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BURSTS OF CIGUATERA AND ENDO-UPWELLING PROCESS ON CORAL REEF

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Flambées de ciguatera et endo-upwelling sur récif corralien.

Résumé : *Il est proposé une relation de cause à effet entre les flambées de ciguatera consécutives à une agression subie par une zone récifale et les sorties d'eaux interstitielles par endo-upwelling riches en nutriments. Ceux-ci n'étant plus utilisés par un écosystème algo corallien stressé ou éliminé, le sont par des planctontes épibenthiques comme* Gambierdiscus toxicus *dont la population augmente brutalement.*

Summary: *We propose a significant relationship between bursts of ciguatera following disturbance on a reef area and seepages of endo-upwelled interstitial waters, rich in nutrients. Such waters cannot continue to be used by a stressed or eliminated algal-coral ecosystem and are taken up by epibenthic planktons* i.e. Gambierdiscus toxicus, *of which population increases sharply.*

I. INTRODUCTION

The epidemiology of ciguatera bursts was carefully studied in French Polynesia since 1967. In many circumstances the occurence of poisonous fish is directly linked to patent changes on reef. New high risk zones are very often areas disturbed by human activities (2). In these zones the populations of toxic *Gambierdiscus toxicus* (ADACHI & FUKUYO, 1979) (1) poor in normal environmental conditions may increase suddenly among macroalgae covering dead coral beds or newly denuded surfaces (4). There, the harmful fish are first herbivores detritus feeders, followed within a few months by carnivores. The link between ciguatera and natural disturbance, less easily experienced by islanders, was questioned (3). But the intimate mechanism of the phenomenon is still to be elucidate. The possible role of endo-upwelling process is hereafter discussed.

II. REEF FUNCTIONING AND THE ENDO-UPWELLING PROCESS

A dynamic model of reef functioning by « geothermal endo-upwelling » was proposed to bridge the paradox between the enormous/huge primary productivity of coral reef ecosystems bathed by a tropical ocean permanently barren of nutrients. The model is based on a geothermally driven upward circulation of deep oceanic water that enters the porous barrier or atoll reef foundation of underlying volcanic basement (6).

Algo-coral communities are settled where these endo-upwelled waters seep out and provide the dissolved nutrients (chiefly P, N and Si), CO_2 and other elements (as iron) to the symbiotic micro-algae dinoflagellates (zooxanthellae) living in the cells and tissues of the coral polyps which in turn furnish organic carbon to polyp cells by direct translocation. Because of the steady supply of nutrients provided by endo-upwelling (7), the zooxanthellae grow at optimal rates (population doubling time is just a few days) and reach densities in the polyps of 1-10 million cells/cm^3. The population growth rates of the zooxanthellae exceed the tissue growth rate of the polyps so that it is necessary to expel the excess zooxanthellae at rates of about 1,000 cells/hour/cm^2 of polyps surface (5). These expelled zooxanthellae constitute an important potential food resource for such planktonic consumers as copepods, oysters and other filter-feeders.

III. DISTURBANCE SCARS ON THE REEF SURFACE AND THE BLOOM OF TOXIC EPIBENTHIC DINOFLAGELLATES

The endo-upwelling model may provide an explanation for ciguatera events: any physical disturbance

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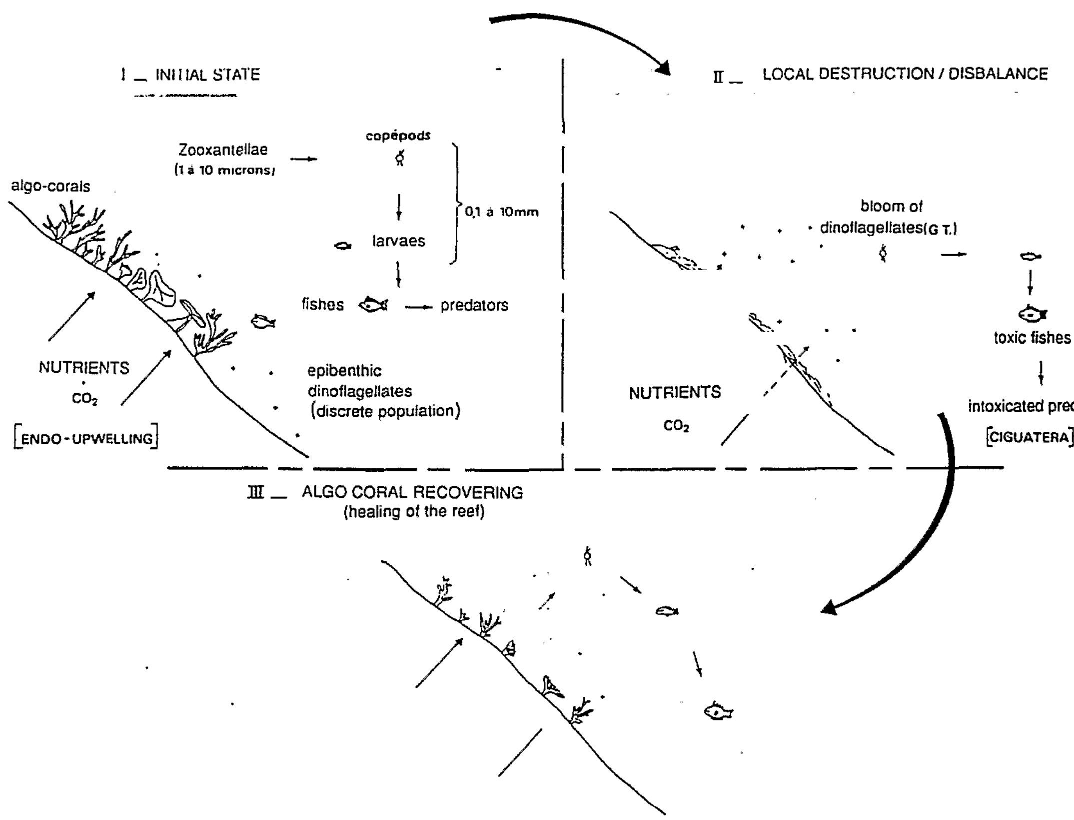

Fig. 1. — Scenario linking coral destruction and/or removal, dinoflagellate (G. toxicus) *blooms and bursts of ciguatera.*

I. Initial step. The normal functioning of the reef ecosystem, including expulsion of symbiotic zooxanthellae which are consumed by zooplankton (copepods, larvae) and secondary herbivores (fishes) and predators.

II. Local destruction of the algo-coral cover. Seepage of nutrient-rich water is facilitated in areas where the normal consumers (micro- and macro-algae) are elimited. Opportunistic epibenthic dinoflagellates (e.g. *G. toxicus*) bloom, their ciguatera toxins enter the reef food chain and inflict/infect fishes and their predators, including humans.

III. Recovery of the surficial corals. *G. toxicus* population declines as the algo-coral cover returns to the reef (cicatrization).

toward- or removal of the algo-coral veneer, corresponds for the reef to a loss of its live skin, similar to a scar on the flesh. Seepage of interstitial water is facilitated. In places where there are few or no more zooxanthellae or benthic calcareous algae to absorb the upcoming nutrients, these will be used by other opportunist macroalgae, planktonic and epibenthic plants, including the dinoflagellate *Gambierdiscus toxicus* which is of similar size and close metabolism to the zooxanthellae. Both microalgae use for their *in vitro* growth seawater enriched with silicates, vitamins and metallic salts. More color changes in the plasts suggest an absorption capacity for organic substances present in the culture medium, and a mixotrophic diet. A bloom of *G. toxicus* may then rapidly follow the local death or loss of corals, leading to the abnormally high production of toxins and their uptake by epibenthic feeders. In this way an atypical food chain is established, based on toxic dinoflagellates, instead of zooxanthellae, which extends up the toxicity to benthic fish and their human consumers. When recolonization of corals begins, which is equivalent to cicatrization of a wound, the dinoflagellate bloom collapses and the ciguatera occurrence diminishes. This scenario (fig. 1) can also account for ciguatera events that follow natural reef stresses such as cyclonic devastation or coral bleaching.

CONCLUSIONS

We propose that bursts of ciguatera are an ecological consequence of a concomitant increase in the seepage of interstitial nutrients where normal sessile users are stressed or eliminated. In well-balanced algo-coral reefs, these nutrients are consumed by symbiotic zooxanthellae whereas in disturbed or stressed reefs they promote bursts in populations of *Gambierdiscus toxicus* because of the reduced nutrient uptake by the coral-zooxanthellae cover. During periods of disturbance or stress, an atypical food chain is created with toxicity transmitted throughout the food web. This scenario that implies the endo-upwelling process in the incidence of ciguatera, needs to be checked by appropriate studies and simulation both *in vitro* and *in situ*.

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