentrated along exposed coral ridges or progressively radiate out of a focal point (known as “Focused biting”) (Bruckner et al., 2000).

Parrotfish predation marks : spot biting by unidentified parrotfish species on massive *Porites* (above) © G. Aeby, and focused biting by unidentified parrotfish species on *Orbicella annularis* (below) © D. Gochfeld

CAUSAL AGENTS

Four Carribean parrotfish species (*Sparisoma viride, S. aurofrenatum, Scarus vetula, S. guacamaia*) and five species in the Indo-Pacific region (*Bolbometopon muricatum, Cetoscarus bicolor, S. frenatus, Chlororus gibbus, S. rivulatus*) are known to frequently feed on live coral. However, several parrotfish (see annexe) consume coral tissue occasionally, especially when algae are scarce (Bruckner & Bruckner, 2015).

Skeletal damage

Distinct

Oblong

Diffuse

Focal

Multifocal

Coalescing

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

Scarus quoyi © Oceanographic Institute of Monaco, F. Pacorel

Coral hosts : Several species – Locations : C; IP; RS; A

4.1 Predation and bioerosion


Skeletal damage


Irregular

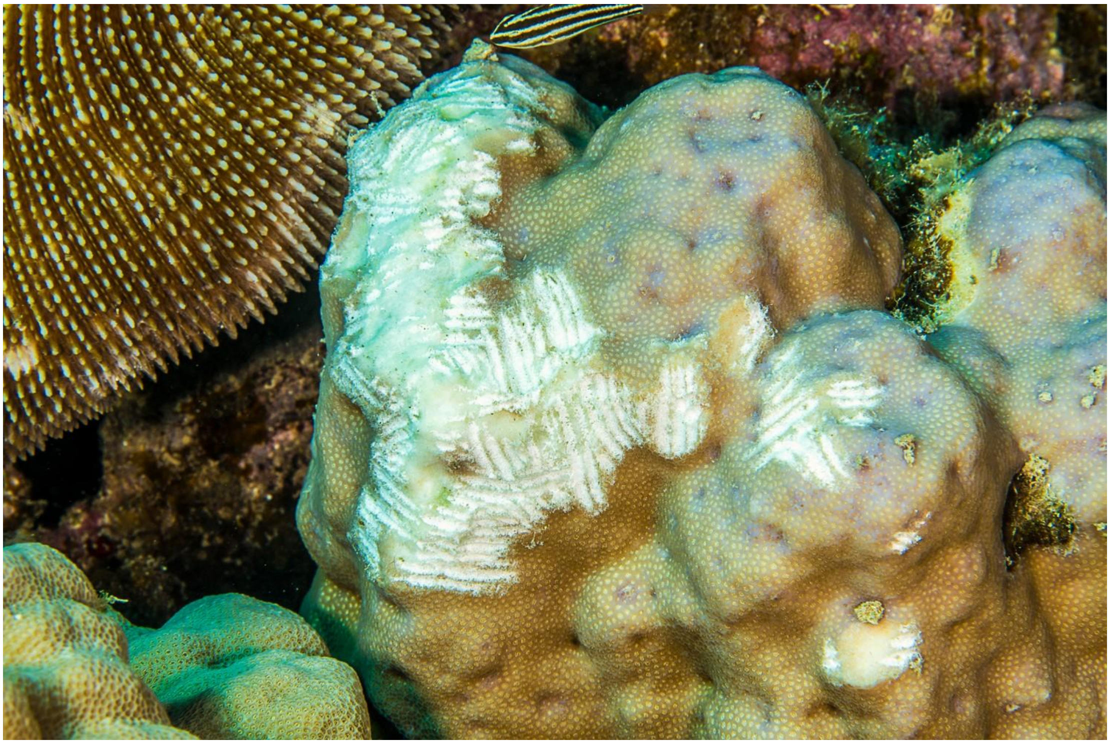

Distinct


Focal

Triggerfish

LESION DESCRIPTION

Irregular lesions due to the uneven bite of the fish characterised by loss of corallite, distinct edges and that often radiate out of a focal point. Clear rectangular teeth marks may appear in pairs, generally shallower than parrotfish feeding marks. However, some species can massively excavate and break coral branches (Bruckner & Bruckner, 2015).



Predation lesion of triggerfish on *Porites* with shallow excavation of the calices and rectangular teeth marks © V. Chalias

CAUSAL AGENTS

Triggerfish are facultative corallivores or bite through coral to access food. As example, *Melichthys niger* may occasionally feed on corals when food sources are scarce (Randall, 1967) and *Balistapus undulatus* can heavily feed on *P. damicornis* and limit the development of the species on the reef (Neudecker, 1977). Among other species, the triggerfish *Balistoides viridescens* is known to bite and break coral colonies to reach its preys like sea urchins or molluscs (Randall, 1998).

Like other triggerfish species, *Balistoides viridescens* has powerfull jaws and sharp teeth to crush coral colonies, enabling the fish to access hidden prey within the coral structure. © F. Libert – Licence CC BY-SA2,0

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

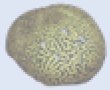
- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

Coral hosts : Several species – Locations : IP; RS; A

4.1 Predation and bioerosion


Tissue Loss


Skeletal damage


Oblong


Distinct

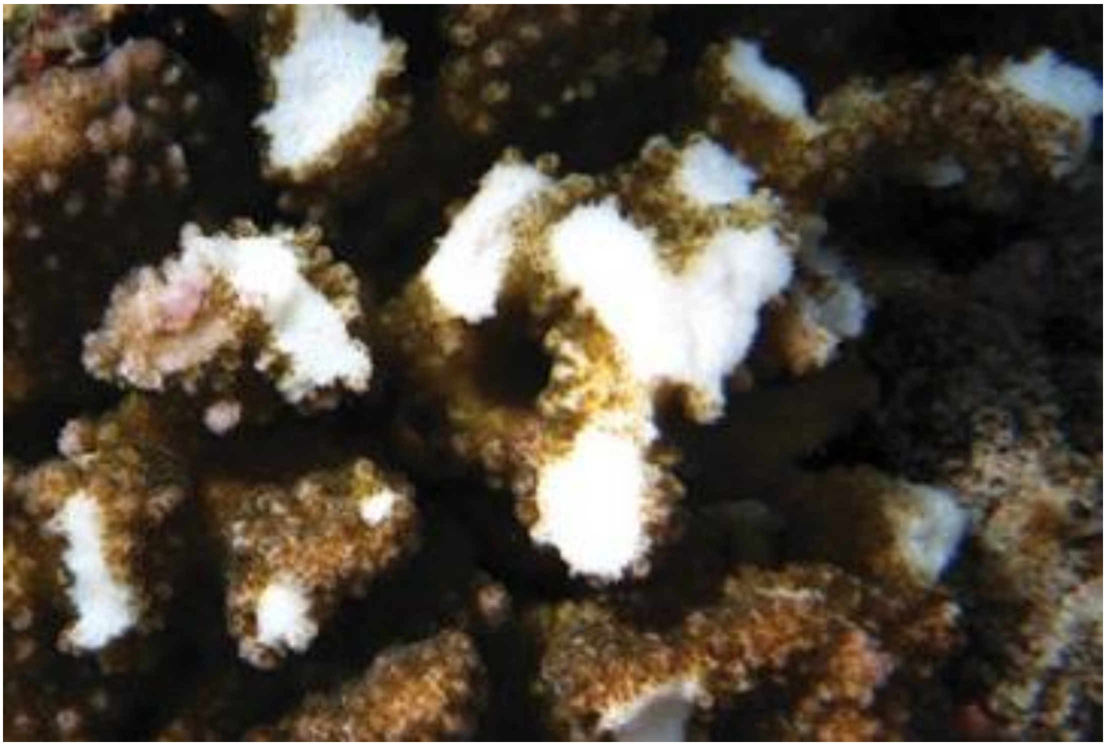

Focal


Multifocal

Pufferfish

LESION DESCRIPTION

Focal to multifocal lesions associated with facultative skeletal damage depending on the bite's depths. Bite marks are relatively rounded to oblong with smooth margins due to the beak-like teeth. Lesions may be focused in a small area or may be distributed more broadly across the colony. The scars are generally concentrated along exposed ridges or branch tips of corals (Bruckner & Bruckner, 2015).



Predation lesions of the pufferfish *Arothron diadematus* on *Pocillopora meandrina,* characterized by the removal of whole branch tips from branching colonies from Bruckner and Bruckner, 2015.

CAUSAL AGENTS

Pufferfish are facultative corallivores, mainly found in the Indo-Pacific, that feed on a range of invertebrates and hard substrates. Member of the genus *Arothron* (*A. hispidus, A. meleagris, A. nigropunctatus* and *A. stellatus*) are known to use their strong beak to bite off chunks of coral (Randall, 2005; Bruckner & Bruckner, 2015).

Arothron meleagris is a species known to feed on corals and others invertebrates © Oceanographic Institute of Monaco, F. Pacorel

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

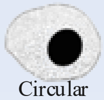
Coral hosts : Several species – Locations : C; IP; RS; A

4.1 Predation and bioerosion

Butterflyfish


Tissue Loss


Skeletal damage


Circular


Distinct


Multifocal

LESION DESCRIPTION

Multifocal, small and circular lesions of tissue loss with distinct edges. Most lesions measure less than 1 centimeter in diameter, reflecting the size of the fish's mouth. Depending on the predator species, the lesion may be accompanied by a loss of skeletal material. In most cases, lesions take the appearance of whitish patches.

Bite marks from *Heniochus singularis*. © J.C. Delbeek

CAUSAL AGENTS

It is in the butterflyfish group that we find the largest number of corallivorous fish (69 sp.). Depending on different feeding strategies, some are facultative corallivores (such as *Chaetodon auriga, C. melannotus, C. speculum, C. vagabundus*) and others are obligatory corallivores (*C. lunulatus, C. meyeri, C. plebeius* and *C. trifascialis*) (Bruckner & Bruckner, 2015). Some of them consume only the mucus without damaging polyps, while others (e.g. *C. unimaculatus*) have robust teeth that can partially remove skeletal material with each bite. Most of butterflyfish have small forceps-like mouths that remove a few coral polyps (e.g. *C. ornatissimus*), forming relatively small whitish areas (Motta, 1988).

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

Chaetodon bennetti is one of the many butterflyfish species that is not considered reef safe as it feeds on coral polyps and filamentous algae © François Libert, © Fishipédia – Licence CC BY-SA2.0

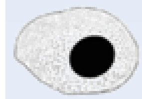
Coral hosts : Several species – Locations : C; IP; RS; A

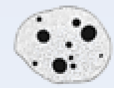
4.1 Predation and bioerosion


Tissue Loss


Growth Anomaly


Irregular


Circular


Multifocal

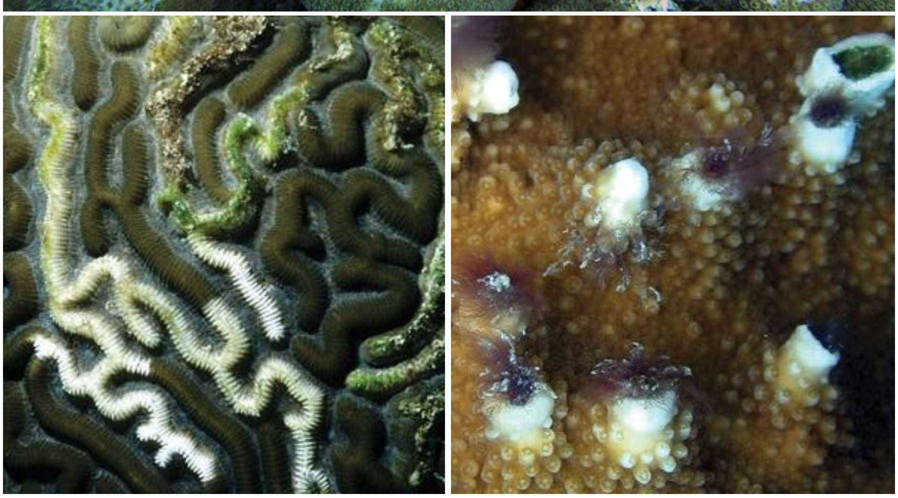

Coalescing

Damselfish

LESION DESCRIPTION

Lesions are typically circular, from 1 to 4 cm in diameter, or more irregular and scattered over the coral colony that may coalesce. They are associated with tissue loss and minimal skeletal damage and range from white denuded skeleton to pale regenerating tissue spots. If fish continuously bites in the same location, it may result in the formation of chimney-like structural anomaly (Kaufman, 1977). Presence of algal growth on older lesions is often encouraged by the damselfish.


Damselfish bites scattered over a colony of *Orbicella annularis*. © D. Gochfeld


Close up photographs of lesions created by *Stegastes planifrons* on ridges of *Diploria strigosa* (left) and of « chimneys » created by repeated biting on *Acropora palmata* (right). Oldest lesions are colonized by algae from Bruckner and Bruckner, 2015

CAUSAL AGENTS

Damselfish are divided in three main trophic groups : herbivorous benthic feeders, omnivores and pelagic feeders mainly eating planktonic preys (Frederich et al., 2016). Some of them are highly territorial benthic fish, and only a few species are polyp feeders. Damselfish species are known for their unique behaviour of cultivating algae on coral reefs. As example, *Stegastes planifrons* kills areas of coral tissue to create algal lawns (Kaufman, 1977). On the other hand, they may also exclude some corallivores and contribute to coral diversity in their territories (Gochfeld, 2010). Among the different species that feed on corals, *Cheiloprion labiatus*, *Neoglyphidodon melas, Plectroglyphidodon dickii, P. johnstonianus* are found in the Indo-Pacific region and *Pomacentrus leucostictus, P. variabilis, S. planifrons* dominate in the Caribbean (Bruckner & Bruckner, 2015).

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

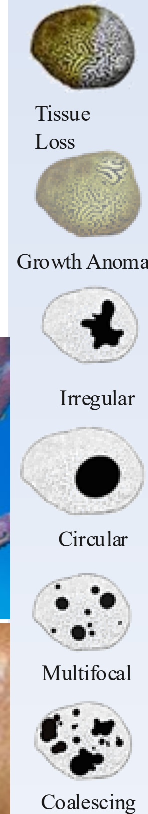
- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

Coral hosts : Several species – Locations : C; IP; RS; A

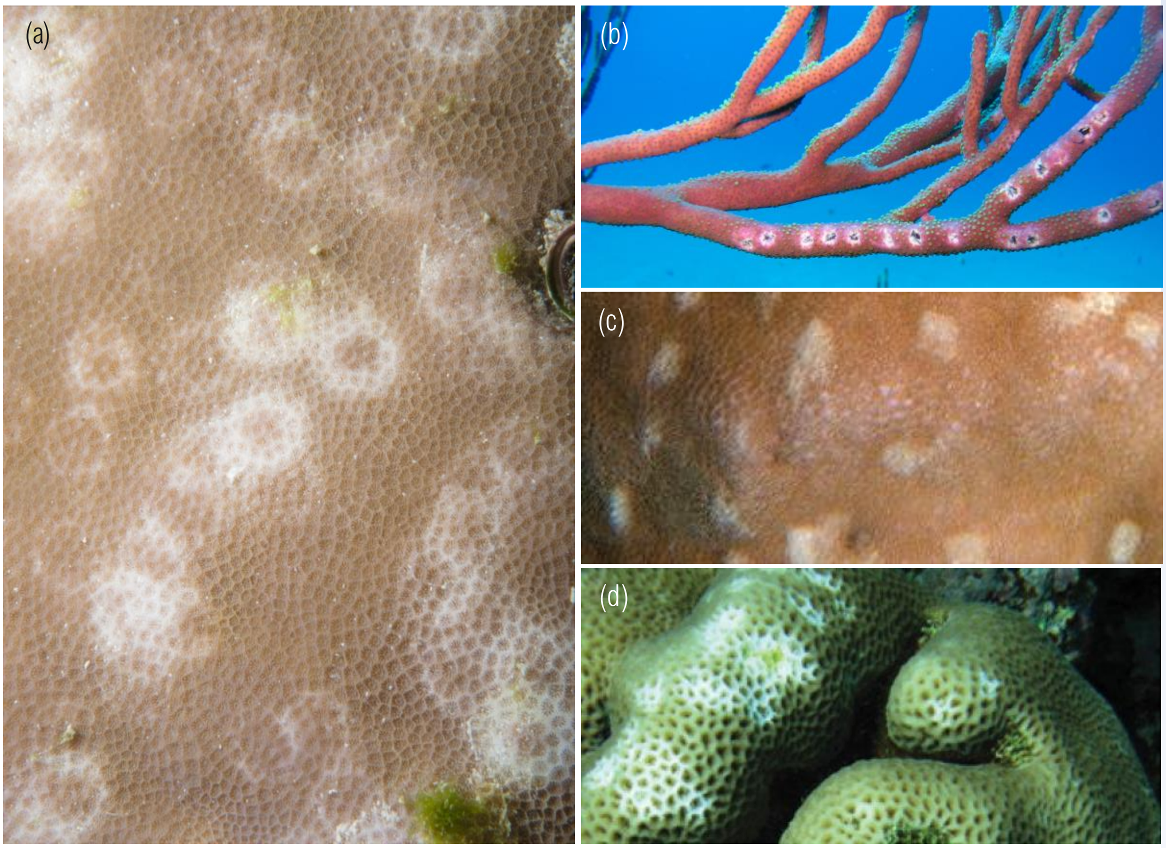
4.1 Predation and bioerosion

Other corallivorous fishes



LESION DESCRIPTION

Focal to multifocal lesions characterized by tissue loss and/or minimal excavation of the calices. Lesion shapes range from circular to irregular and may coalesce. If not, the shallow lesions with only a few polyps missing may look like bleaching spots.



Fish predation lesions on coral colonies. (a) Unknown fish bite marks on *Porites* sp. in Guam, 2013, J.C. Delbeek © California Academy of Sciences. (b) Cowfish bites on *Plexaurella* © D. Gochfeld. (c) Bite marks of an unidentified wrasse on a massive colony of *Porites* and (d) abrasions on *Goniastrea* resulting from fish predation from Bruckner and Bruckner, 2015.

CAUSAL AGENTS

Alongside the taxa listed on the previous sheets, which constitute the bulk of corallivorous fishes, around fifty other species are known to feed on corals. The main groups concerned are wrasse, blenny/goby, angelfish, filefish, boxfish and moorish idol (Bruckner & Bruckner, 2015).

Several wrasse species (mainly the genus *Labropsis*) feed on corals in the Indo-Pacific region, and some of them are obligate corallivores (Cole et al., 2008). The blenny and goby species spend much of their time on sea floor and inhabit cervices in reefs. Two species are known to consume coral polyps : *Exallias brevis* and *Gobiodon citrinus* (Sano, 1984). Although facultative corallivores, certain species of angelfish (e.g. *Centropyge multispinis, Pomacanthus semicirculatus*) can be particularly voracious in the presence of corals and can seriously damage colonies. In the Indo-Pacific region, the moorish idol (*Zanclus cornutus*) has also been observed occasionally grazing on coral tissue (McClanahan et al., 2005), as well as the two species of boxfish *Ostracion cubicus* and *Lactoria diaphana* (Moyer & Sano, 1987).

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for the fish. Sufficient, varied and suitable food may reduce the fish's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet might help divert their attention.

- **Relocation** : If only one colony is targeted, relocating the colony to another area of the aquarium or rearrange rockwork or coral placement to make the colony less accessible may reduce predation. If predation persists, rehome the offending fish or the coral colony may be necessary. If predation lesions are distributed over different colonies, you may need to consider moving the predator to an aquarium better suited to its food preferences.

Prevention : By assessing species compatibility, considering tank setup and ensuring proper nutrition.

Blenny bite marks (see blue arrows) on *Millepora* sp. in Guam, 2013. J.C. Delbeek © California Academy of Sciences

Coral hosts : Several species – Locations : C; IP; RS; A

Tissue Loss

Irregular

Linear

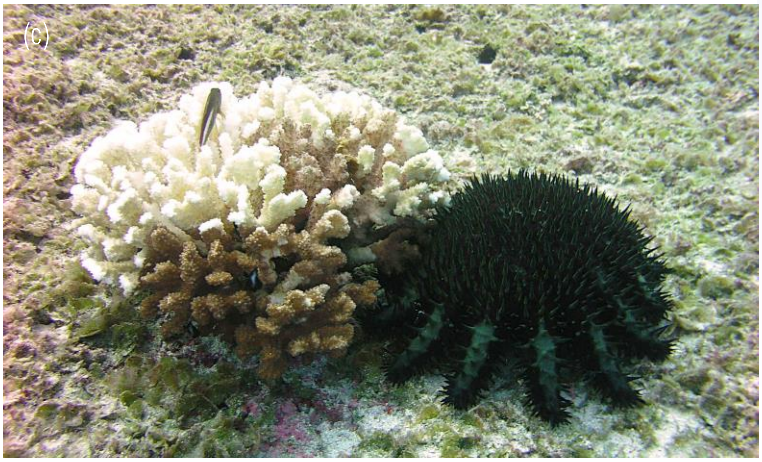
Serpiginous

4.1 Predation and bioerosion

Starfish

LESION DESCRIPTION

Lesions can vary in size and shape, are characterized by tissue loss, revealing the white skeleton without structural damage. Feeding scars often display serpiginous margins and may extend across the colony surface in a linear or irregular pattern (Bruckner & Bruckner, 2015).



Sea stars and associated lesions. (a) *Asterina* at the border of a lesion on *Millepora* in aquarium © Oceanographic Institute of Monaco, F. Pacorel. (b) Recent lesion of *Acanthaster planci* on *Goniastrea*, with typical serpignous margins from Bruckner & Bruckner, 2015. (c) *A. planci* feeding on branching coral © G. Aeby.

CAUSAL AGENTS

Several species of sea stars are facultative corallivores and have been observed consuming coral tissues. The only species that demonstrated a major impact on coral reefs is *Acanthaster planci* (known as the crown-of-thorns sea star, COTS) (Birkeland, 1989). Other asteroids, such as *Culcita* spp., are mostly detritivores or generalist predators feeding on benthic organisms and may occasionally eat coral polyps (Thomassin, 1976). When their favourite food sources become scarce, some individuals may turn to eating soft corals or scleractinian coral tissues. The small starfish *Asterina* spp. is considered both harmless and useful by consuming undesirable algae and potentially threatening to small coral colonies because it multiplies rapidly (Knop, 2020).

PROPOSED SOLUTIONS

Since the introduction of the COTS sea star into an aquarium is highly unlikely, the main source of trouble is likely to come from the excessive proliferation of *Asterina*. Overall, here is how to proceed:

- **Manual removal** : The simplest method to reduce the population in the aquarium is to remove a few organisms regularly (i.e. by siphoning).

- **Biological control** : Harlequin shrimp, *Hymenocera picta*, can be a good candidate for controlling the *Asterina* population, as they only feed on starfish. But the shrimps will deplete the prey population very quickly and then need additional food sources (Knop, 2020).

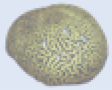
Prevention : By limiting nutrient loads and frequently removing individuals

Hymenocera picta © Oceanographic Institute of Monaco, M. Dagnino

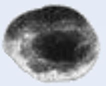
Macrophotograph of *Asterina* sp. © Oceanographic Institute of Monaco, F. Pacorel

Coral hosts : Several species – Locations : C; IP; RS; A


Tissue Loss


Skeletal damag


Irregular

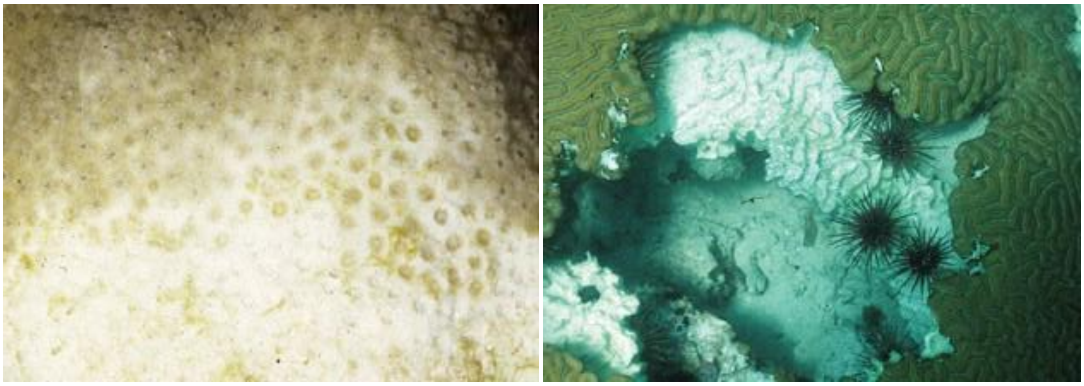

Diffuse

4.1 Predation and bioerosion

Sea urchins

LESION DESCRIPTION

Lesions can vary in size, shape and depth. Shallower lesions are characterized by diffuse tissue abrasion, partially revealing the skeleton with characteristic stellate dental browsing scraps (Bromley, 1975). The branch tips may appeared planed if they are targeted by grazing. Deeper lesions often appear as focal depression in the skeleton when urchins create home cavities.



Predation lesion of *Diadema antillarum* on *Montastrea annularis* (left) and excavation of a brain coral, *Colpophyllia natans,* by *Echinometra viridis* sea urchins (right) from Bruckner and Bruckner, 2015.

CAUSAL AGENTS

Sea urchins are known to consume coral tissue directly or indirectly when grazing on algae or creating home cavities. When their favourite food sources become scarce, some individuals may turn to eating soft corals or scleractinian coral tissues. *Diadema* spp. and *Echinometra* spp. are examples of bioeroders that can abrade coral tissues and creating cavities for shelter (Herring, 1972; Griffin et al., 2003). Other species, such as *Eucidaris thouarsii* feed on algae, a wide range of invertebrates and may also consuming coral polyps (Glynn et al., 1979).

Diadema setosum usually feeds on algae but can also abrade coral tissue while moving over the colonies © Oceanographic Institute of Monaco, M. Dagnino

PROPOSED SOLUTIONS

Once the causative agent has been identified, you have a few options open to you :

- **Feeding adjustment** : Coral feeding can be a sign of nutritional deficiencies for sea urchins. Sufficient and suitable food may reduce the urchin's need to prey on corals. For species that are known to be facultative corallivores, the use of food that mimics their natural diet (like dried algae) might help divert their attention (Carl, 2008).

- **Relocation :** Rearrange rockwork to provide enough hiding space and shelters for urchins. It will prevent undesirable excavation of coral colonies. If only one colony is targeted, relocating the colony to another area of the aquarium to make the colony less accessible may reduce damages. If they continue to erode coral colonies, you may need to consider removing individuals from your reef tank and rehome them.

Prevention : By assessing species compatibility, considering tank setup.

Coral hosts : Several species – Locations : C; M; A

Tissue Loss

Linear & Smooth

Apical

4.1 Predation and bioerosion

Fireworms

LESION DESCRIPTION

Lesions characterized by band or area of acute tissue loss with smooth margins, often beginning from the branch tips (apically) or colony projections. Lesions rarely extend over flattened surfaces of healthy corals, however worms have been observed consuming tissues on flattened areas adjacent to tissues affected by BBD (sheet 26), WP (sheet 32) and WBD (sheet 33) (Bruckner & Bruckner, 2015).

White tips of an *Acropora cervicornis* colony showing signs of recent tissue consumption by *Hermodice carunculata* (left) and *H. carunculata* engulfing a colony branch (right), from Santiago et al., 2023. © J. Valazquez

CAUSAL AGENTS

Hermodice carunculata is called “Fireworm” or also and is part of the group of errant marine polychaetes called bristle worms. This worm have sharp, venomous bristles (chaetae) along its body, which can penetrate the skin of other organisms, causing intense pain, irritation or allergic reaction. Known for being a voracious predator of corals, anemones and clams but also for scavenging dead or dying organisms. If a fireworm is noticed in the aquarium, it should be removed as soon as possible (Delbeek & Sprung, 1994).

Close-up image of the venomous, white and needle-like structures on *Hermodice carunculata*. These bristles are used for defense and can cause painful irritation if they into contact with skin. © S. Faulwetter – Licence CC BY-NC-SA2.0

PROPOSED SOLUTIONS

Here are suggestions for eliminating them from the aquarium :

- **Manual removal** : Manual removal of larger errant worms is the best way of reducing the polychaetes population. Sensitive to movement and vibrations, they are active at night. The most effective way to bring them out of hiding is to lure them. Not feeding the aquarium for a few days will improve your chances of catching the fireworms. By placing a container that is easily closable on the aquarium bottom, well away from their hiding place, with some bait such as fresh clams or shrimps, you will probably find some worms after a few hours in the dark that you can then trap and remove. You can also try to pluck them off the bottom with a net or a pair of long handled tweezers. An alternative is to place a box containing bait and pierced with holes (just large enough to let the worms pass through) that will trap them, as once the prey has been eaten, they will be too thick to get out. Be aware that those worms can inflict painful bites with their powerful jaws. Other options, like commercialized devices or DIY traps, are available and can help you to regulate the bristleworm population (Delbeek & Sprung, 1994; Carl, 2008).

- **Biological control :** Wrasses species can help to regulate bristle worm population at early stages of development. The sea snail *Bursa bufonia* has been observed consuming errant polychaetes (for smaller species), as well as the zebra seabream (*Diplodus cervinus*), but is only found in the Mediterranean and Atlantic, so it is not ideal to introduce the fish in an Indo-Pacific aquarium (Knop, 2020; Leewis et al., 2009).

Prevention : By isolating and quarantining all new corals, introducing a natural predator.

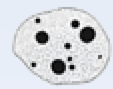
Coral hosts : Several species – Locations : C; IP; RS; A


Tissue Loss


Irregular


Undulating


Focal


Multifocal

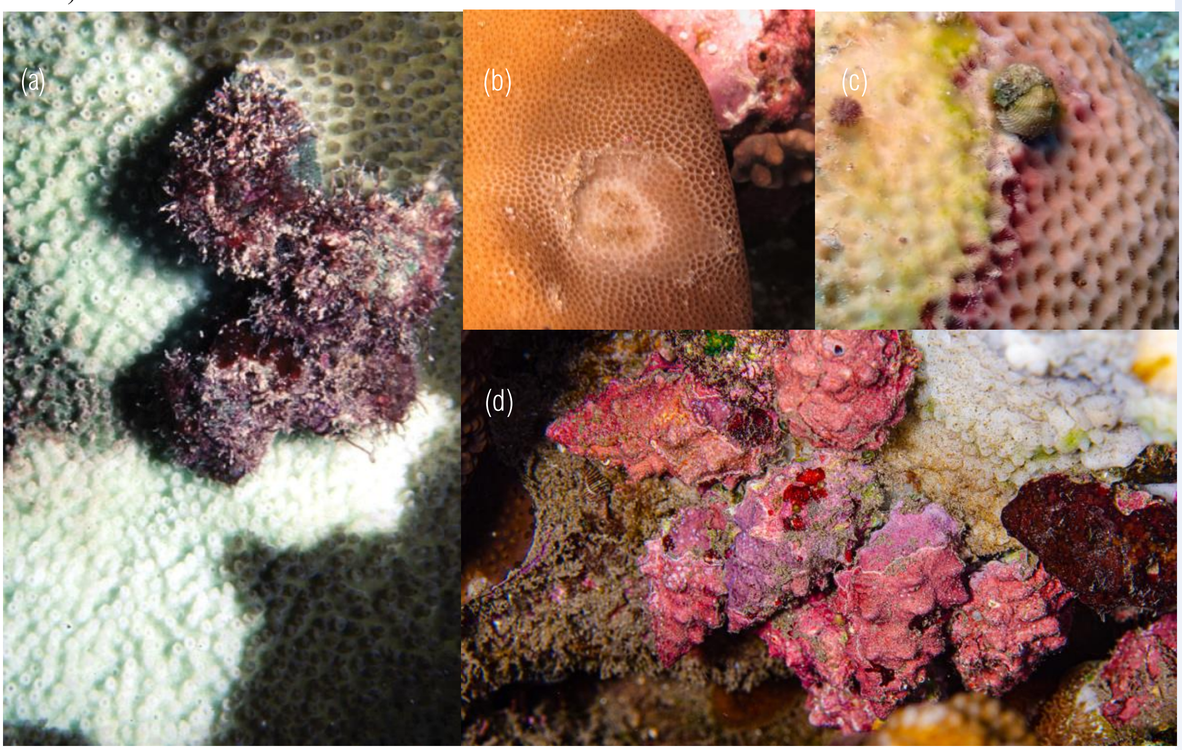

Coalescing

4.1 Predation and bioerosion

Snails

LESION DESCRIPTION

Lesion shapes are typically ovoid to irregular, with undulating margins, exposing the bare skeleton. Distribution of feeding marks may be focal, multifocal to coalescing, but lesions often extend from branch bases or colony edges. Small aggregation of gastropods can be found conspicuous around tissue loss areas or hiding at colony base or crevices (Bruckner & Bruckner, 2015).



Predation lesions of corallivorous snails : (a) typical predation lesion on *Acropora palmata* with scalloped margin and an aggregate of four *Coralliophila abbreviata,* from Bruckner and Bruckner, 2015; (b) focal predation scars created by *Coralliophila* © G. Aeby; (c) *Coralliophila* sp. feeding on *Siderastrea siderea* © D. Gochfeld; (d) aggregate of *Drupella* predating on *Acropora* fragments © V. Chalias

CAUSAL AGENTS

The most common corallivorous snails encountered in the aquarium are the genera *Coralliophila* and *Drupella.* They tend to occupy fast-branching coral (i.e. acroporids) and can become highly invasive (Baums et al., 2003; Schoepf et al., 2010). *Coralliophila* spp. measure less than 6 cm, have a typically purple aperture and use a strong proboscis to rip the coral tissue (Robertson, 1970). *Drupella* spp. have a small and thick shell that blend into coral reef structures and typically occur in small aggregations on a colony (Johnson & Cumming, 1995). Like the genus *Drupella, Jenneria pustulata* is a gastropod that may kill large coral in feeding aggregation. They scrape off the tissue of coral colonies with their radula and move as they feed, exposing areas of white skeleton (Bruckner & Bruckner, 2015).

Among other corallivorous species, several members of the family Ovulidae feed on soft corals and gorgonians. *Cyphonoma gibbosum,* a well-known species in the west Atlantic, eats exclusively gorgonians and may remove large areas of tissue from its prey (Lasker et al., 1988). *Epitonium* spp., *Qoyula* spp., *Rapa rapa* and *Heliacus areola* can also frequently create difficulties by feeding on soft corals and zoanthids (Delbeek & Sprung, 1994).

Some other herbivore species can become opportunistic when their main food sources become scarce. Most of these snails cannot reproduce in aquariums because their larvae are planktonic and are eliminated by the system's filters and skimmers, which limits damage (Knop, 2020).

PROPOSED SOLUTIONS

Once the causative agent has been identified, here are the recommendations :

- **Manual removal** : The simplest method is to remove the organisms by hand, using tweezers to pull the snails off rocks and corals. They are more active at night or early in the morning, and they hide in crevices, under rocks and coral colonies during the day. Commercial snail traps or DIY traps can attract snails with food inside.

Prevention : By isolating and quarantining all new corals, assessing species compatibility

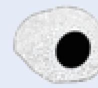
Cyphonoma gibbosum predating on the branching gorgonian *Eunicea* sp., from Bruckner and Bruckner, 2015

Coral hosts : Several species - Locations : IP; A

Tissue Loss

Focal

Irregular



Circular

4.1 Predation and bioerosion

Nudibranchs

LESION DESCRIPTION / INFESTATION SIGNS

Lesions are characterized by often small focal, circular to irregular-shaped area of tissue loss. An other infestation signs is the presence of egg clusters in the shape of a spiral or gelatinous ribbon, often attached on the underside of coral surfaces. Lesions may be associated with inhibition of polyp extension or colour loss.

CAUSAL AGENTS

Several species of nudibranchs feed on corals. While they consume coral tissues, they also ingest and store the algal symbiont in their cerata (dorsal and lateral outgrowths of the body), which often mimic the shape of the host polyps (Delbeek & Sprung, 1994). Nudibranchs are typically nocturnal, may be difficult to distinguish from their environment and the presence of multiple cerata can constitute a good visual indicator to detect them (Barton et al., 2020).

Members of the family Aeolidiidae (e.g. *Aeolidia, Aeolidiopsis, Aeolidiella* and *Phyllodesmium* spp.) possess many cerata and vary in size, but they are generally larger than many other nudibranch families. They tend to target soft corals, leaving patches of dead tissue or causing bleaching around the affected areas (Delbeek & Sprung, 1994).

An example of extremely well camouflaged is the flat nudibranch *Pinufius rebus,* which feeds exclusively on *Porites* spp (Rudman, 1982).

Phestilla subodiosus predating on *Porites cylindrica,* leaving area of tissue loss (photo above) and white egg clusters on denuded skeleton, from Adams, 2020 Photo by Jake Adams. Courtesy of Reef Builders (reefbuilders.com)

Other *Phestilla* sp. feeding on *Goniopora,* with egg clusters in shape of orange ribbon, from Hu et al., 2020.

Certain Trinchesiidae species like *Tenellia* spp. (Wong et al., 2017) or *Phestilla* spp. are also known to feed on coral colonies, with *P. sibogae* that preys exclusively on *Porites* species (Gochfeld & Aeby, 1997). Their small size, combined with their camouflage abilities, can make them difficult to spot on their preys.

Dendronotus and *Tritonia* spp. are commonly encountered in the aquarium. They are specialists of soft corals and have an elongated body with highly branched cerata (Delbeek & Sprung, 1994).

PROPOSED SOLUTIONS

Different methods exist to remove undesirable nudibranchs :

- **Manual removal** : as they avoid light and are well camouflaged, the best way to find them during daylight is to detect coral colonies (mostly soft corals) that don't have their polyps open. Otherwise, a red-light torch can be used to spot them in the dark, mainly in crevices, at the base of colonies or on rocks next to corals (Knop, 2020). You can use tweezers or forceps to grasp the nudibranchs without damaging coral tissue. You should also look for egg clusters (small spirals or patches) on the underside of coral surface or area of exposed skeleton and carefully scrape them off. In case of persistent infestation over several months and if conditions allow, fragmenting infected corals seems to produce healthy new colonies when placed in an aquarium without predators (Carl, 2008).

- **Freshwater dips** : an effective way to rapidly dislodge the nudibranchs from coral tissues by osmotic shock. 5 to 10 seconds dip in a bath with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994). A safer alternative is to use a hypo-osmotic solution of seawater, 15 ppt and max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals like acroporids or xenids. Don't forget to look for egg clusters and scrape them off (or waterjet).

- **Chemical treatment** : A common treatment against diseases or parasitic infections in aquariology is Lugol's or other iodine-based dip. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing, shaking and brushing the colony to remove as many molluscs and eggs as possible before rinsing the coral with clear seawater. The procedure should be repeated at least once a week later to get rid of any juveniles that may have hatched in the following days (Leewis et al., 2009). For heavier infestation, levamisole hydrochloride is classified as an antihelmintihic and can paralyse nudibranchs. The treatment must be done on the isolated colony in another container, such as a bucket, to limit damage to other invertebrates in the aquarium. To detach nudibranchs, a bath for 4 hours, at a concentration of 40 mg/L (e.g. 5,3 mL of 7,5 % levamisole in 10 L of seawater) is effective. As the eggs are not affected by the treatment, the coral should be inspected during the bath to identify and remove (by scraping or water jet) any visible egg masses. After treatment, the colony is placed in a second bucket with clear seawater and shaken for 1 minute to remove excess levamisole and hidden molluscs (or even waterjet). Then the infested colony should be placed in a quarantine tank, and the treatment repeated once per week for four weeks to allow any remaining eggs to hatch (Carl, 2008; Leewis et al., 2009).

Other commercial products are also used to eradicate nudibranchs, such as CoralRx.

- **Biological control :** Certain wrasse species like *Halichoeres chrysus,* or *Coris gaimard* (but be careful with the latter, which does not hesitate to turn over rocks to reach its preys, regardless of the surrounding corals) (Knop, 2020). *Pseudocheilinus hexataenia* (Leewis et al., 2009), *Chaetodon auriga* (Gochfeld & Aeby, 1997)

Prevention : By isolating and quarantining all new corals, introducing a natural predator.

Coral hosts : Several species – Locations : A; RS; IP; A


Colour Change


Multifocal

4.2 Allies and parasites

Acoel flatworm infestation

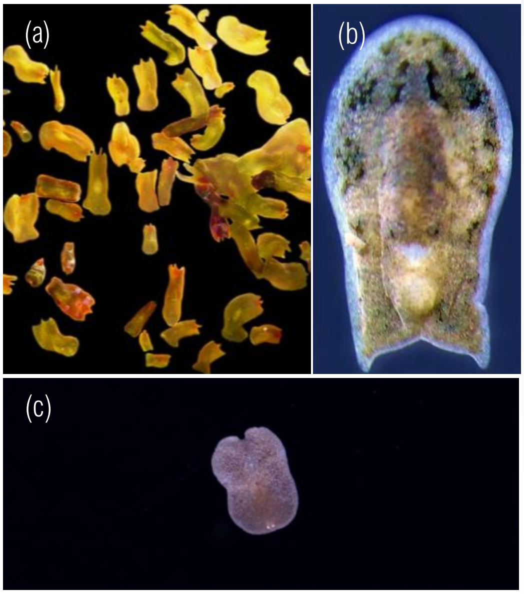
LESION DESCRIPTION / INFESTATION SIGNS

Coral surface is covered with brownish, fleshy, and ovoid flatworms of less than 5 mm in length. These worms do not generate lesions as such, as they have not been observed consuming coral tissue. However, they do colonise the surface and may cause stress by shading the coral colony.

Acoel flatworm infestations. Mushroom anemones covered by a few planaria (left) and flatworms infesting a *Turbinaria* sp. at high density (right) © Oceanographic Institute of Monaco, F. Pacorel.

CAUSAL AGENTS

Coral-infesting acoels are likely to be widespread in the marine environment (Ogunlana et al., 2005). *Convolutriloba* is a genus mainly described from marine aquaria. *Convolutriloba retrogemma* are reddish-brown flatworms with an oblong body, or "shield-like" shape. They can be confused with the flatworm species *Heterochaerus australis* that has an oblong body shape with two caudal appendages (Hendelberg & Akesson, 1988). These genus are both found on diverse substrates in aquaria and can proliferate rapidly (Barton et al., 2020). Excessive development of *Convolutriloba* seems to be linked to very high oxygen saturation in the aquarium. In other words, an imbalance between the oxygen production by algae and the oxygen consumption by the animals' metabolism. These are generally tanks rich in algae and poor in fish (Knop, 2020). The genus *Waminoa* is commonly found in aquariumand harbour several morphotypes, from a discoid to a"molar-like" body shape (Kunihiro et al., 2019). Theycolonize preferentially coral host, on which they mayhave negative impacts by consuming coral mucus, inhibiting the photosynthesis of algal symbionts (Barneah et al., 2007) and consume zooplankton caught in coral polyps (Wijgerde et al., 2012). Their multiplication may be enhanced by high levels of phosphates in the aquarium (Knop, 2020).



The main genera of acoel flatworms encountered in aquaria are (a) *Convolutriloba* from Shannon, 2007, (b) *Heterochaerus* from Achatz and Hooge, 2006 and (c) *Waminoa* © Oceanographic Institute of Monaco, F. Pacorel.

PROPOSED SOLUTIONS

Several methods exist to remove these parasites :

- **Manual removal** : the simplest method for an isolated case is to remove the infected colony from the tank and to vigorously shake it in a different volume of seawater. The remaining flatworms can be eliminated by using a soft paintbrush and then siphoned out (Delbeek and Sprung, 1994). A very effective way to eliminate recalcitrant worms is to expose the surface of the colony to a strong current (by directing a pump toward the infested coral) or by using jets of seawater (using a seawater outlet or syringe).

- **Freshwater dips** : an effective way to rapidly dislodge the flatworms from coral tissues by osmotic shock. 5 to 10 seconds dip in a bath with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994). A safer alternative is to use a hypo-osmotic solution of seawater 15 ppt and max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals (i.e. acroporids) or xenids.

- **Chemical treatment** : A common treatment against diseases or parasitic infections in aquariology is Lugol's or other iodine-based dip. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove as many flatworms as possible before rinsing the coral with clear seawater and returning it to its aquarium (Leewis et al., 2009). Levamisole hydrochloride is classified as an antihelmintihic and is relatively efficient to kill many flatworm species. The treatment must be done on the isolated colony in a tank treatment or a bucket to limit damage to other invertebrates in the aquarium. To detach acoel flatworms, a bath for 5 minutes, at a concentration of 22,5 mg/L (e.g. 3 mL of 7,5 % levamisole in 10 L of seawater) is highly efficient. After treatment, the colony is placed in a second bucket with clear seawater and gently shaken for 1 minute to remove excess levamisole and worms (Leewis et al., 2009). Then the coral colony can be safely returned to its aquarium.

Note that these *Convolutriloba* release toxins when they die, so it is preferable to remove as many as possible by siphoning before treatment (Delbeek & Sprung, 1994).

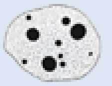
Other commercial products are also used to eradicate flatworms, such as CoralRx, Blue Life Flatworm Control or Flatworm eXit.

- **Biological control :** Certain wrasse species like *Halichoeres leucurus, H. melanurus, H. chrysus, Pseudocheilinus hexataenia* or the dragonets *Synchiropus* spp. appear to be effective in reducing the flatworm populations. Nudibranchs of the genus *Chelidonura* are predators of *Convolutriloba* and *Waminoa*, but their lifespan in aquariums is limited because their larvae do not develop in reef aquariums. They are therefore not a sustainable means of control (Carl, 2008; Delbeek & Sprung, 1994).

Prevention : By reducing the level of phosphates in the aquarium, rebalancing the algae/animal ratio, limiting nutrient loads, adding strong water current and skimming, introducing a natural predator.

Coral hosts : *Acropora* spp. and *Montipora* spp.– Locations : A; IP

Tissue Loss



Multifocal

Coalescing

4.2 Allies and parasites

Platyhelminthe flatworm infestation

LESION DESCRIPTION / INFESTATION SIGNS

Visible lesions are characterized by multifocal small circular feeding scars that may coalesce. An other infestation signs is the presence of reddish egg clusters on bare coral skeleton. The worms are difficult to distinguish from the coral tissue, they tend to live in the cryptic and lower portions of the coral colonies.

Platyhelminthe flatworm infestation. Photograph above shows typical feeding scars of *Prosthiostomum acroporae*, with five camouflaged flatworms and a small patch of eggs (bottom left corner) laying on the colony,. The photo below shows reddish egg masses on denuded skeleton containing, from Ehlers, 2017. Photo by Andrea Ehlers. Courtesy of Reef Builders (reefbuilders.com)

NAEFW is a new *Acropora*-eating flatworm recently discovered that feeds also on corals, whose appearance differs from that of the AEFW. Significantly smaller (3 mm long) and darker (purplish brown), ovoid in shape, it can be found on *Acropora* branches where it feeds on the tissues and algal symbionts (Wang et al., 2019).

CAUSAL AGENTS

Prosthiostomum acroporae (previously *Amakusaplana acroporae*), also know as Acropora Eating Flatworms (AEFW), is a platyhelminthe species widely reported in the coral aquaculture community (Delbeek & Sprung, 2005) and also reported by Rawlinson and Stella (2012) in the wild. This predator feeds exclusively on *Acropora* species and can lead to the rapid death of colonies in reef tanks. Adult forms measure 6-17 mm long, are oval in shape and appear translucent with brown speckling as they consume the coral tissues and their algal symbionts (Rawlinson et al., 2011).

Prosthiostomum montiporae demonstrates similar ecology to the AEFW but obligate ectoparasite of *Montipora* spp. They measure around 12 mm long and appear translucent with brown speckling as they consume the coral tissues and their algal symbionts (Jokiel & Townsley, 1974). The egg capsules are smaller and can be more difficult to detect compared to those of *P. acroporae* (Barton et al., 2020).

Macrophotograph of *Prosthiostomum acroporae,* from Barton, 2020

PROPOSED SOLUTIONS

Several methods exist to remove these parasites :

- **Manual removal** : the simplest method for an isolated case is to remove the infected colony from the tank and to vigorously shake it in a different volume of seawater. The remaining flatworms can be eliminated by using a soft paintbrush and then siphoned out (Delbeek & Sprung, 1994). A very effective way to eliminate recalcitrant worms is to expose the surface of the colony to a strong current (by directing a pump toward the infested coral) or by using jets of seawater (using a seawater outlet or syringe).

- **Freshwater dips** : an effective way to rapidly dislodge the flatworms from coral tissues by osmotic shock. 5 to 10 seconds dip in a bath with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994). A safer alternative is to use a hypo-osmotic solution of seawater 15 ppt and max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals (i.e. acroporids) or xenids.

- **Chemical treatment** : In the case of AEF, it is best to use levamisole at the first sign of infestation. Levamisole hydrochloride is classified as an anthelmintihic and is relatively efficient to kill many flatworm species. The treatment must be done on the isolated colony in another container, such as a bucket, to limit damage to other invertebrates in the aquarium. To eliminate *Prosthiostomum* flatworms, a bath for one hour, at a concentration of 40 mg/L (e.g. 5,3 mL of 7,5 % levamisole in 10 L of seawater) is successful. As the eggs are not affected by the treatment, the coral should be inspected during the bath to identify and remove (by scraping or water jet) any visible egg masses. After treatment, the colony is placed in a second bucket with clear seawater and gently shaken for 1 minute to remove excess levamisole and worms. Then the infested colony should be placed in a quarantine tank, and the treatment repeated once per week for four weeks to allow any remaining eggs to hatch (Carl 2008, Leewis et al., 2009). Another anthelmintic, the praziquantel, has been proposed by Barton et al., 2021 with a concentration of 50 mg/L for a one-hour immersion. The product is less harmful than levamisole but has a poor solubility in seawater (stock solution with dilution in 100 % ethanol) and is a little more expensive. Lugol's or other iodine-based bath can also be used. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove as many flatworms as possible before rinsing the coral with clear seawater (Leewis et al., 2009). Dip the coral one per week for four weeks and make sure to remove all signs of eggs (Carl , 2008).

Other commercial products are also used to eradicate flatworms, such as CoralRx, Two Little Fishies Revive or Flatworm eXit.

- **Biological control :** Various fish species like *Pseudochromis* spp., pipefish (Syngnathidae) or the dragonets *Synchiropus* spp. can be a natural means to eradicate a *Prosthiostomum* infestation in its early stages (Carl, 2008). Barton et al. (2020) demonstrated that both the peppermint shrimp *Lysmata vittata* and the six-line wrasse *P. hexataenia* are effective at reducing the population of P. acroporae, with the difference that shrimp also consume AEFW eggs.

Prevention : By isolating and quarantining all new corals, introducing a natural predator.

Coral hosts : mainly *Acropora* spp. – Locations : A

Colour Change

Multifocal

Red bugs / Black bugs

LESION DESCRIPTION / INFESTATION SIGNS

Colonies severely infested display at least two or more following states : lesion of tissue loss propagating upward from the coral base, abnormal polyp extension, generalized loss of pigmentation, elevated mucus production and/or loss of distal coloration in axial corallites, suggesting a perturbation of colonial growth (Christie and Raines, 2016). Small crustaceans (typically less than 1 mm), red to greyish in colour, may be visible on the surface of the coral.

Red bugs (*Tegastes acropornus*) eating on *Acropora* sp. from *Acropora Red Bugs*, 2016. Photo courtesy of www.reefs.com

Focus on *Tegastes* sp. © E. Borneman, from Borneman, 2004

CAUSAL AGENTS

More than 300 species of copepods have been identified living in symbiosis with scleractinian corals (Cheng et al., 2016). The coral-associated copepods can be divided in three main groups based on their respective ecological niches : gall-inducing (cf. following sheet), ectoparasitic and endosymbiotic copepods (Barton et al., 2020).

Ectoparasitic copepods are observed in natural reef environments, live on coral epidermis and presumably consume coral tissue and mucus (Cheng et al., 2016). The genus *Tegastes* has been essentially described in aquaria and are known as “red bugs” or “black bugs” (Riddle, 2010). They act as irritant to the host and can lead to coral mortality in severe infestation cases (Carl, 2008).

The Xarafiidae are a group of endosymbiotic copepods that live in gastrovascular cavities of the coral polyps and may consume their endosymbiotic algae. It remains unclear if those copepods are commensal or have negative impact on their host (Cheng & Dai, 2010).

PROPOSED SOLUTIONS

Some methods exist to remove these parasites :

- **Chemical treatment** : Milbemycin oxime is a heartworm drug for dogs. It demonstrates good results at a concentration of 0,016 mg/L for a 5 to 7 hour bath. The corals can either be treated in the exhibit tank or separately, but will affect any other chitin-based shell and crustaceans may be lost during the treatment. Try to remove ornamental and mutualist crabs and shrimps for the duration of the bath. At the end, carbon filtration and a small water change (25% of volume) are recommended. The number of treatments may vary depending on the severity of the infestation, ranging from once or twice a week for three weeks (Carl, 2008; Sprung & Delbeek, 2005). Lugol's or other iodine-based bath can also be used. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove all the copepods before rinsing the coral with clear seawater (Leewis et al., 2009).

Other commercial products are also used to eradicate flatworms, such as CoralRx or Revive Coral Cleaner.

- **Biological control :** Small wrasses (i.e. *Pseudocheilinus hexataenia*), pipefish (Syngnathidae), dragonets *Synchiropus* spp or symbiotic crabs *Trapezia* spp. can be a natural means to limit the development of copepod populations (Carl, 2008).

Prevention : By isolating and quarantining all new corals, introducing a natural predator.

Synchiporus splendidus eats small crustaceans, including parasitic copepods © Oceanographic Institute of Monaco, M. Dagnino.

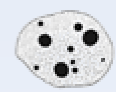
Coral hosts : Several species – Locations : C; IP; RS; A


Skeletal damage


Growth Anomaly


Colour Change


Focal

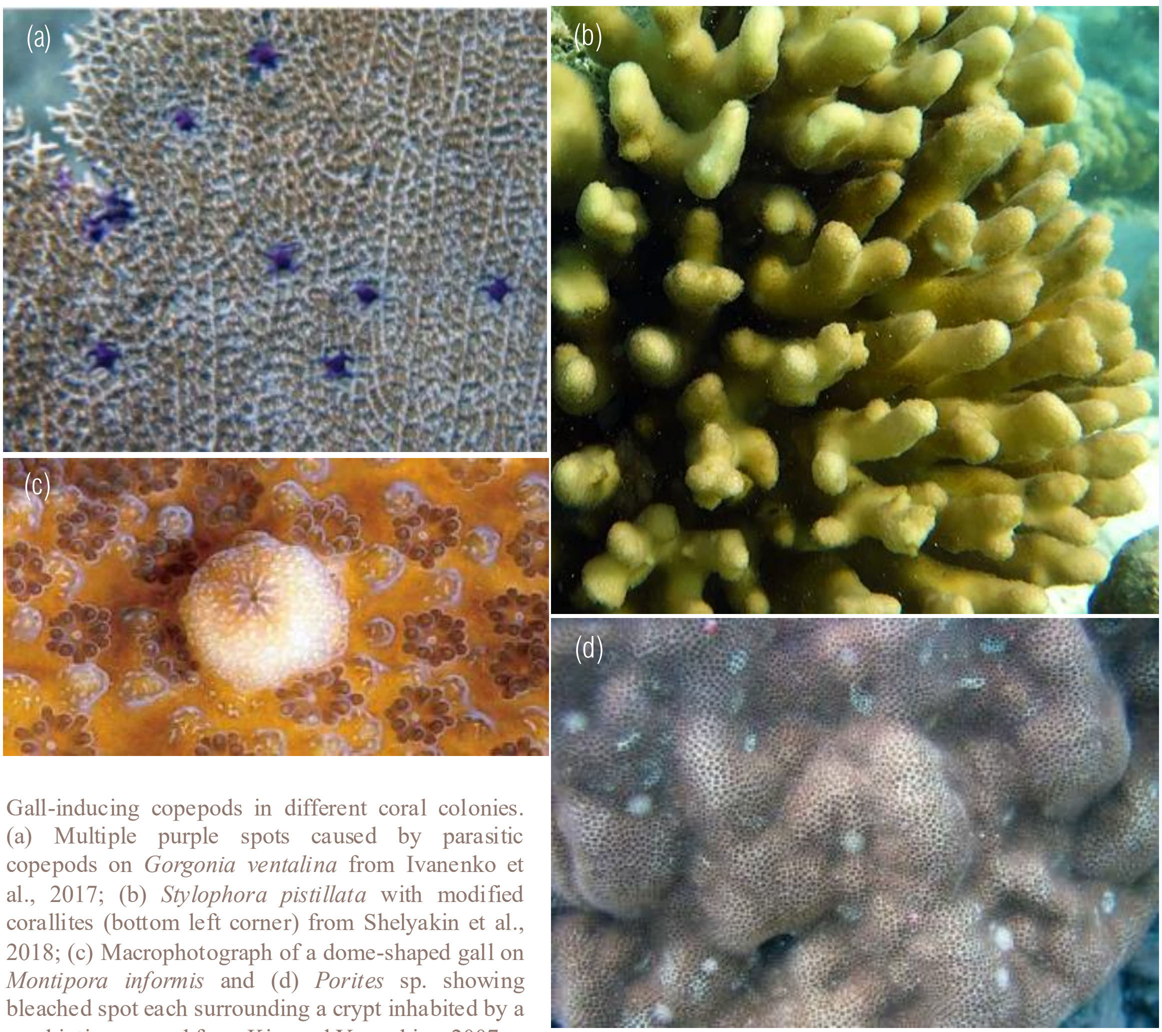

Multifocal

4.2 Allies and parasites

Gall copepods

LESION DESCRIPTION

Focal to multifocal protruded elements (galls), mostly resulting from a tubular-shaped modification of corallites (Ivanenko et al., 2014), and/or bleached spots surrounding each inhabited crypt on coral colony. Pit openings are oval, measure less than 1 mm and are covered by a thin membrane, which makes them difficult to distinguish (Kim & Yamashiro, 2007).



Gall-inducing copepods in different coral colonies. (a) Multiple purple spots caused by parasitic copepods on *Gorgonia ventalina* from Ivanenko et al., 2017; (b) *Stylophora pistillata* with modified corallites (bottom left corner) from Shelyakin et al., 2018; (c) Macrophotograph of a dome-shaped gall on *Montipora informis* and (d) *Porites* sp. showing bleached spot each surrounding a crypt inhabited by a symbiotic copepod from Kim and Yamashiro, 2007.

CAUSAL AGENTS

Gall copepods often measure less than 1 mm in length and are obligate symbionts of marine invertebrates, including corals (Cheng et al., 2016). Not all species cause protrusions on the colony surface, but can, for instance, induce bleached spots surrounding each crypt (Kim & Yamashiro, 2007). Potential impact of these symbiotic copepods on the state of coral hosts remains unknown; nevertheless, the settlement of the gall-inducing copepods is likely to cause a form of physiological stress to the coral host (Dojiri, 1988). A list of copepods affecting hexacorallians was published in 2021 by Korzhavina O, and Ivanenko V (2021) in: *Global diversity and distributions of symbiotic copepod crustaceans living on hexacorallians.*

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of copepods is high and threatening the host colony. Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

There are no solution mentioned in the literature, but here is a suggestion for a relatively non-invasive treatment to try:

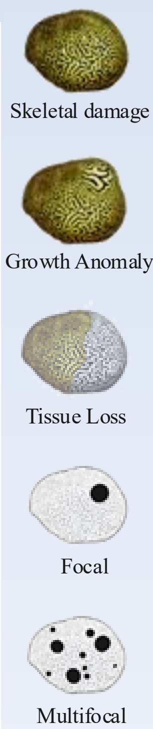
- **Manual removal** : This method is a delicate operation as it requires a little skill to limit the impact on the colony. It consists of removing the copepod encapsulated in the skeleton or tissue by digging with a pick, scalpel or small forceps. A iodine-based bath is recommended after the manipulation to disinfect the coral.

- **Chemical treatment** : Lugol's or other iodine-based bath can also be used. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove all the copepods before rinsing the coral with clear seawater (Leewis et al., 2009).

Other commercial products are also used to eradicate flatworms, such as CoralRx or Revive Coral Cleaner.

Prevention : By isolating and quarantining all new corals.

Coral hosts : Mainly branching species – Locations : C; IP; RS; A



4.2 Allies and parasites

Gall crabs

LESION DESCRIPTION

Focal to multifocal depressions or protruded elements (galls) on coral colony associated with small pits in the skeleton. The morphology of the pits ranges from crescent-shaped to circular or irregular openings. Lesions can be related with minimal tissue loss or settlement of algae around the opening.

Gall-inducing crabs in various scleractinian host corals. (a) Cryptochirid crab in *Turbinaria reniformis* and (b) two galls and modified skeletal growth on *Danafungia horrida* © B.W. Hoeksema from van der Schoot and Hoeksema, 2024; (c) A colony of *Seriatopora* sp. showing several galls at different development stages from Terrana et al., 2016; Gall crabs dwellings in (d) *Colpophyllia natans* and the characteristic cresent-shaped opening, (e) *Orbicella franksi* associated with gall crab dwellings and (f) *Meandrina meandrites* with algal settlement © S.E.T van der Meij, from van der Meij, 2014.

CAUSAL AGENTS

Gall crabs belong to the family Cryptochiridae, often measure less than 1 cm and are obligate symbionts of scleractinian corals (Wei et al., 2013). They live in burrows or cavities (pits) within the coral skeleton and feed on coral mucus (Kropp, 1986), organic particles and plankton (Abelson et al., 1991). There is no consensus on whether cryptochiridae are parasitic or commensal (Terrana et al., 2016), but it has been argued that they may inhibit the growth rate of corals (Simon-Blecher et al., 1999) as they can cause some localized changes to the coral tissue by reducing growth or lead to tissue necrosis.

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of crabs is high and threatening the host colony. Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

There are no solution mentioned in the literature, but here is a suggestion for a relatively non-invasive treatment to try:

- **Chemical treatment** : Lugol's or other iodine-based bath can also be used. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove all the crabs before rinsing the coral with clear seawater (Leewis et al., 2009).

Other commercial products are also used to eradicate flatworms, such as CoralRx or Revive Coral Cleaner.

Prevention : By isolating and quarantining all new corals.

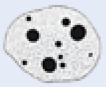
Example of cryptochirid species associated with scleractinian coral © S.E.T. van der Meij, from van der Meij and Shubart, 2014.

Coral hosts : Several species – Locations : C; IP; RS; A

Skeletal damage

Growth Anomaly

Focal



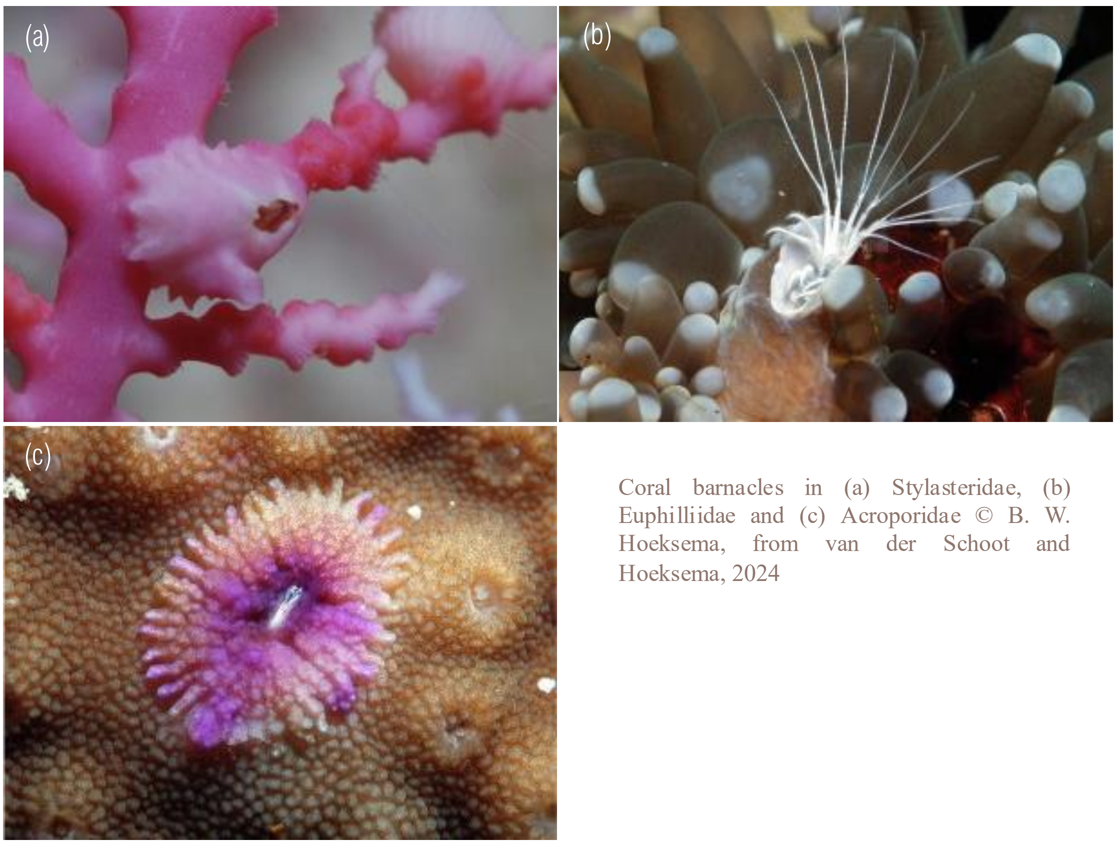
Multifocal

4.2 Allies and parasites

Coral barnacles

LESION DESCRIPTION

Focal to multifocal openings of a few millimeters in the colony associated with a calcified surrounding plate that may be embedded in the coral skeleton or slightly protrude from the surface. The operculum is often visible as a small slit-like aperture when the organisms retract their feeding apparatus (or cirri). Most of the time, cirral nets are extended through the openings and are easily distinguishable from the rest of the coral colony (Anderson, 1992).



Coral barnacles in (a) Stylasteridae, (b) Euphilliidae and (c) Acroporidae © B. W. Hoeksema, from van der Schoot and Hoeksema, 2024

CAUSAL AGENTS

Coral barnacles belong to the family Pyrgomatidae and are obligate symbionts of scleractinian corals (Anderson, 1992). Except the genus *Hoekia*, they are suspension feeders and exchange nutrients with their hosts, therefore the symbiotic relationship is considered mutualistic (Cook et al., 1991). They are nestled between the polyps of the colony, with their calcified shell generally located at the same level as the coral surface and covered by coral tissue. *Hoekia* spp. have an adapted feeding apparatus to feed directly on coral tissue and may compromise the health of the colony (Ross & Newman, 1969; Ross, 2000).

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of barnacles is high and threatening the host colony, as the larval settlement can induce physiological response of the host, such as defence mechanisms (Liu et al. 2016). Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

Here are some suggestions for eliminating them from the colony :

- **Manual removal** : the simplest and probably least invasive method is the sealing of opercular plates. Simply apply one or two drops of epoxy resin or cyanoacrylate gel to the barnacle's opercular plates and leave the seal to dry for 2-3 minutes. The colony can then return to the aquarium. Another method a bit trickier is to destroy the barnacle with an ice pick. Using a Dremel® may be more effective for fragile colonies.

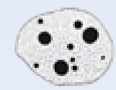
Prevention : By isolating and quarantining all new corals.

Coral hosts : Several species – Locations : C; IP; RS; A

Skeletal damage

Growth Anomaly

Focal



Multifocal

4.2 Allies and parasites

Worm snails

LESION DESCRIPTION

Focal to multifocal openings of approximatively 5 mm diameter that may protrude of the colony surface, with a “finger-like” structure (Bergsma, 2009). The tubes are often partially or entirely overgrown by green or red algae, sometimes only by coral tissue. The circular opening is occluded by an operculum and often associated with mucus nets that extend over the colony (Hadfield et al., 1972).

Tube of a vermetid snail completely overgrown by the coral tissue of a *Montipora* © Oceanographic Institute of Monaco, F. Pacorel

Vermetid snail embedded in a *Porites* with a mucus net extended over the colony © Oceanographic Institute of Monaco, F. Pacorel

Visible striated tubes of vermetids on another colony © Oceanographic Institute of Monaco, F. Pacorel

CAUSAL AGENTS

Members of the Vermetidae, worm snails are common inhabitants of coral reefs, where they live in a tube-shaped shell that may be embedded in coral colony or other substrates. The tube generally protrude from the surface and is often surrounded by dead coral tissue or algae. The vermetids are suspension feeders that trap particles in net-like mucus secretions (Hughes & Lewis, 1974). Their two tentacles can be seen when their operculum is partially closed. They can irritate and stress the surrounding polyps and may alter growth and survival of the colony at high densities (Shima et al., 2010). Like other boring organisms, they may weak the structural integrity of corals, that can break more easily.

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of vermetids is high and threatening the host colony. Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

Here are suggestions for eliminating them from the colony :

- **Manual removal** : the simplest and probably least invasive method is the sealing of opercular plate. Simply apply a few drops of epoxy resin or cyanoacrylate gel to the operculum and leave the seal to dry for 2-3 minutes. You can try cutting off the part of the tube that protrudes from the colony before applying the product. The colony can then return to the aquarium.

- **Biological control :** Bumble bee snails (*Engina mendicaria*) are known to prey on vermetid snails and may help to reduce their population in case of moderate infestations (Sheppard, 2023).

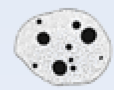
Prevention : By isolating and quarantining all new corals, reducing feeding or introducing a natural predator.

Coral hosts : Several species – Locations : C; IP; RS; A

Skeletal damage

Growth Anomaly

Focal



Multifocal

4.2 Allies and parasites

Date mussels

LESION DESCRIPTION

Focal to multifocal openings of a few millimeters in the colony characterized by a “figure-of-eight”, “dumbbell” or oval in shape. Some holes may be lined with a white calcareous sheet excreted by the mussels and form a tube which may protrude slightly from the surface of the host (Hoeksema et al., 2022).

Numerous boring orifices of date mussels on a colony of *Cyphastrea kausti* (above) and example of a boring mussel being housed inside a mushroom coral (below) © B. W. Hoeksema from van der Schoot and Hoeksema, 2024

CAUSAL AGENTS

Date mussels belong to the family of Lithophaginae and are known to burrow into different calcareous substrates (e.g., reefs, shells, manmade structures) for shelter (Owada, 2007). For feeding and respiration, the mussels inhale and exhale surrounding seawater through a pair of siphons, which open at the coral surface and give an oval or “figure-of-eight” opening (Hoeksema et al., 2022). Like other boring organisms, they may weak the structural integrity of corals, that can break more easily (Scott & Risk, 1988).

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of date mussels is high and threatening the host colony. Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

Here are suggestions for eliminating them from the colony :

- **Manual removal** : the simplest and probably least invasive method is the sealing of the borehole openings. Simply apply a few drops of epoxy resin or cyanoacrylate gel into the holes and leave the seal to dry for 2-3 minutes. The colony can then return to the aquarium.

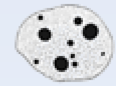
Prevention : By isolating and quarantining all new corals.

Coral hosts : Several species – Locations : C; IP; RS; A

Skeletal damage

Growth Anomaly

Focal



Multifocal

4.2 Allies and parasites

Tube worms

LESION DESCRIPTION

Focal to multifocal openings of a few millimeters in the colony associated with a calcified tube that may be embedded in the coral skeleton or partially protrude from the surface. When the organisms retract their feeding apparatus (or radiolar crown), the operculum is often visible as an aperture that is often adorned with spines and may become covered by several kinds of epibionts, like algae or sponges. Most of the time, radioles are extended through the openings and are easily distinguishable from the rest of the coral colony.

Example of serpulid worm with its bilobed radiolar crown and the operculum at the front of the structures on *Pavona varians* © Oceanographic Institute of Monaco, F. Pacorel.

CAUSAL AGENTS

Tube worms belong to the family Serpulidae and are sedentary worms which secretes calcareous tubes, nestled between the polyps of the colony, completely or partially embedded. Also known as “Christmas tree worms”, they project bilobed feeding structures and gills (radiolar crown) up into the water column for filter feeding (Bok et al., 2017). Most serpulids have an operculum that they close when they retract their radiolar crown. The family Sabellidae, known as “fan worms”, are also a major group of worms living inside tubes burrowed in coral colonies (van der Schoot & Hoeksema, 2024). Like other boring organisms, they may weak the structural integrity of corals, that can break more easily. They can also irritate and stress the surrounding polyps and can be deleterious at high densities (Hoeksema et al., 2019 ; 2022).

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of tube worms is high and threatening the host colony. Otherwise, we suggest leaving these small lodgers setting there as they have minimal impact on the coral health.

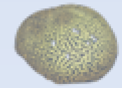
Here are suggestions for eliminating them from the colony :

- **Manual removal** : the simplest and probably least invasive method is the sealing of the operculum or borehole opening. Simply apply a few drops of epoxy resin or cyanoacrylate gel into the holes and leave the seal to dry for 2-3 minutes. The colony can then return to the aquarium.

Prevention : By isolating and quarantining all new corals.

Macropharyngodon bipartitus is a carnivorous wrasse feeding on small invertebrates like crustaceans, worms and mollusks and may prove useful in reducing the population of undersirable organisms © Oceanographic Institute of Monaco, F. Pacorel.

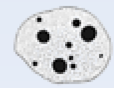
Coral hosts : Several species – Locations : C; IP; RS; A



Skeletal damage

Growth Anomaly

Focal



Multifocal

4.2 Allies and parasites

Sedentary and errant polychaetes

LESION DESCRIPTION

Visible lesions typically involve focal to multifocal openings of a few millimeters that may erect from the colony surface due to the combined growth of worm tubes and host tissue. For spionid worms, a pair of palps often waves from the tube.

Macrophotograph of a small syllid worm feeding on *Montastrea cavernosa,* living specimen crawling on the coral (left) and introducing into the gastral cavity of a closed polyp (pictures 1 and 2 from Martin et al., 2015, © Cynhtia R Abgarian, picture 3 © Oceanographic Institute of Monaco, F. Pacorel.)

CAUSAL AGENTS

Several sedentary polychaetes are known to burrow into coral skeleton, specifically in the family Spionidae and Eunicidae. Like other boring organisms, they may weak the structural integrity of corals, that can break more easily (Molodtsova et al., 2016). Their diets vary across genera, but sedentary worms are predominantly detritivores, while several species may burrow into sponges, soft corals or stony corals and consume the tissues of these invertebrates. Bristleworms are mainly scavengers and can be beneficial in the aquarium for nutrient cycling (Delbeek & Sprung, 1994). Errant polychaetes, such as the family Syllidae or Nereididae, are mainly carnivores to omnivores and can be harmful in the aquarium (Martin et al., 2015), by feeding both on coral tissues, other small invertebrates and fish (Knop, 2020). The fireworm *H. carunculata,* is a voracious predator for corals and a description of associated lesions can be found in the technical sheet #9.

PROPOSED SOLUTIONS

Eradication solutions may be considered whether the density of polychaetes is high and threatening the coral colonies. Otherwise, we suggest leaving these small setting there as they have minimal impact on the coral health.

Here are suggestions for eliminating them from the colony :

- **Manual removal** : Manual removal of larger errant worms is the best way of reducing the polychaetes population. By placing a container that is easily closable on the aquarium bottom with some bait such as clams, you will probably find some worms after a few hours in the dark that you can then trap and remove. Be aware that those worms can inflict painful bites with their powerful jaws (Leewis et al., 2009). For boring worms, the simplest and probably least invasive method is the sealing of the borehole openings. Simply apply one or two drops of epoxy resin or cyanoacrylate gel into the holes and leave the seal to dry for 2-3 minutes. The colony can then return to the aquarium.

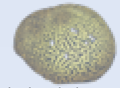
- **Chemical treatment :** Ivermectine can be used efficiently on sedentary polychaetes. A dosis of 2mg/L during 5 hours has proven its efficiency if repeated every week for 4 weeks.

- **Biological control :** Wrasse species *Halichoeres* spp. or *Pseudocheilinus hexataenia* may help to control sedentary polychaetes (Knop, 2020). The sea snail *Bursa bufonia* has been observed consuming errant polychaetes (for smaller species), as well as the zebra seabream (*Diplodus cervinus*), but is only found in the Mediterranean and Atlantic, so it is not ideal to introduce the fish in an Indo-Pacific aquarium (Knop, 2020; Leewis et al., 2009).

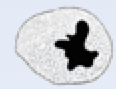
Prevention : By isolating and quarantining all new corals, introducing a natural predator.

Coral hosts : Several species – Locations : IP; C; RS; A


Tissue Loss


Skeletal damage


Focal


Irregular

4.2 Allies and parasites

Crabs and shrimps

LESION DESCRIPTION

Focal or irregular lesion associated with tissue loss between branches. Coral colonies may exhibit higher mucus production.

CAUSAL AGENTS

Some species of crabs are known to reside between branches of coral colonies (*Trapezia* spp. generally on pocilloporids, *Tetralia* spp. on acroporids) (Patton, 1994), feed on the mucus and occasionally tissue of their host (Stimson, 1990). Tissue loss can be observed in areas occupied by crabs, However they are also considered mutualists by guarding their hosts against more damaging predators or parasites (Stella et al., 2011). In contrast, xanthid crabs (e.g. *Cymo melanodactylus*) are generally removed from aquaria as they may cause mortality by heavy feeding on their host (Pratchett et al., 2010). Two Hermit crabs (e.g. *Tripazopagurus magnificus, Aniculus elegans*) living in coral colonies can produce large amounts of calcareous sediments by creating small excavations while feeding (Carpenter, 1997).

Symbiotic crabs living between branches of coral colonies. Top photo : *Trapezia* sp. living between branches of *Pocillopora damicornis* host © Oceanographic Institute of Monaco, F. Pacorel. Bottom photo : *Cymo* © Kaeli Swift – Licence CC BY-NC

Although many shrimp species make valuable aquarium allies for cleaning, algae control, pest control and aesthetics, some species can also attack corals. As example, Marble shrimp (*Saron marmoratus*) and Buffalo shrimp (*S. inermis*) venture out across the reef at night and can eat anemones and corals, such as zoanthids (Delbeek & Sprung, 1994).

Other species are not primarily coral eater but don't hesitate to mistreat coral colonies when they are a bit hungry. It is the case for some members of the family of Rhynchocynetidae (e.g. *Rhynchocinetes uritai*) that don't necessarily restrict their diets to anemones and attack other cnidarian. The common Cleaner shrimp *Lysmata amboinensis* or the Banded Coral shrimp (*Stenopus hispidus*) will not hesitate to steal food in the coral polyps or even tear them open to remove the content (Delbeek & Sprung, 1994).

Stenopus hispidus © Oceanographic Institute of Monaco, F. Pacorel

PROPOSED SOLUTIONS

As mentioned above, *Tetralia* and *Trapezia* crabs are valuable housekeepers for their host colony, as well as other crab and shrimp species in your tank and contribute also to the biological richness of your aquarium, so there's no point in trying to get rid of them. However, if you suspect that one of the small crustaceans is attacking the coral, here's what you should consider:

- **Feeding adjustment** : Some individuals may behave undesirably towards a colony, but this can be a sign of nutritional deficiencies for them. Sufficient and suitable food may reduce the crab and shrimp's need to prey on corals (Knop, 2020).

- **Manual removal** : In case of overabundant crab or shrimp population that may threat the balance of the tank, or no other options but to remove a crab, the use of a trap (commercialized or handmade) with bait can facilitate extraction. Note that some crabs and shrimps are active at night and never leave their shelters during the day.

Prevention : By isolating and quarantining all new corals, assessing species compatibility

Coral hosts : mainly euphylliidae and acroporidae – Locations : A

Tissue Loss

Irregular

Linear

Brown Jelly Syndrome
(BJS)

LESION DESCRIPTION

Irregular to linear lesion associated with tissue loss (necrotic tissue) that tends to form a rapidly progressing, bandlike feeding front of ciliates. The brown jellylike coating is also associated with high mucus production (Raymundo & Weil, 2015).

Hydnophora sp. affected by Brown Jellly Syndrome, © E. Borneman, from Borneman, 2004

ASSOCIATED ORGANISM

Helicostoma nonatum has a brownish elongated and cylindrical body, may be a close relative to the genus Philaster (Zhang et al., 2011) and is the suspected ciliate pathogen associated with the BJS (Borneman and Lowrie, 2001). The disease is likely related to decreased coral health or stress conditions (Carl, 2008) and is one of the most common occurring in aquaria and has currently not been reported in the wild (Sweet et al., 2012). It is not clear whether the condition represent the same disease as BrBD operating under different environmental conditions or whether it is two distinct diseases.

PROPOSED SOLUTIONS

During an outbreak, affected corals should be removed from the reef tank if at all possible and placed in a quaranting tank with an increased water flow. Here are some suggestions for limiting progression over the colony :

- **Manual removal** : First, siphoning off necrotic tissues and gelatinous mass directly into the aquarium can limit the risk of further coral contaminations. Afterwards, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the coral is fragmented, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant. To limit the diffusion of resistant infectious agent, the sealing of debrided wound edges with epoxy resin or cyanoacrylate gel may be effective (Sprung & Delbeek, 1997).

- **Freshwater dips** : an effective way to rapidly dislodge the ciliates from coral tissues by osmotic shock. 5 to 10 seconds dip in a bath and water-jet with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994). A safer alternative is to use a hypo-osmotic solution of seawater, 15 ppt and max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals like acroporids or xenids.

- **Chemical treatment** : In case of severe infection, the use of antibiotics may eventually eradicate the disease and can be performed following a Lugol's immersion to improve treatment efficiency and reduce the risk of bacterial resistance. In a separate tank or container, mix 0,5 mL (or 10 drops) of 5 % Lugol's solution per litre of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 30 minutes (Delbeek & Sprung, 1994). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The antibiotic treatment must be done on the isolated colony in another tank well aerated, to prevent damage to other organisms in the main aquarium. Among antibiotics, doxycycline (2,5 mg/L for two days, daily water changes), oxytetracycline (30 mg/L for three days, daily water changes) (Leewis et al., 2009) and chloramphenicol (10 to 50 mg/L for three days, daily water changes) (Sprung & Delbeek, 1997), have been suggested in the literature and have demonstrated varying levels of success. At the end of the treatment, the colony should be dip again in a Lugol's bath (10 drops in 1 liter of seawater) so that most of surviving microorganisms are eliminated and then rinsed thoroughly with clean seawater before returning to the exhibition aquarium.

Other commercial products are also used to treat RTN and STN, such as RTN/STN X or Prime Coral Prevent RTN.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Prevention : By ensuring moderate to strong waterflow, stable water quality and appropriate chemical filtration.

Coral hosts : mainly acroporidae and pocilloporidae - Locations : IP

4.3 Diseases - Pigmented Lesions


Tissue Loss


Basal / Periphera


Linear & Smooth

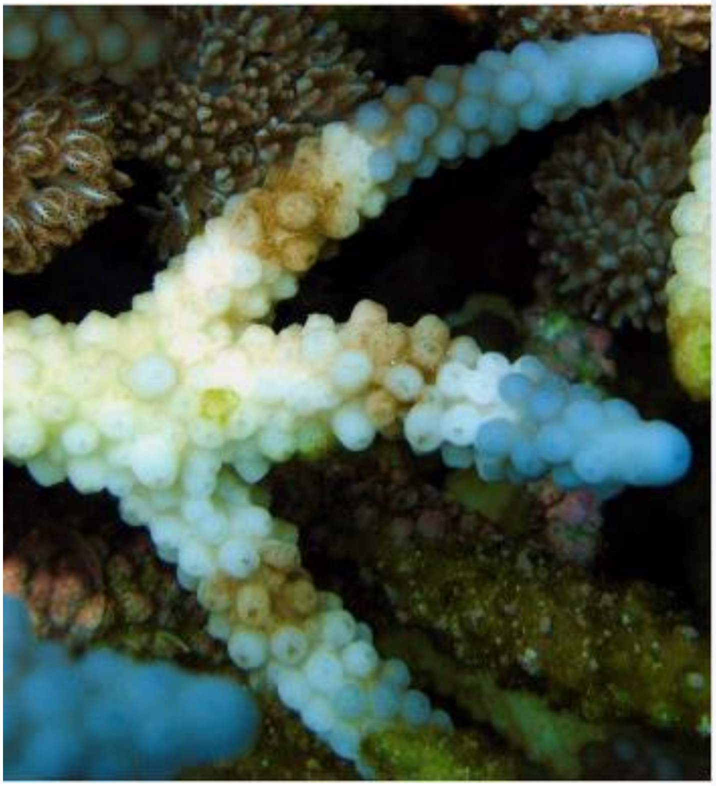
Brown Band Disease
(BrBD)

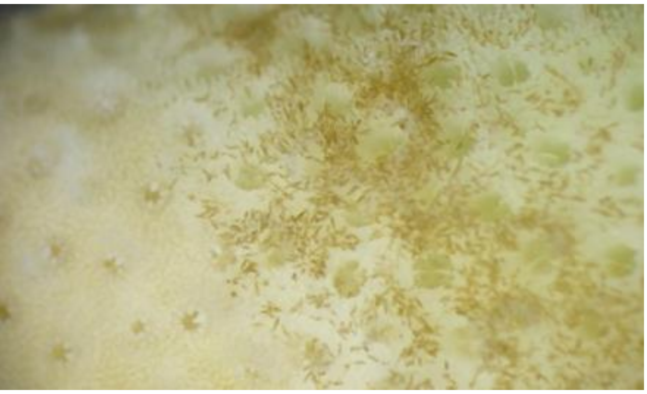
LESION DESCRIPTION

Linear lesion associated with tissue loss that usually originates basally or peripherally and progresses upward on colony branches or toward the centre of massive colonies. Lesion margins are smooth and characterized by a golden-brown band up to 1 cm wide, often isolated from the intact coral tissue by a band of exposed stark white skeleton (Raymundo and Weil, 2015).

ASSOCIATED ORGANISM

Philaster guamensis is the dominant species of ciliates associated with the BrBD and is found at the lesion front of the colony (Sweet & Bythell, 2012). These organisms are yellow to brown coloured, have a cylindrical to fusiform body and consume coral tissue and their algal symbionts. It is not well understood whether the microbial agents are responsible for tissue mortality or whether they opportunistically feed on injured tissue, or both. Ciliates move freely within the coral skeleton during active feeding of coral tissue, then they become immobile during a quiescent phase. These immobile ciliates are settled on the coral skeleton, giving the brown band appearance of the disease (Lobban et al., 2011).


BrBD affecting *Acropora hemprichii* © A. Bruckner, from Sisney et al., 2018




Macrophotographs of *P. guamensis*. Low density of active ciliates feeding on coral live tissue (left) and coral skeleton covered of enkysted ciliates (right) © Laurie J Raymundo, from Lobban et al., 2011

PROPOSED SOLUTIONS

Although this pathology has not been reported in aquariums, if there is suspicion of BrBD, affected corals should be removed from the reef tank if at all possible and placed in a quaranting tank with an increased water flow. Here are some suggestions for limiting progression over the colony :

- **Manual removal** : First, siphoning off ciliate aggregates directly into the aquarium can limit the risk of further coral contaminations. Afterwards, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the coral is fragmented, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant. To limit the diffusion of resistant infectious agent, the sealing of debrided wound edges with epoxy resin or cyanoacrylate gel may be effective (Sprung & Delbeek, 1997).

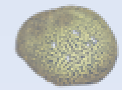
- **Freshwater dips** : an effective way to rapidly dislodge the ciliates from coral tissues by osmotic shock. 5 to 10 seconds dip in a bath and water-jet with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994). A safer alternative is to use a hypo-osmotic solution of seawater 15 ppt for max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals like acroporids or xenids.

- **Chemical treatment :** the ciliates associated with brown band disease being closely related to those associated with BJS, we would recommend the same treatments as for this syndrome (see technical sheet 23).

Coral hosts : several species – Locations : IP; RS; C; A

4.3 Diseases - Pigmented Lesions


Tissue Loss


Skeletal damage

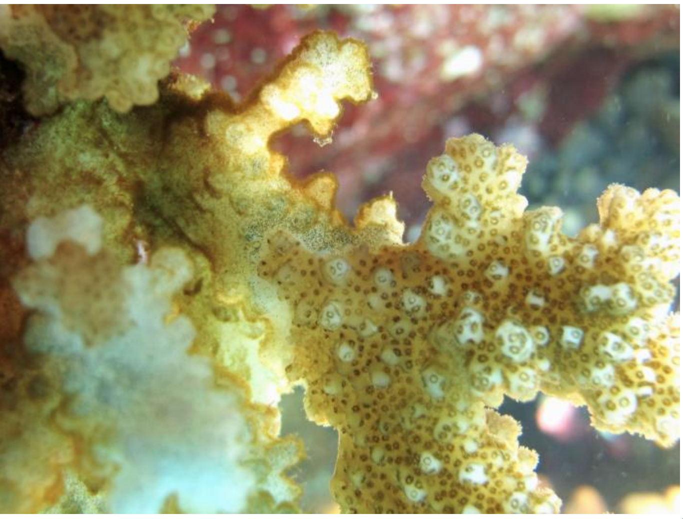

Basal / Periphera


Linear & Smooth

Skeletal Eroding Band / Caribbean Ciliate Infection (SEB/CCI)

LESION DESCRIPTION

Linear lesion associated with tissue loss that usually originates basally or peripherally and progresses upward on colony branches or toward the centre of massive colonies. Lesion margins are smooth and characterized by a dark band of scattered ciliates. Coral skeleton can appear eroded at the lesion front and the colour of the band can vary with ciliate densities (Page et al. 2015).



Infestation of ciliates on different coral species. Photographs above (left) show a light band of ciliates on *Pocillopora darmicornis* © G. Aeby, and (right) a denser ICC on *Diploria labyrinthiformis* © D. Gochfeld.

Photos opposite and below are close-ups showing *Hallofocullina* ciliates on *Acropora muricata*. On the opposite, the coral skeleton appears eroded with a grainy aspect. The macrophotograph below shows motile ciliates adjacent to live tissues and sessile trophonts anchored to the denuded skeleton, from Page et al., 2015.

ASSOCIATED ORGANISM

Hallofolliculina sp. is associated with the SEB (also known in west Atlantic as Caribbean Ciliate Infection, CCI). The ciliates have two phases in their life cycle : a sessile trophont form, and a motile stage of ciliates which may cause tissue mortality by releasing chemicals during lorica secretion. The chemical secretions of ciliates can damage the structure of the coral's skeleton and cause the characteristic eroded appearance adjacent to the lesion front (Antonius & Lipscomb, 2000).

PROPOSED SOLUTIONS

A little is known about the control of this disease in aquarium, but here is what has been proposed by Bartlett, 2013 :

- **Manual removal** : the simplest method for an isolated case is to remove the infected colony from the tank and place it in a different volume of seawater. The ciliates can be eliminated by scrubbing the infected area with a toothbrush or by exposing the infected area of the colony to a strong current (by directing a pump toward the infested coral) or by using jets of seawater (using a seawater outlet or syringe).

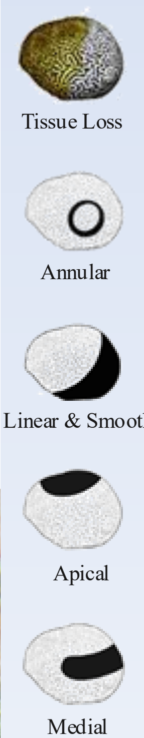
- **Freshwater dips** : another method to dislodge the ciliates from coral skeleton is by osmotic shock. 5 to 10 seconds dip in a bath with freshwater (max. 30 sec), free of chlorines and bromines, and pH- and temperature-matched (Delbeek & Sprung, 1994; Bartlett, 2013). A safer alternative is to use a hypo-osmotic solution of seawater 15 ppt for max. 3 minutes (Sweet et al., 2012). When using the procedure on new species, ensure to minimise the exposure time. You might avoid doing this on small polyp corals (i.e. acroporids) or xenids.

- **Chemical treatment** : A common treatment against diseases or parasitic infections in aquariology is Lugol's or other iodine-based dip. In a separate tank or container, mix 0,5 – 1,3 mL (or 10 to 20 drops) of 5 % Lugol's solution per liter of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 10-15 minutes (Bartlett, 2013). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The procedure may be combined with rinsing and shaking the colony to remove as many flatworms as possible before rinsing the coral with clear seawater and returning it to its aquarium (Leewis et al., 2009).

Prevention : By maintaining good water filtration

Coral hosts : Several species – Locations : C; IP; RS

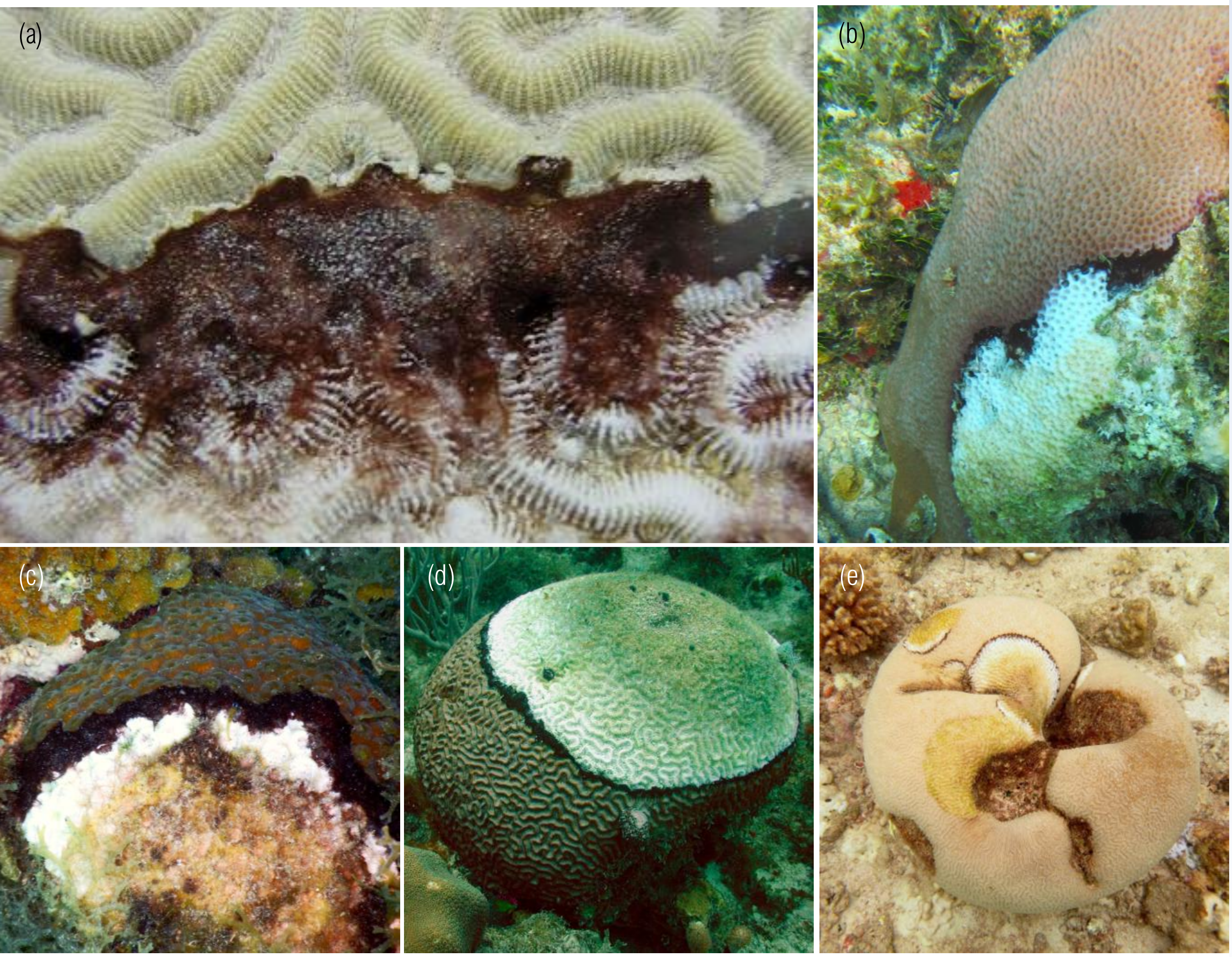
4.3 Diseases - Pigmented Lesions



Black Band Disease
(BBD)

LESION DESCRIPTION

Annular or linear lesion associated with tissue loss that usually occurs apically or medially. Lesion margins are smooth and characterized by a black to reddish band/mat of several cm wide that separates healthy tissue from freshly exposed skeleton. The colour of the band depends on different conditions (i.e. band width, amount of light, host species) (Sussman et al., 2006).



BBD takes the form of a filamentous mat, appearing red on *Diploria strigosa* © L. Richardson, from Richardson et al., 2015. Lesions begining at the medial portion of *Siderastrea siderea* (b) and *Montastrea cavernosa* (c), or as a focal point at the apical portion of *Pseudodiploria strigosa* (d) © D.Gochfeld and *Platygyra* (e) © G. Aeby.

CAUSATIVE AGENTS

BBD consists in a dense microbial consortium overlying coral tissue dominated by filamentous cyanobacteria that contain phycoerythrin, a red pigment that give the dark colour of the band and sulfur-oxidizing bacteria. The cyanobacteria and the sulfate reducers (delta-proteobacteria) present in the lesion produce toxins or toxicants that lyse coral tissue (Richardson et al., 2015).

PROPOSED SOLUTIONS

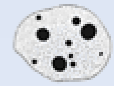
Although this pathology has not been reported in aquariums, methods have been developed to slow or even halt the progression of the disease :

- **Manual removal** : Using an underwater aspirator or scrubbing with the flat edge of a knife combined with suction by siphoning will remove the microbial mat. You can then cover the affected margin with a sealant like modelling clay to curtail reinfection (Hudson, 2000). To increase the probability of eliminate potential bacterial pathogens, you can mix the sealant (modelling clay, epoxy resin or cyanoacrylate gel) with chlorine powder (15 mL/50 mL epoxy) (Aeby et al., 2015).

Macrophotograph of the BBD lesion with the exposed skeleton on the left and the apparently healthy tissue on the right © L. Richardson, from Richardson et al., 2015.

Coral hosts : Several species – Locations : C; IP

Tissue Loss



Multifocal

Coalescing

Annular

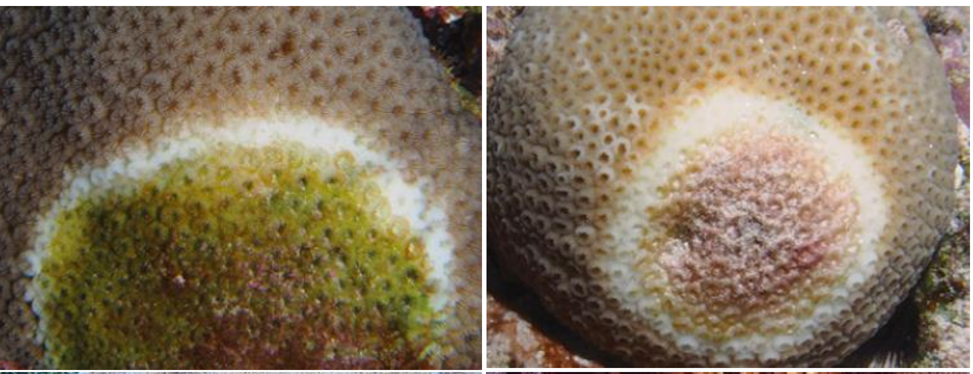
Linear & Distinct

4.3 Diseases - Pigmented Lesions

Yellow Band Disease (YBD)

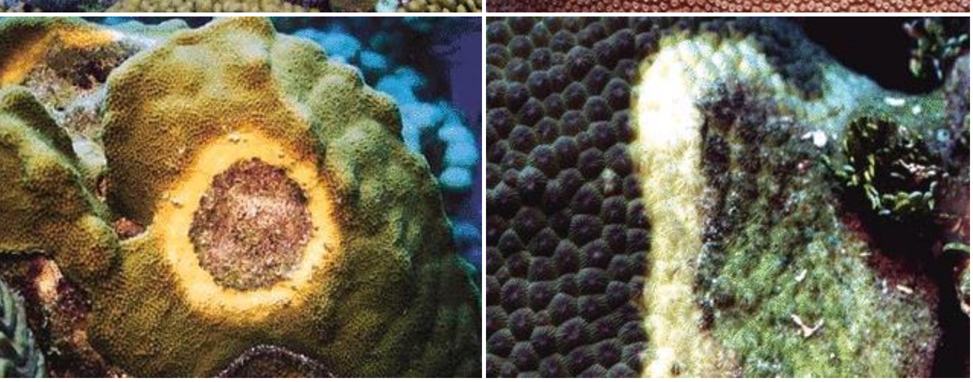
LESION DESCRIPTION

The disease, also known as Yellow Blotch Disease, manifests differently between regions. In Arabian sea, the lesion is characterized by a linear to annular pattern of bright yellow band, producing a margin of bleached tissue adjacent to healthy coral tissue (Bruckner & Riegl, 2015). In the Caribbean and Pacific, the lesions are randomly distributed and exhibit as yellow blotches, or rings, that may coalesce over the time. The gross skeleton may retain a yellow pigmentation and secondarily colonized by epibionts (Cervino et al., 2008).



Pacific YBD with a close-up photograph of *Diploastrea heliopora* with a focal lesion expanding outward © A. Bruckner, from Bruckner and Riegl, 2015

Caribbean YBD on *D. heliopora* with coalescing rings (left) and irregularly shaped lesion (right), from Cervino et al., 2008



Caribbean YBD on *D. heliopora* with older lesions secondarly colonized by epibionts, from Cervino et al., 2008

CAUSATIVE AGENT

Unknown. Several *Vibrio* species have been identified in the YBD lesions of Caribbean and Pacific regions (Cervino et al., 2008).

PROPOSED SOLUTIONS

Although this pathology has not been reported in aquariums, researchers show that by isolating healthy from infected tissue, it is possible to slow the progression of the disease (Randall et al. 2018). Here are the suggestions :

- **Manual removal and isolation** : Depending on the size of the lesions and of the affected colony, you can either fragment or chisel it to isolate the lesions from the healthy tissues. For fragmentation, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). If you choose to preserve the integrity of the colony, you can create a trench of approximately 1 cm deep and 1 cm wide by using a chisel to encircle the entire lesion (Randall et al., 2018). Once the coral is fragmented or chiselled, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant. To limit the diffusion of resistant infectious agent, the sealing of debrided wound edges with epoxy resin or cyanoacrylate gel may be effective (Sprung & Delbeek, 1997).

- **Chemical treatment** : as the pathogen linked to the coral disease is likely bacterial, it makes treatment with a broad-spectrum antibiotic a viable option. Antibiotics commonly used in aquariology, such as doxycycline, (oxytetracycline (cf. Leewis et al., 2009), or chloramphenicol (cf. Sprung & Delbeek, 1997) can be applied carefully to affected corals. This approach targets a range of potential bacterial culprits, offering a chance to curb disease progression. To minimize environmental impacts and the risk of antimicrobial resistance, refer to the existing protocols mentioned above for proper dosing and application techniques.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Coral hosts : Several species – Locations : C; IP

4.3 Diseases - Pigmented Lesions

Dark Spots Disease
(DSD)

LESION DESCRIPTION

Focal to multifocal lesions brown to purple, with smooth or slightly undulating margins and distinct edges. The lesions are randomly distributed and exhibit as discoloured patches that may coalesce. The centre of the patches may manifest chronic tissue loss, depressed skeleton structure and algal colonization (Work & Weil, 2015).

Lesions variability of DSD; small lesions on *Agaricia* (a), *Siderastrea radians* showing circular lesions with smooth margins (b), dark band with irregular borders advancing on *Stephanocoenia,* leaving dead tissue behind (c), a colony of *Siderastrea siderea* affected by DSD in multiple points with depressed areas (d), *Madracis mirabilis* with lesions progressing upwards (e). © D. Gochfeld

CAUSATIVE AGENT

Unknown. Presence of endolithic hypermycosis that may be associated with the disease (Work et al., 2008).

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. There are no suggested cures in the literature for this disease. Since the associated pathogen appears to be fungal rather than bacterial, antibiotic treatments will have no effect on the progression of the lesions (Gil-Agudelo et al., 2004). Based on treatments offered for other types of pathology, here is what we suggest :

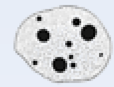
- **Manual removal and isolation** : Depending on the size of the lesions and of the affected colony, you can either fragment or chisel it to isolate the lesions from the healthy tissues. For fragmentation, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). If you choose to preserve the integrity of the colony, you can create a trench of approximately 1 cm deep and 1 cm wide by using a chisel to encircle the entire lesion (Randall et al., 2018). Once the coral is fragmented or chiselled, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant. To limit the diffusion of resistant infectious agent, the sealing of debrided wound edges with epoxy resin or cyanoacrylate gel may be effective (Sprung & Delbeek 1997). To increase the probability of eliminate microbial pathogens, you can mix the sealant (modelling clay, epoxy resin or cyanoacrylate gel) with chlorine powder (15 mL/50 mL epoxy) (Aeby et al., 2015).

Tissue Loss

Colour Change

Annular

Linear & Distinc



Multifocal

Coalescing

4.3 Diseases - Pigmented Lesions

Aspergillosis

LESION DESCRIPTION

Lesion shapes vary between annular, irregular or band-like appearance. They are characterized by focal to multifocal and coalescing purple areas (process also referred as « purpling », Alker et al., 2004) around tissue loss that exposes the axial skeleton. The lesions usually progress along the major colony veins and sometimes the disease manifests also as a tissue overgrowth (Kim & Rypien, 2015).

Aspergillosis on *Gorgonia* © D. Gochfeld

CAUSATIVE AGENT

The fungus *Aspergillus sydowii* has been identified as pathogenic agent for the disease (Geiser et al., 1998). However, this species is also observed in healthy coral tissue and surrounding water and might commonly belong to the coral microbiome. It is a terrestrial fungus that has probably been introduced in the marine environment through waterborne and airborne dispersion processes (Kim & Rypien, 2015).

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. Note that purpling can also be a general response to contact with biotic agents (Alker et al., 2004). Make sure there are no potential organisms adjacent to the lesions or developing directly on the sea fan that may cause purpling. However, there are no suggested therapeutic in the literature for this disease. What we recommend here to preserve the colony is to isolate healthy from diseased tissues by following the procedure below :

- **Manual removal and isolation** : Depending on the size of the lesions and of the affected colony, you can either fragment or chisel it to isolate the lesions from the healthy tissues. For fragmentation, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the coral is fragmented or chiselled, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant.

Prevention : By ensuring stable water quality and appropriate chemical filtration.

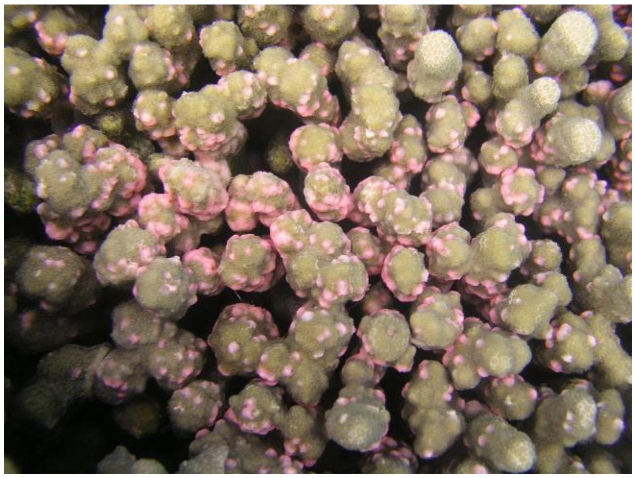
Coral hosts : *Porites* spp. – Locations : IP

4.3 Diseases - Pigmented Lesions

Trematodiasis

LESION DESCRIPTION

Multifocal to coalescing lesions of swollen tissue. Affected areas may look like protruded nodules (1-2 mm wide) which range from pale pink to white.

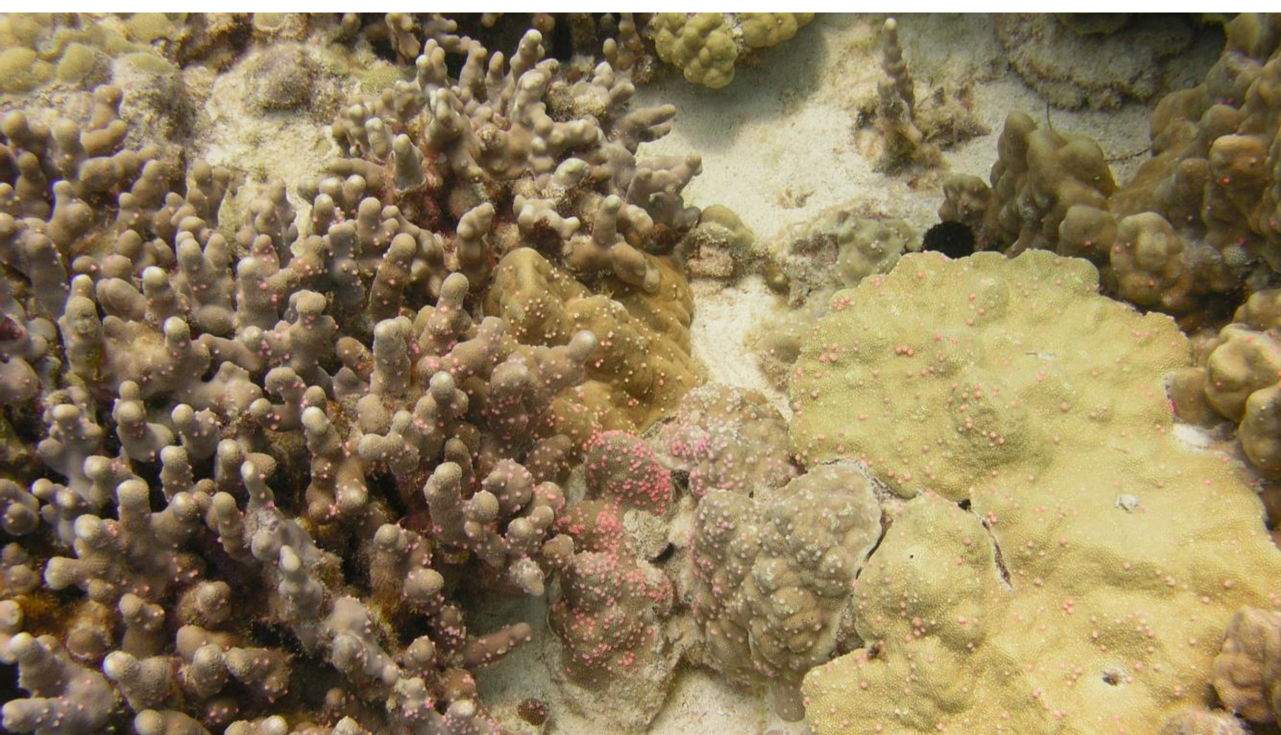


Porites compressa with trematodiasis in pink and white phase
© G. Aeby

CAUSATIVE AGENT

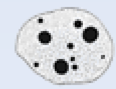
Trematodes are parasitic flatworms with a complex life cycle that involves two or more hosts. The species *Polypipapiliotrema stenometra* is known to encyst in coral polyps and cause irregular pink growth nodules on *Porites* spp. This appearance is referred as trematodiasis and persists until nodules are removed by corallivorous organisms or by senescence. This pathology seems to reduce the coral growth, however there in no evidence that it may cause coral mortality (Aeby, 1998; 2003).

Trematodiasis on several *Porites* colonies © G. Aeby



Growth Anomaly

Colour Change



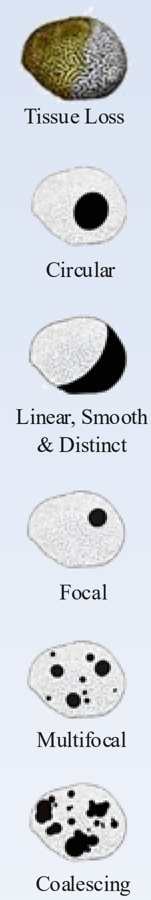
Multifocal

Coalescing

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. There are no suggested cures in the literature for this infection as the lesions will simply degenerate through senescence. Over the months, the pink colour will fade gradually toward the normal tan coloration of the coral, in parallel of the regression of the swelling infected polyps (Aeby, 1998).

Coral hosts : Several species – Locations : C

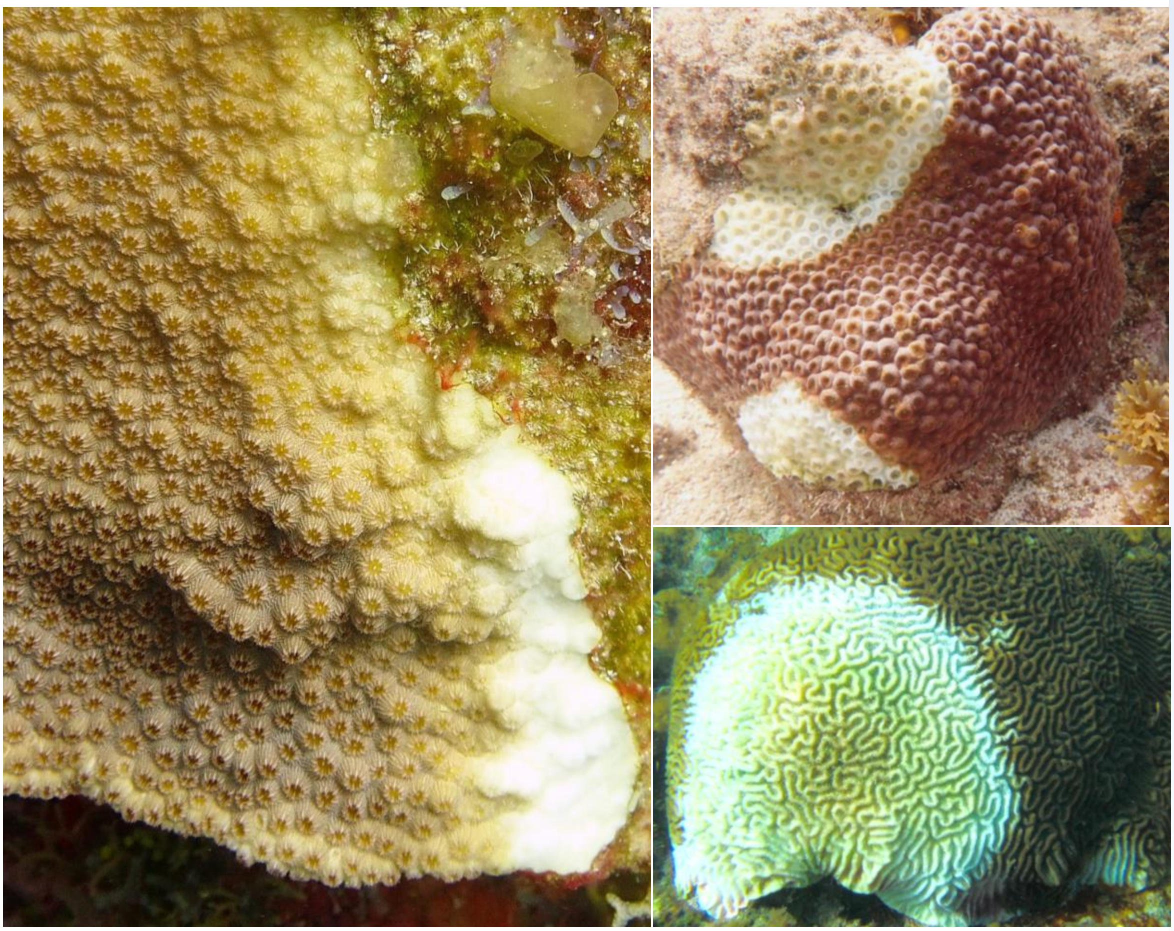


4.4 White Syndromes

Stony Coral Tissue Loss Disease (SCTLD)

LESION DESCRIPTION

Focal to multifocal and coalescing lesions with smooth and distinct edges. The lesions are randomly distributed, progress rapidly over the colony surface (a few cm day-1). Lesion shape can be highly variable and the margin of tissue loss can be preceded by a region of bleached tissue up to several cm wide (SCTLD Case Definition, 2018).



Multiple lesions of SCTLD showing distinct edges and surrounded by bleached tissues on (a) *Orbicella faveolata*, (b) *Montastrea cavernosa* © G. Aeby, and (c) *Colpophyllia natans* © D. Gochfeld

CAUSATIVE AGENT

Unknown. There are evidence of bacteria that may be associated with the disease progression (Papke et al., 2024)

PROPOSED SOLUTIONS

Although this pathology has not been reported in aquariums, during an outbreak, affected corals should be removed from the reef tank if at all possible and placed in a quaranting tank with an increased water flow.

Here are some suggestions for limiting the disease progression over the colony :

- **Chemical treatment** : The use of antibiotics may eventually eradicate the disease and can be performed following a Lugol's immersion to improve treatment efficiency and reduce the risk of bacterial resistance. In a separate tank or container, mix 0,5 mL (or 10 drops) of 5 % Lugol's solution per litre of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 30 minutes (Sprung & Delbeek, 1997). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The antibiotic treatment must be done on the isolated colony in another tank well aerated, to prevent damage to other organisms in the main aquarium. Miller et al. (2020) identified amoxicillin as the most effective antibiotic when applied directly to the tissue margin. For topical treatment, 65 mg of amoxicillin mixed with 1.5 mL of coral dental paste can be applied along the lesion margins on the coral skeleton. A single application is recommended, accompanied by 100% daily water changes for at least 7 days. However, additional applications may be necessary depending on the severity of the disease and the progress observed during monitoring. Other approaches, such as antibiotic dips, have also proven effective in treating SCTLD. Pelose et al. (2024) outline a 10-day *ex-situ* treatment protocol that incorporates hydrogen peroxide, amoxicillin, and ciprofloxacin.

Additional comments : All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Coral hosts : Several species – Location : C; RS

4.1 White Syndromes

White Plague
(WP)

LESION DESCRIPTION

Lesion shape can be highly variable (circular, irregular, linear), showing sharp boundaries between intact tissue and exposed skeleton. Multifocal to coalescing lesions can vary throughout a colony, with a progression rate of a few mm per day (WP I) or a few cm par day in the most virulent cases (WP II, WP III) (Bruckner, 2015).

WP on *Dichocoenia stokesii* with very linear and distinct lesion spreading upwards (left) and WP on *Diploria labyrinthiformis* with progressive colonization of the exposed skeleton by other organisms, indicating a slow progression rate (right) © D. Gochfeld

WP on *Orbicella faveolata* with multifocal lesions irregular in shape (left) and a macro photograph of the lesions showing sharp boundaries between intact tissue and exposed skeleton (right) © D. Gochfeld

CAUSATIVE AGENT

The disease affects several species of stony corals and is one of the most destructive coral diseases in the Caribbean. Although highly variable in shape and distribution on the colony's surface, the lesions are characterized by a sharp demarcation between apparently healthy tissue and exposed skeleton (Bruckner, 2015). Three types of WP have been identified and may be differentiated by their progression rates : type I (WP I), with a progression of the disease front of a few mm per day; type II (WP II), which has a higher progression rate of 1-2 cm per day; and type III (WP III) with a progression rate of > 2 cm per day (Richardson & Aronson, 2002). The pathogens causing the WP I and III remain unknown, and the bacterium *Aurantimonas coralicida,* has been identified as pathogen for WP II (Denner et al., 2003). Another WP disease with similar signs has been reported in the Red sea and its responsible pathogenic agent is a new bacterium named *Thalassomonas loyana* (Thompson et al., 2006).

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. Phage therapy appears promising to treat the lesions caused by *Thalassomonas loyana*, although it is still in the experimental stage (Atad et al., 2012). However, if a coral colony shows symptoms similar to those of WP, this can be treated as a case of white syndrome and the spread of the lesions can be limited by removing the margins as follow (Dalton et al., 2010) :

- **Manual removal :** Depending on the size of the lesions and of the affected colony, you can either fragment or chisel it to isolate the lesions from the healthy tissues. For fragmentation, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the coral is fragmented or chiselled, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant.

- **Chemical treatment** : as the pathogen linked to the coral disease is likely bacterial, it makes treatment with a broad-spectrum antibiotic a viable option. Antibiotics commonly used in aquariology, such as doxycycline, (oxytetracycline (cf. Leewis et al., 2009), or chloramphenicol (cf. Sprung & Delbeek, 1997) can be applied carefully to affected corals. This approach targets a range of potential bacterial culprits, offering a chance to curb disease progression. To minimize environmental impacts and the risk of antimicrobial resistance, refer to the existing protocols mentioned above for proper dosing and application techniques.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Coral hosts : *Acropora* spp. – Locations : C; IP; RS

Tissue Loss

Linear & Smooth

Annular

Basal

4.4 White Syndromes

White Band Disease
(WBD)

LESION DESCRIPTION

Linear or annular lesion with a sharp and smooth demarcation between intact tissue and exposed skeleton, usually beginning at the basal portion of the colony with a progression rate of a few mm per day (type I). A margin of bleached tissue separating bare skeleton and apparent healthy tissue may be present, then generally progressing downwards (type II) (Bruckner, 2015).

White band disease (type I) with lesions progressing upward on *Acropora cervicornis* (left) from Gignoux-Wolfsohn et al., 2012 and on *A. palmata* (right) from Bruckner, 2015

CAUSATIVE AGENT

The disease only affects *Acropora palmata* and *A. cervicornis* (Gladfelter, 1982). WBD takes two forms: type I (WBD I), with a progression of the disease front of a few mm per day and a sharp demarcation between apparently healthy tissue and exposed skeleton; and type II (WBD II), which has a higher progression rate of several cm per day, a typical band of bleached tissue at the border of the lesion and frequently originates at the branch tips (Bruckner, 2015). The pathogen causing the WBD I remains unknown, however it is likely that the disease is of bacterial origin. *Vibrio carchariae*/*Vibrio harvey* is a potential pathogenic candidate for WBD II (Gil-Agudelo et al., 2006).

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. Ampicillin, a broad-spectrum antibiotic, has been shown to be effective in halting the progression of the disease (Kline & Vollmer, 2011).

- **Manual removal :** Use a sharp tool (cutters, forceps, or chisel and hammer) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the area is cleared, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant before returning it to the aquarium.
- **Chemical treatment** : In case of strong infection, the use of antibiotics may eventually eradicate the disease and can be performed following a Lugol's immersion to improve treatment efficiency and reduce the risk of bacterial resistance. In a separate tank or container, mix 0,5 mL (or 10 drops) of 5 % Lugol's solution per litre of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 30 minutes (Sprung & Delbeek, 1997). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The antibiotic treatment must be done on the isolated colony in another tank well aerated, to prevent damage to other organisms in the main aquarium. For the antibiotic treatment, add ampicillin (100 mg/L of seawater) every 12 hours and replace half of the water in the tank, for a total of 6 days (Sweet et al., 2014). At the end of the treatment, the colony should be dip again in a Lugol's bath (10 drops in 1 liter of seawater) so that most of surviving microorganisms are eliminated and then rinsed thoroughly with clean seawater before returning to the exhibition aquarium.

Coral hosts : Primarily *Porites* spp. – Locations : IP; C

Tissue Loss

Colour Change

Multifocal

Coalescing

Smooth / Distinct

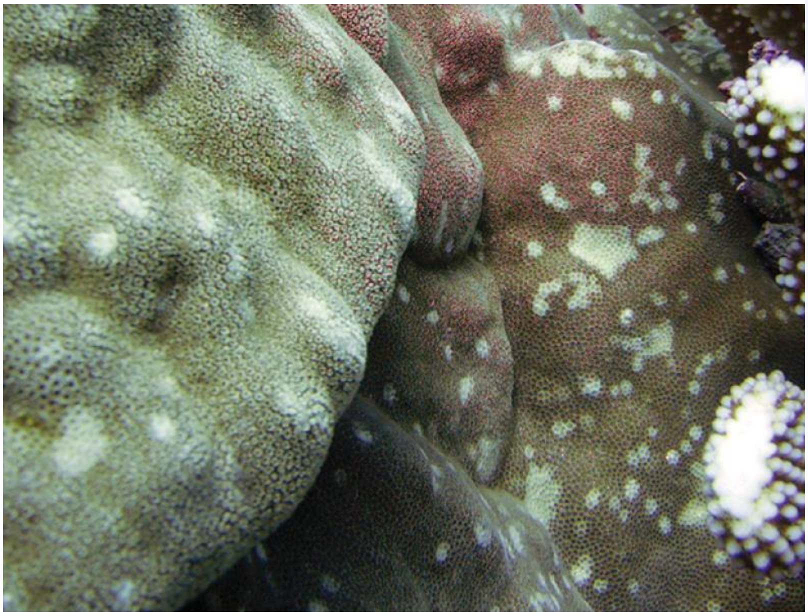
4.4 White Syndromes

Ulcerative White Syndrome (UWS)

LESION DESCRIPTION

Multifocal to coalescing circular lesions with smooth or distinct borders, typically 3-5 mm diameter. Early stages may be characterized by patterns of bleached tissue before exhibiting tissue loss and exposing areas of bare white skeleton (Raymundo et al., 2003).

Ulcerative white spots with multifocal lesions on *Echinopora,* from *Coral Disease – Diagnostic Decision Tree,* © NOAA - https://cdhc.noaa.gov/coral-disease/diagnostic-decision-tree/.



Ulcerative white spots with multifocal lesions coalescing on colony of *Porites,* © L. Raymundo from Bourne et al., 2015

CAUSATIVE AGENT

Unknown. *Vibrio* spp. have been associated with the disease progression (Arboleda & Reichardt, 2010).

PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. There are no specific therapeutic or control management reported in the literature for this pathology.

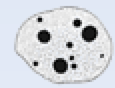
- **Chemical treatment** : as the pathogen linked to the coral disease is likely bacterial, it makes treatment with a broad-spectrum antibiotic a viable option. Antibiotics commonly used in aquariology, such as doxycycline, (oxytetracycline (cf. Leewis et al., 2009), or chloramphenicol (cf. Sprung & Delbeek, 1997) can be applied carefully to affected corals. This approach targets a range of potential bacterial culprits, offering a chance to curb disease progression. To minimize environmental impacts and the risk of antimicrobial resistance, refer to the existing protocols mentioned above for proper dosing and application techniques.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Coral hosts : *Acropora palmata* – Location : C


Tissue Loss


Irregular


Multifocal


Coalescing


Distinct

4.4 White Syndromes

White Pox Disease
(WPD)

LESION DESCRIPTION

Multifocal to coalescing irregular patches of tissue loss with distinct margins, highly variable in size. Lesions of exposed skeleton can develop on all surfaces of the colony and enlarging at a progression rate of a few cm per day (Sutherland et al., 2015).

Acroporid serratiosis characterized by irregular patches of tissue loss with distinct margins on *Acropora palmata*. The lesions are highly variable in size and may coalesce over the colony © J. W. Porter, University of Georgia

CAUSATIVE AGENT

Also called white patch disease or Acroporid serratiosis, the disease affects only *A. palmata and* the responsible agent that has been identified is *Serratia marcescens,* a common enterobacterium associated to discharge sewage (Patterson et al., 2002; Sutherland et al., 2011).

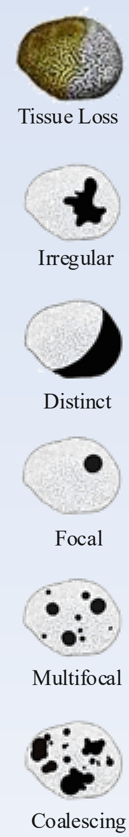
PROPOSED SOLUTIONS

This disease is unlikely to be observed in aquarium. There are no specific therapeutic or control management reported in the literature for this pathology.

- **Chemical treatment** : as the pathogen linked to the coral disease is likely bacterial, it makes treatment with a broad-spectrum antibiotic a viable option. Antibiotics commonly used in aquariology, such as doxycycline, (oxytetracycline (cf. Leewis et al., 2009), or chloramphenicol (cf. Sprung & Delbeek, 1997) can be applied carefully to affected corals. This approach targets a range of potential bacterial culprits, offering a chance to curb disease progression. To minimize environmental impacts and the risk of antimicrobial resistance, refer to the existing protocols mentioned above for proper dosing and application techniques.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Coral hosts : Several species – Locations : A



4.5 Others

Rapid Tissue Necrosis
(RTN)

LESION DESCRIPTION

Irregular or focal to multifocal lesions that may coalesce with distinct edges. Fast and diffuse tissue degradation (peeling, perforation) that may start at the margin of an injury and propagate with a high rate of progression (Luna et al., 2007). Slow Tissue Necrosis (STN) is a related pathology with a slow progression that can take weeks to months (Carl, 2008).

Acropora cervicornis demonstrating Shut Down Reaction, also known as RTN, hours after being shipped and placed in an aquarium (top left), *Galaxea fascicularis* (top right) and another *Acropora sp.* (bottom) with RTN symptoms. Note the perforation and peeling appearance of the lesions © E. Borneman, from Borneman, 2002. https://reefkeeping.com/issues/2002-03/eb/index.php

CAUSATIVE AGENT

Unknown. *Vibrio* species are more abundant in affected corals than in healthy corals (Luna et al., 2007). Also referred as "Shut Down Reaction", this condition shares similarities with White Syndromes but is not classified as one of them. It is typically restricted to corals in aquarium and may be due to autolysis in response to stress factors (i.e. handling and variation of temperature, salinity, pH) or kind of "allergic reaction" to certain chemical compounds produced by other organisms in the tank (Borneman, 2002).

PROPOSED SOLUTIONS

During an outbreak, affected corals should be removed from the reef tank if at all possible and placed in a quarantine tank with an increased water flow.

Here are some suggestions for eliminating them from the colony :

- **Manual removal** : First, siphoning off necrotic tissues directly into the aquarium can limit the risk of further coral contaminations. Afterwards, use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting at least 5 mm into apparent healthy tissue to fully excise any affected tissue (Carl, 2008). Once the coral is fragmented, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant. To limit the diffusion of resistant infectious agent, the sealing of debrided wound edges with epoxy resin or cyanoacrylate gel may be effective (Sprung & Delbeek, 1997).

- **Relocation** : If a colony shows sign of STN, one reason may be its environmental conditions. Try to relocate the coral colony to another area of the aquarium and increase food to create conditions more conducive to its development (Carl, 2008).

- **Chemical treatment** : In case of severe infection, the use of antibiotics may eventually eradicate the disease and can be performed following a Lugol's immersion to improve treatment efficiency and reduce the risk of bacterial resistance. In a separate tank or container, mix 0,5 mL (or 10 drops) of 5 % Lugol's solution per litre of seawater. Once the bath is homogenized, you can place the infested colony in it and let it soak for 15-30 minutes (Bartlett, 2013; Sprung and Delbeek, 1997). As Lugol's is subject to light-induced degradation, avoid direct exposure to UV sources during treatments for best results. The antibiotic treatment must be done on the isolated colony in another tank well aerated, to prevent damage to other organisms in the aquarium. Among antibiotics, doxycycline (2,5 mg/L for two days, daily water changes), oxytetracycline (30 mg/L for three days, daily water changes) (Leewis et al., 2009) and chloramphenicol (10 to 50 mg/L for three days, daily water changes) (Sprung & Delbeek, 1997), have been suggested in the literature and have demonstrated varying levels of success. At the end of the treatment, the colony should be dip again in a Lugol's bath (10 drops in 1 liter of seawater) so that most of surviving microorganisms are eliminated, and then rinsed thoroughly with clean seawater before returning to the exhibition aquarium.

Other commercial products are also used to treat RTN and STN, such as RTN/STN X or Prime Coral Prevent RTN.

Additional comments : Note that some antibiotics are light-sensitive (i.e. oxytetracycline) and should be applied in dark conditions, others can cause serious human health problems (i.e. chloramphenicol) and not all coral species tolerate exposure to these types of treatments. Instead of chloramphenicol, we recommend other molecules like florfenicol, metronidazole and dimetridazole. All treatment water enriched with antibiotics must be treated before being released into the sewage system. To this purpose, mix 3 mL of full-strength chlorine bleach per litre of water and leave for several hours to neutralize the antibiotic (Sprung & Delbeek, 1997).

Prevention : By ensuring moderate to strong waterflow, stable water quality and appropriate chemical filtration.

Coral hosts : Several species – Locations : C; IP; RS

4.5 Others

Growth Anomalies
(GA)

LESION DESCRIPTION

Focal to multifocal protruded lesions, circular to irregularly shaped. Sometimes skeletal deformations (i.e. desorganized or enlarged skeletal elements) are associated with tissue discoloration and/or chaotic polyp development. Neoplasia are characterized by desorganized growth patterns, while hyperplasia has a growth pattern typically organized.


Porites GA associated with apigmented tissue (left) and *Dichocoenia stokesii* GA with enlarged calices (right) © D. Gochfeld

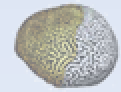

Colpophyllia natans GA's associated with apigmented tissue (left) and with swollen coenosarc (right) © D. Gochfeld


Montipora GA with apigmented tissue, desorganized skeleton and reduced polyp structure (left), *Porites* with enlarged coenosarc and pale tissues (right) © G. Aeby

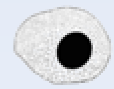
CAUSATIVE AGENT

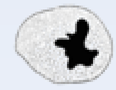
The exact causes of GAs in corals are not well understood but several factors are thought to contribute : environmental stress such as deteriorated water quality (Aeby et al., 2011), pathogens (bacteria, viruses, fungi) and encapsuled microorganisms (algae, fungi, invertebrates) (Work et al., 2015) are believed to trigger abnormal growth, but also mutation of the genome in coral cells (Peters et al.,1986).


Growth Anomaly


Tissue Loss


Colour Change


Circular


Irregular


Multifocal


Coalescing

PROPOSED SOLUTION

Growth anomalies don't cause immediate tissue death, however they may alter coral growth. If the lesions observed seem to have an impact on the overall health of the colony, here is a suggestion :

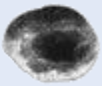
- **Manual removal** : Use a sharp tool (cutters or forceps) to carefully remove the affected areas. Ensure that you are cutting slightly beyond the visible anomaly to fully excise any affected tissue. Once the area is cleared, it is recommended to disinfect the colony in a 0,5% Lugol's (or other iodine-based) solution bath for around 5 minutes. Alternatively, you can apply iodine directly to the affected area if a bath isn't practical. After the iodine bath, rinse the coral colony to remove any residual disinfectant before returning it to the aquarium.

Additional comments : This procedure is not always effective, and the GAs may eventually re-occur if the factor inducing their development is distributed systemically throughout the colony, is a genetically-based factor or is persistent in the environment, such as a virus (Williams, 2013).

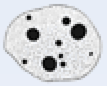
Coral hosts : Several species – Locations : C; IP; RS; A


Colour Change


Irregular


Diffuse


Focal


Multifocal

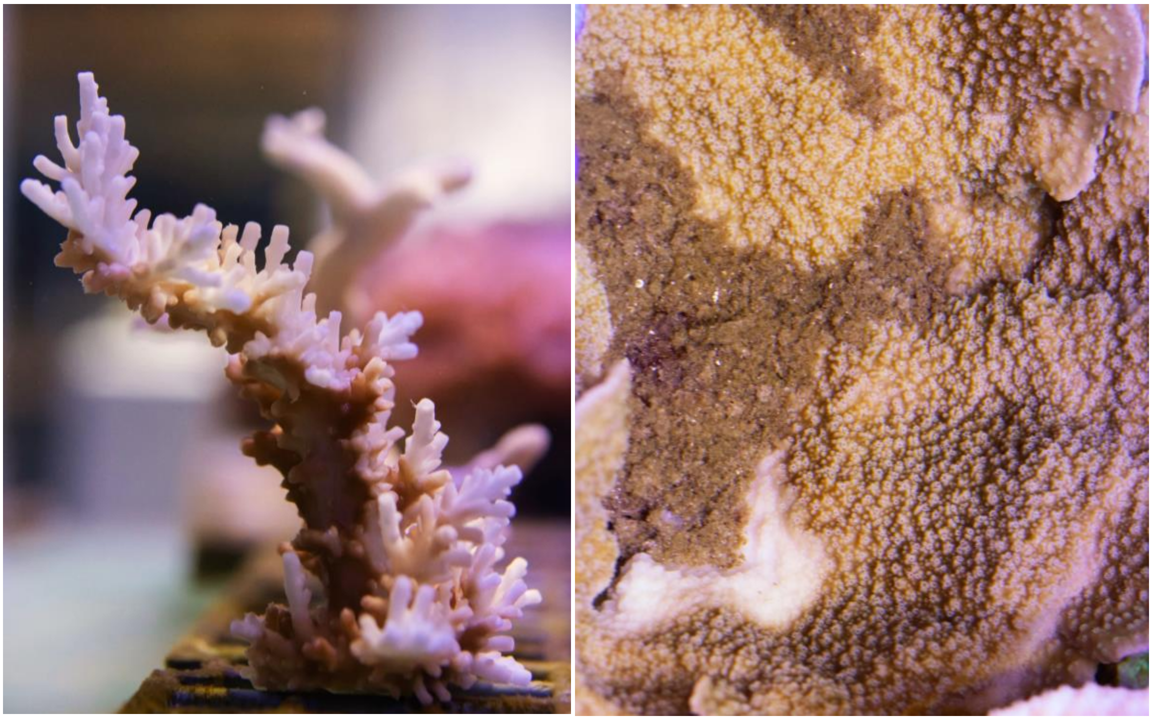

Coalescing

4.5 Others

Bleaching

LESION DESCRIPTION

Whole or partial bleaching of the colony (or even reef-wide). White lesions are characterized by alive coral tissue and presence of polyps. Another way of differentiating between bleaching and tissue loss is that the skeleton is not exposed and likely to be secondarily colonised by epibionts.



Coral colonies displaying clinical signs : *Acropora valida* partially bleached due to excessive lightning and loss of algal symbionts by *Montipora capricornis* due to accumulation of sediments © Oceanographic Institute of Monaco, F. Pacorel

CAUSATIVE AGENT

Bleaching is defined as the breakdown of the coral-algal symbiosis, which means that the Symbiodiniaceae are expelled from the colony, allowing the white skeleton to become visible through the transparent coral tissue. This process is a general stress response and may be coral species-specific, depending on the coral tolerance to different environmental stressors : extreme variations in temperature (Coles & Jokiel 1977; Jokiel & Coles 1990), light (Toller et al., 2001; Lesser et al., 1990), salinity (Van Woesik et al., 1995; Ferrier-Pages et al., 1999), reduction in pH (Anthony et al., 2008), poor water quality and exposure to different pollutants like herbicides, copper, cyanide, oil, sunscreen or sediments (Jones, 2004; Cervino et al., 2003; Haapkylä et al., 2007; Danovaro et al., 2008; Piniak, 2007), but can also be triggered by infectious agents (i.e. *Vibrio shiloi, V. coralliilyticus*) (Ben-Haim & Rosenberg, 2002). In aquarium, an excessive use of activated carbon, and subsequent reduction of trace elements, especially iodide, may also trigger coral bleaching (Delbeek and Sprung, 1994). Mild or short-lived bleaching is often reversible, but if it becomes prolonged or severe, it may result in colony death (Baker & Cunning, 2015).

PROPOSED SOLUTION

If a coral colony shows signs of bleaching or paling, you should likely check the physicochemical parameters of the tank. However, a paling colony is not necessarily declining; it may simply be adapting to more intense lighting, as happens naturally with corals near the surface. In some cases, the colour change results from a decrease in Symbiodiniaceae pigments rather than their expulsion. Bleaching can also occur when excessive activated carbon filtration depletes trace elements (e.g., iodine) essential for the symbionts' and host's physiological functions (Delbeek & Sprung, 1994).

- **Relocation** : Initially, ensure that light quantity meets the colony's requirements. If the coral is exposed to low light, gradually move it (over several weeks) to an area that receive more light. If the colony receives too much light, relocate it to a lower light area to improve its recovery.

Be cautious when changing lamps, as you may need to reduce light quantity initially by raising the light fixture or dimming lighting to avoid stressing the corals.

To help a colony recover after bleaching, place it in a stable environment with good water flow.

Prevention : By ensuring moderate to strong waterflow, stable water quality and appropriate chemical filtration.

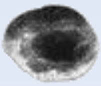
Colony of *Pavona* before (left) and after (right) bleaching © Oceanographic Institute of Monaco, F. Pacorel

Coral hosts : mainly *Acropora* spp. and *Porites* spp. – Locations : C; IP; RS; A

4.5 Others

Colour Change

Irregular



Diffuse

Focal

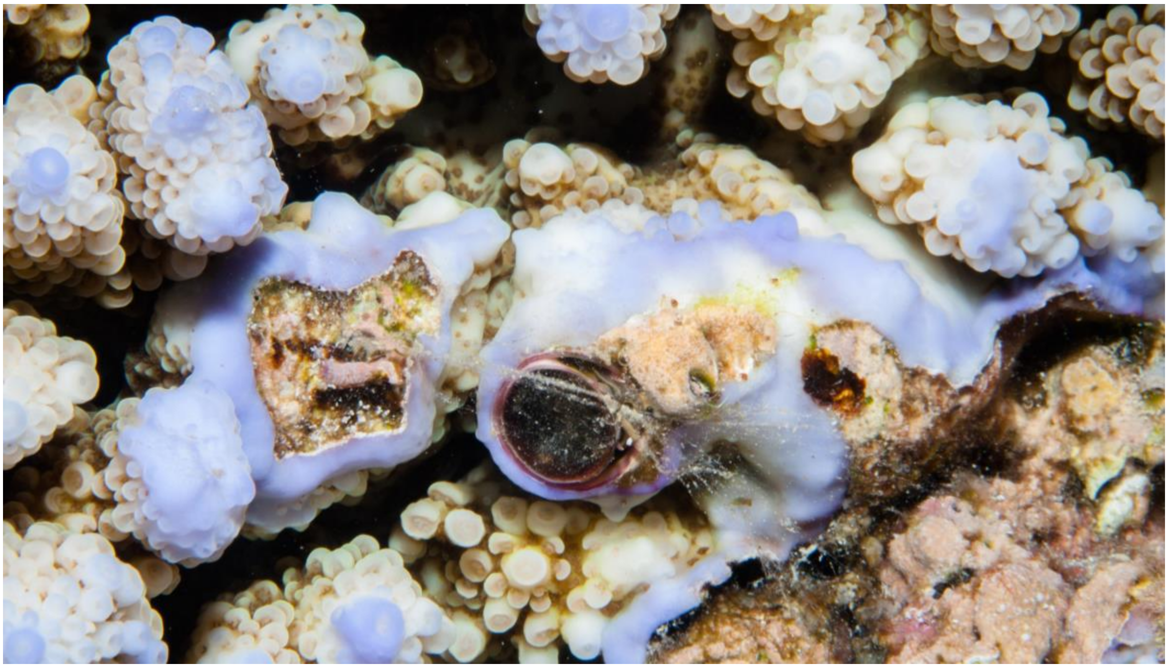
Multifocal

Coalescing

Pigmentation response

LESION DESCRIPTION

Irregular or focal to multifocal pigmented patches that may coalesce or diffuse over the colony surface. The lesions may be swollen and take on different shapes, typically appear pink/purple on *Porites* spp. and bluish on *Acropora* spp.



Vermetidae snail on *Acropora*, blue pigmentation response. J.C. Delbeek © California Academy of Sciences

CAUSATIVE AGENT

This type of lesions seems to be an "inflammation response" by coral tissue when it has been compromised by injury (Palmer et al., 2009). Pigmentation responses can therefore be observed around areas of tissue loss caused by predators, boring organisms, algal abrasion, breakages, etc.

Porites pink pigmentation in response to fish bites (Palmer et al., 2009)

PROPOSED SOLUTION

The pigmentation response appears in areas of compromised coral tissue and is often associated with other types of lesions. Unless you notice that the pigmentation spots are multiplying and compromising the health of the colony (e.g. repeated predation), you should not worry, as the coloration generally fades over time. Otherwise, you can refer to the other technical sheets to find a suitable solution.

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