ATOLL RESEARCH BULLETIN
No. 286

ENVIRONMENTAL SURVEY OF MATAIVA ATOLL, TUAMOTU ARCHIPELAGO FRENCH POLYNESIA

By
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Issued By
THE SMITHSONIAN INSTITUTION
Washington, D. C., U.S.A.
May 1985

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In addition to the author's own research results, this paper includes contributions by many colleagues, from unpublished reports, theses in progress and other data, which are here gratefully acknowledged. These collaborators and their affiliations are listed below. All are also attached to the Centre de l'Environnement in Moorea(1).

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By

B. Delesalle and Colleagues *

INTRODUCTION

Mataiva Atoll, one of 84 in French Polynesia, is a small coral island at the western edge of the Tuamotu Archipelago. This atoll occupies a particular place among the French Polynesian atolls since the discovery beneath the lagoon sediments of deposits of phosphates soon to be exploited. In order to estimate the environmental effects of such exploitation and plan a management scheme, numerous studies have been carried out since 1978 by many scientific organizations: Antenne du Muséum National et de l'Ecole Pratique des Hautes Etudes en Polynésie Française, Office de la Recherche Scientifique et Technique d'Outre-Mer (ORSTOM), B.C. Research, Institut de Recherches Médicales Louis Malardé (IRMLM), Centre National pour l'Exploitation des Océans (CNEXO) and Commissariat à l'Energie Atomique (CEA-LESE).

Because of the unusual and interesting results of these impact studies, the Antenne Museum-E.P.H.E. has, since 1981, continued the scientific survey of Mataiva Atoll. The geology and geomorphology of the atoll, the hydrological characteristics of lagoon waters and the abundance and diversity of the marine flora and fauna have been investigated by about 20 scientists. Several contributions, including for example studies of fishes, crustaceans and phytoplankton, are extracted from doctoral manuscripts.

Mataiva atoll has been chosen as the site of a post-Congress field trip of the Fifth International Coral Reef Congress, to be held in Tahiti in June 1985.

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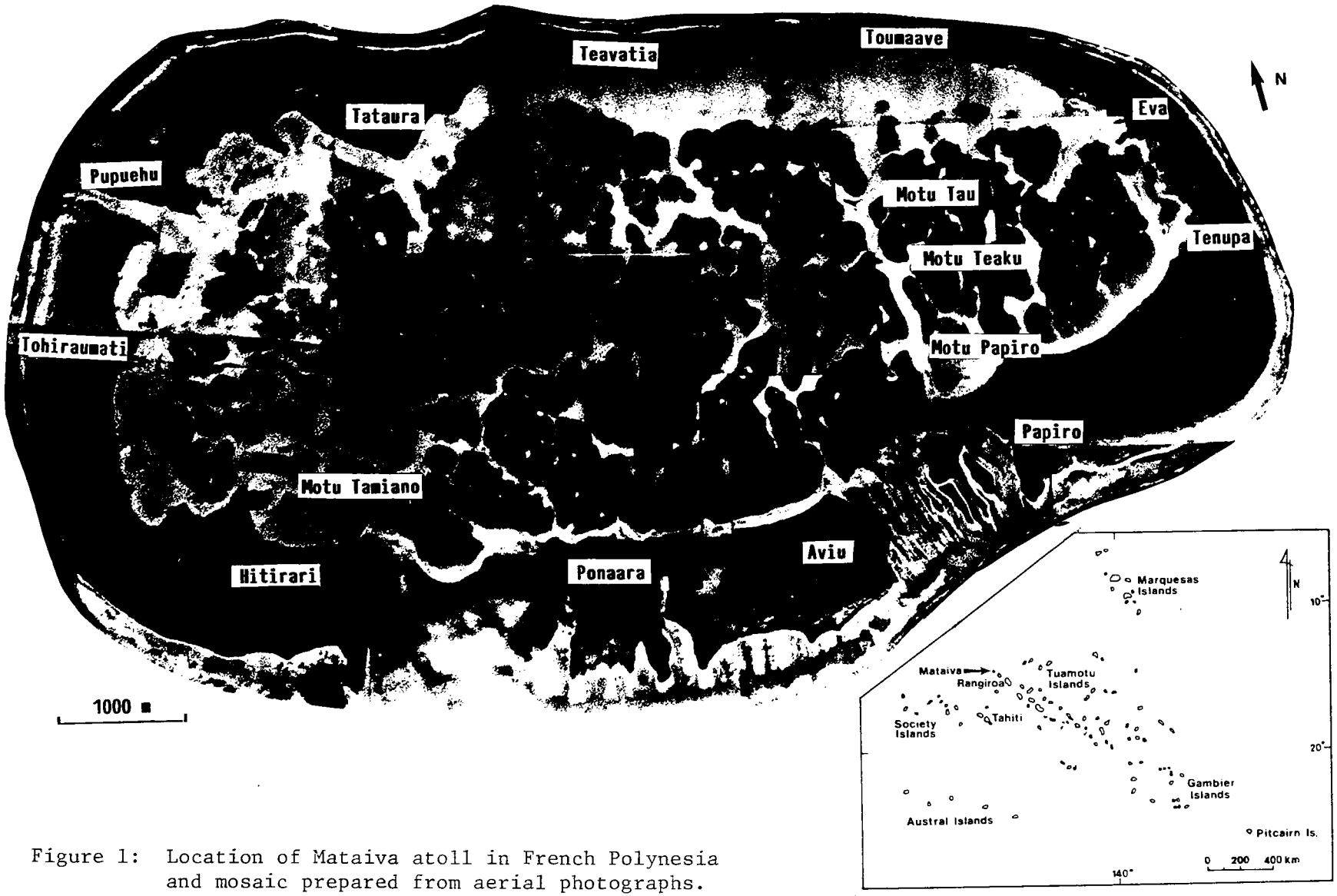

Figure 1: Location of Mataiva atoll in French Polynesia and mosaic prepared from aerial photographs.

PRESENTING MATAIVA ATOLL

Geography

Mataiva atoll is located 300 km north of Tahiti, 14° 55′ lat. S and 148° 36′ long. W. It is the westernmost atoll in the Tuamotu Archipelago. This small island, 10 by 5 km, is distinguished by its unusual morphology: a wide atoll rim, almost continuous, allowing only limited oceanic exchanges, and a reticulated lagoon divided into numerous basins by a network of slightly submerged partitions (Figure 1).

The climate is not unlike that elsewhere in Polynesia, i.e. tropical, hot and humid, with 2 seasons: one, relatively dry and cool (24-27° C) from April to September, and the other, hot and rainy (28-30°C) from October to March. Since the atoll has little relief, rainfall rarely exceeds 2.5 m per year, and the amount of sunshine is high (2500 hours per year). Storms and cyclones are rare with the exception of 1983, when 3 cyclones hit Mataiva. Trade winds are dominant, blowing from the eastern sector at an average speed of 7 to 10 m/s. The swell is generally less than 4 m, coming mainly from the South.

Background and population

Europeans discovered Mataiva in 1819: it was then named Lazareff Island by Bellingshausen. The numerous archeological discoveries bear witness to a more or less permanent pre-European settlement. Mataiva then belonged to the 8 independent kingdoms of the western Tuamotu, which formed the cultural and linguistic area of Mihiroa. However, this island was often uninhabited, particularly after its people were massacred in the 18th century by the inhabitants of Anaa atoll.

The present population on Mataiva is of recent origin. Around 1940, representatives from various families of the neighbouring atoll, Tikehau, who were exploiting Mataiva's copra, decided to settle there. The atoll was declared autonomous in 1950 and in 1971 was associated with the community of Rangiroa (Jarrige et al., 1978).

In 1983, the population of Mataiva numbered 183. It is a population of predominantly younger generation (55.8% are under 20 years old), slightly unbalanced (63.4% being female) and very fluctuating because of its proximity to Tahiti. The relationship, with Tikehau and Makatea, to the larger community of Rangiroa, explains the frequent population surges to these islands, whether temporary or permanent. For example, of the 172 persons established on Mataiva recorded in a survey taken in 1964 only 41 were still there in 1983.

Economy

Fishing and copra production are the two traditional means of support on the Tuamotu Atolls. These two natural resources are enough to insure the subsistence of the inhabitants and to allow the surplus to be commercially exploited. Being close to Tahiti, the main market, Mataiva

glories in its privileged position; moreover, it will be able to add the yield from the exploitation of phosphates to its future revenue.

Fishing. . On atolls generally, the sea provides about 70% of the proteins consumed, mainly through fish, but also sea food (shell fish and crustaceans) collected along the reef, and turtles which are considered a great delicacy. Fishing techniques vary: spears ("pupuhi"), rods ("aira"), lines or nets are used, but commercial fishes are above all collected in fish traps, then sold to passing schooners. These fish traps are located in the pass and next to the hoa (ocean-lagoon channels) and passively catch reef fishes. The amount of the catch varies greatly throughout the year and provides around 45 tons annually.

Copra. An essential atoll resource, copra occupies a large majority of the population throughout the whole year: the upkeep of the coconut grove, harvesting and drying of the nuts and the export to Tahiti. Due to the size of its emerged reef rim, Mataiva is an important producer with an annual harvest of nearly 450 tons, i.e. about 5% of the total production in the Tuamotu Archipelago. Unfortunately, this production was completely eliminated as a result of the 1983 cyclones and for at least two years, the main activity has been devoted to the restoration of the devastated coconut plantations.

Phosphates. The phosphate deposit represents the future--although at the moment hypothetical--wealth of Mataiva. It extends for approximately 5 km^2 and represents 15 millions tons of ore, 10 of which can be extracted. Its exploitation, forecast to last 10 to 15 years, will necessitate the employment of about 200 people. Such a project will result in complete upheaval in the atoll's morphology and the way of life for its inhabitants, but should not do so to the detriment of its traditional resources. One hopes that Mataiva will not experience the same fate as its neighbouring island, Makatea, which was practically deserted following the exploitation of its deposits.

GEOLOGICAL SETTING OF MATAIVA ATOLL

The morphological and sedimentological characteristics of Mataiva atoll are rather different from those encountered in most other atolls of French Polynesia. These singularities appear to be a consequence of unusual and late geological events which caused, among other things, the formation of a reticulated lagoon and deposits of exploitable phosphates. In particular, tectonic uplift of the NW Tuamotu atolls presumably resulted from the loading effects of the nearby volcanic complex. A crustal moat has developed peripheral to Tahiti, Moorea and Mehetia volcanoes. Beyond the outer edge of the moat, flexuring (buckling) has developed an arch which has been uplifted by about 10 meters (Pirazzoli and Montaggioni, in press).

Geomorphology of Mataiva

When approaching Mataiva by plane, one is immediately struck by 2 morphological characters: a wide reef rim and a partitioned lagoon.

The emerged reef ring is 200 to 1500 m wide, i.e. somewhat wider than found in the other atolls of the Tuamotu Archipelago. This reef rim is almost continuous, broken only by some channels (hoa) on its southern coast and a small atypical pass in the NW. The N and E coastlines form a single islet (motu).

A topographic cross-section (Figure 2) allows a proper understanding of this atoll's morphology. It reveals a marked dissymmetry between the N end S coasts of the atoll--the N and NE coasts are narrow (200-500 m) and of relatively high altitude (+ 6 m), whereas the southern coasts are lower and wider (1000-1500 m). In the same way, this asymmetry continues to the inner slope, which is wider (300 m) on the N coast than on the southern one (50 m). This dissymmetry is easily accounted for by the violent storms coming from the N wit-h the resultant accumulation of storm ridges on the N coast, while the lagoon muds are transported southwards where they contribute to the supratidal accretion of the southern motu. This high energy sedimentation contrasts with that which prevails in a "normal" meteorological situation, where the influence of the S E tradewinds favours rather the widening of the northern inner slope.

The outer reef, of variable width (150-500 m), is characterised by 2 fundamental features :

- The presence of a reef flat flagstone, more or less eroded, located below and behind the algal ridge, where biodetritic sedimentation is weak or non-existent.
- The presence of an algal ridge in the process of chemical erosion; remnants of a raised, fossil ridge appear in some places; crusts of living coralline algae are spotty. Construction is quite inactive and the relief is in the process of degradation.

The lagoon morphology is the most original characteristic of Mataiva atoll. It is a reticulated or partitioned lagoon, made up of about 70 pools of varying sizes (100 m to over 2 km), with an average depth of 8 m. The shallows which separate these pools are under 0.1-0.8 m of water and form a network over 200 km long.

This sort of reticulated lagoon seems to be the only one in French Polynesia but its morphology is reminiscent of certain reef zones of Bora Bora (Society Archipelago) or of Ponape (Caroline Islands), which also consist of such lagoon pools each isolated from the others. Surveys conducted in the lagoon reveal that this reticulation seems directly related to paleotopography, most likely a pre-Pleistocene surface, buried under 10-15 m of present-Holocene sediments. This paleotopography influences the present topography and makes up the framework of the atoll's general morphology. However, Holocene coral remnants located 30-40 cm above mean lagoon level, determine the morphology of the lagoon coast and form some small islets in the eastern and southwestern parts of the lagoon.

Outer reefal and lagoonal sediments

Grain-size analyses of bottom surface samples have only been made on the fraction larger than 40 µm. Two textural parameters (mean size, Mz

and sorting, So) have been graphically determined from the cumulative frequency curve. There appears to be a sharp difference between the reefal and lagoonal sediments (Figure 3). On the reef rim, the sediments are medium to coarse sands or granules (Mz= 0.67-3.45 mm), usually well sorted (So = 0.76-0.91), except in the western sector (So= 2.18). In all cases, fractions smaller than 0.5 mm do not exceed 25%. On the contrary, sediments in the lagoon are fine or very fine sands, to muddy sands (10-50% of fractions < 40 µm), or to sandy silts (over 50% < 40 µm). The sorting is usually good (So = 0.28-1.48). Higher percentages of silts have been found on the shoals sides or at the bottom of the basins, mainly in the N and E sectors of the atoll (50-80% of silts).

The composition of sediments reveals 2 main sources, corals and Corallinaceae. Green calcareous algae (Halimeda), Foraminifera and molluscs can also make up an important part of the sediment. Crustacea, serpulids, sponges and Bryozoa are also found. Figure 3 shows the grain size and composition of sediments in different parts of the outer reef and lagoon. The important features to emphasise are the abundance of Foraminifera on the southern outer reef, the great variation of percentages of Halimeda and Foraminifera in the lagoon, and the better representation of Corallinaceae and molluscs in the lagoon than on the outer reef.

Sequence of the main geological events at Mataiva atoll

Geological investigations by subsurface drilling showed the dominant influence of the pre-Holocene surfaces on the topography of Mataiva's reef structures. By reference to the geological history of other French Polynesian atolls and particularly that of Makatea (Montaggioni, 1985), the geological history of Mataiva can be summed up as follows :

During the Mio-Pliocene(?) a platform-like reef developed. This old reef is at present emerging along the N coast in the upper part of the ocean side beach. In the central and southern parts of the atoll, it is buried under a layer (a few to 30 m deep) of Holocene deposits. During several spells of emergence, this old reef underwent severe meteoritic solution and partial dolomitization.

During a later stage (Pliocene ?), the cavities of the karst thus formed were filled up with a phosphate deposit. The contrast in facies between the rocks of the old reef and the deposit demonstrates the totally different conditions of deposition for the phosphate. However, at present it is not possible to offer a reliable reconstruction of the deposition environment of the phosphates. Three alternatives may be proposed for their origin: on weakly consolidated carbonate rocks (high residual porosity), phosphorites may have been formed by (a) alteration and diagenesis of sea birds excrements and bones, (b) alteration of marine organic matter, deposited under low oxygen conditions, (c) post-depositional alteration of drift volcanic material that accumulated as soils.

Subsequent to phosphatogenesis, Mataiva Island underwent a slight tectonic uplift which appears to be confirmed by the absence of deposits linked to the 120,000 B.P. high sea level, which is found at Moruroa

atoll between 7 and 11 m below the Holocene deposits (Buigues, 1983).

The island was later submerged and thus the phosphate deposits and the rest of the old reef were recolonised by coral growth during the Holocene transgression, about 6,000 years ago.

Lastly, between 5,000 and 2,000 B.P., coral growth developed at Mataiva at a level slightly higher than the present one. The relicts of algal ridges found on the outer reef (2,200 ± 130 yrs) and the Porites colonies of the lagoon motu (5,210 ± 130 yrs) are at elevations similar to the emerged beachrocks, in which lithification patterns indicate an exposure patterns to vadose diagenetic environments during their formation (Montaggioni and Pirazzoli, 1984).

HYDROLOGICAL ENVIRONMENT

The hydrological characteristics of Mataiva atoll have a direct connection with 2 main morphological features: (1) a lagoon of reduced size and depth, whose shoals further restrict the volume (2) limited but still existing relations with the ocean through hoa and pass. Consequently, the physicochemical characteristics of the lagoon waters, if they show a certain spatial homogeneity, present an enormous temporal variability, principally dictated by climatic conditions (Delesalle, 1982).

Currents

The hoa's position, close together on the S side of the atoll and facing the dominant swells, in relation to that of the pass on the opposite sheltered coast, brings about a general circulation of the waters from the S towards the NW. Oceanic waters enter the lagoon through the hoa, whilst, in the pass, the current is most often outgoing (Figure 4).

In the lagoon, the partitions slow down considerably the water's circulation, and only the wind-induced currents are measurable. However, because of the larger size of the basins along the northern and southern coasts, the flow of water may preferentially follow them, and avoid the atoll's centre. In this case, the eastern part of the lagoon, isolated by a transversal string of islets, appears more confined.

Water level

The small amount of ocean-lagoon exchanges, added to the relatively reduced volume of the lagoon, explains how the water level can undergo considerable variations. An example of such variations, recorded daily since 1979 next to the pass, is given in Figure 5. Their usual amplitude is about a metre, but can reach or surpass 1.5 m when a very strong swell occurs. On the other hand, these variations are very rapid, a rise of 40 cm in 24 hours is not unusual. Considering the area of the lagoon (2500 ha), such an increase corresponds to an entry of water of about 10^7 m^3, i.e. 1/10 of the lagoon volume. The lowering of this level is more gradual, around 10 cm in 24 h, but can last for periods of 7 to 10 days, and thus reach such a low level that the coral colonies on the top of the partitions emerge.

The general evolution of the level over 5 years shows a certain predominance of lower levels between July and December, but without well defined cycles.

The variations in the lagoon level show that Mataiva cannot be called a closed atoll. The existence of a pass, although atypical and shallow, guarantees permanent oceanic exchanges.

Temperature and salinity

Water temperatures in the lagoon do not vary much and generally follow the air temperatures with a maximum (29°-31°C) in the rainy season and a minimum (25°-27°C) during the dry season. If there is a slight warming up of the surface waters during the day, still a marked thermic stratification does not occur as could be expected in the absence of circulation.

This homogeneity of the water column is confirmed by salinity levels which differ little between surface and bottom. Temporal variations in salinity are more marked. In fact, if the lagoon waters near the hoa show salinity values usually close to those of the ocean (36 g/l), in the rest of the lagoon drops in salinity (30.77 to 33.89 g/l in April 1981) or increases (36.56 to 37.64 g/l in October 1983) can be observed.

If climatic conditions (heavy rains or long periods of dryness) directly influence the salinity of lagoon waters, the phreatic freshwater, held in the atoll foundation, also plays a role: the low salinity levels observed in April 1981 were measured after a month without noticeable precipitation while over 500 mm of rain had been recorded the month before.

Turbidity and light penetration

The lagoon waters of Mataiva always have a more or less pronounced milky appearance. Secchi disc measurements of water transparency reach 50 m in the ocean, but do not exceed 7 m in the lagoon near the hoa and 2.5 m near the pass. Quantum measurements indicate a quick absorption of light with depth (Figure 6). The attenuation coefficient deduced from these curves is weaker near the hoa (0.14) than towards the north of the lagoon (0.28); the most turbid waters (0.36) are found near the pass. However, the amount of suspended matter is not very great: 6.7 to 9 mg/l. This strong decrease in light in the water is caused by very fine, silty, calcareous particles.

Dissolved oxygen

Levels of dissolved oxygen vary very little (5.4 to 7mm/l) and remain close to, or higher than the level of water saturation, depending on temperature and salinity. Such values indicate a confined environment where photosynthetic organisms play a major role in water oxygenation.

Nutrients

Lagoon waters of atolls are usually considered to be oligotrophic because of the absence of continental influences. Mataiva lagoon water, on the contrary, contains high and variable concentrations of dissolved nutrients, especially nitrates and silicates (0.10-13.99 uatg N-N03/1, 0.3-16.5 uatg Si/1). Heterogeneity is very marked between different areas of the lagoon and different periods of measurements, but no well-defined pattern can be recognized from the distribution of the values.

The confinement of the lagoon water, its lack of depth and its division into numerous pools, appear to be factors that allow such high and variable concentrations. Moreover, the migration of nutrients from the oceanic deep layers and the volcanic substratum through the coral foundation, as shown in Moruroa atoll (Rougerie et al.,1982) and in Takapoto atoll (Rougerie, 1983), might be an important contribution to the enrichement of the waters. Although we have no information about the porosity of the coral foundation of Mataiva, it is probably not less than on Takapoto considering the geological events (uplifts, karstification) undergone by Mataiva Atoll.

PRIMARY PRODUCERS OF MATAIVA LAGOON

Phytoplankton

The phytoplankton of the lagoon waters is of relatively low specific diversity. Six classes of algae can be identified, Diatomophyceae, Dinophyceae, Chlorophyceae, Cyanophyceae, Cryptophyceae and Chrysophyceae (Coccolithophorideae), but with few species (Table A).

The diatoms dominate the phytoplanktonic flora by the diversity of the existing species, particularly the genera Mastogloia, typical of tropical seas, Nitzschia and Navicula. The scarcity of strictly planktonic forms such as Rhizosolenia, Chaetoceros or Thalassiosira must be noted. These are found only near the hoa, where oceanic waters enter the lagoon. The populations are mainly made up of phytoplanktonic species. Dinoflagellates are also represented by species from calm and shallow environments: Gymnodinium, Gonyaulax and Prorocentrum (notably P. ovum). The other classes, especially Cryptophyceae and Chlorophyceae, are not often found in the plankton of atoll lagoons. The presence, and, at times the abundance, of some species such as the green alga Pyramimonas is a peculiar characteristic of Mataiva plankton.

The abundance of Mataiva's phytoplankton varies from 10^3 to 5 10^5 cells per litre. Quantitatively the small-sized phytoflagellates (10.30 µm) are often dominant while the diatoms are only locally abundant. A dinoflagellate Gymnodinium and a chlorophyceae Pyramimonas sometimes represent 90% of the cells counted.

The presence and importance of phytoflagellates in Mataiva plankton are characteristic of a calm and shallow environment. However, because of the richness in nutrients of the waters, one might expect a high

biomass in the plankton. On the contrary chlorophyll measurements give low values : 0.3 to 1 ug chl *a* l^{-1} in surface waters, to 5 near the bottom. Neverthless, the low percentage of degraded pigments (less than 35%) as well as the high level of primary production (23-90 mg cm^{-3} d^{-1}), so much higher than values usually observed in atolls (Sournia et Ricard, 1976; Delesalle et al. 1983), are indicative of a rapid turn-over in the phytoplanktonic populations. Such a paradox between low biomass and strong primary production can be partially explained by the wealth of zooplanktonic populations whose grazing can keep the phytoplanktonic biomass at a low level.

Benthic macroflora

The benthic macroflora in Mataiva's lagoon is characterised by a small number of species, of which only a few are abundant (Table B). Essentially, it is a hard substratum flora. Only a sea-grass, Halophila cf. ovalis, forms extensive grassbeds on the sandy shoals. A filamentous green alga, Enteromorpha, can also on occasion form large masses on the north inner slope.

Unlike high volcanic islands, where brown algae are the most abundant species, atoll floras are usually dominated by green and red algae. At Mataiva, the green algae are the most abundant and diversified (22 species), particularly the genera Caulerpa and Halimeda. One of them, Halimeda (opuntia group) is strongly developed on Mataiva, an unusual situation for an atoll lagoon. Among the Rhodophyceae, the crustose algae are more numerous in the lagoon and on the outer reef; however, gelidial turfs are well developed on the lagoon's dead corals and on the outer reef's flagstone. Cyanophyceae make up the 3rd class in the algal complement; if the usual extensive blue-green formations of atoll lagoon bottoms are not found in Mataiva, these algae do however form a discrete felt on dead corals and on Halophila leaves; their development is also important on beach edges, where they form an algal mat at times very thick, and in the brackish ponds of the atoll rim.

The distribution of algae in the lagoon is fairly homogeneous. Few species are present simultaneously. The specific diversity and abundance increase considerably near the zones of water exchange with the ocean (hoa and pass). On the outer reef flat, the eroded flagstone is covered with Gelidiales turf, while the brown alga Pocockiella variegata is dominant on its outer zone. Near the reef front, soft algae common to this zone (Microdyction, Dyctiosphaeria cavernosa, Neomeris van bosse) appear, as well as crustose corallinaceae, Porolithon onkodes, Chevalierícrusta sp. But they never form an algal ridge typical of the reef front of an atoll, and their mass always remain poorly developed.

Thus, Mataiva's marine flora is that of a closed environment, with few species, some of which are abundant. It is homogeneous and gradually changes near the ocean exchange zones. Although not a rich flora, its vitality is demonstrated by the presence of numerous young shoots. The existence of large Halophila grassbeds and the unusual development of Halimeda (opuntia group) remain the distinctive characteristics of this flora.

MATAIVA LAGOON FAUNA

Zooplankton

The zooplankton of Mataiva atoll is mainly composed of typical, lagoonal holoplanktonic species where 6 species of Copepods, 2 species of Chaetognaths, 1 Appendicularia, 1 Ostracod and 1 Decapod Sergestid are dominant. Surprisingly, the meroplankton is extremely rare, 5% of the total plankton, whereas its true contribution is usually 35-65%. This meroplankton is made up of crustacean larvae (Stomatopods, Decapod Reptantia and Natantia), fish eggs and larvae, and Foraminifera. In other respects, while all of the Mataiva zooplankton species are recorded from other atolls, the absence of groups occurring in atolls open to the ocean, e.g. Pteropods, Salps, Doliolids and some Copepods, is noteworthy.

The zooplankton biomass is much higher than in the nearby ocean: 300-500 mg/m^{-3} in the lagoon, 10-18 mg m^{-3} in the ocean.

The distribution of this biomass is very heterogeneous. Horizontally, the western and southern sectors of the atoll are about 3 times richer than the eastern and northern areas. Vertically, a very marked diurnal stratification exists between the surface (80 mg m^{-3}) and the bottom (2 000 mg m^{-3}) of the lagoon. This phenomenon has been observed in other atolls: Rangiroa (Michel, 1971), Mururoa (Michel, 1969), Takapoto (Renon, 1977), Bikini (Johnson, 1949).

The ocean-lagoon exchanges through the hoa and the pass are very important: entry of reef plankton, mainly meroplankton, and outpouring of lagoon plankton through the pass, in quantity about 35 times higher than what enters the lagoon. The lagoon thus constitutes an extremely productive environment, greatly enriching the nearby ocean.

The abundance and composition of Mataiva's zooplankton are somewhat unusual:

Firstly, its biomass is on the average 2 to 3 times greater than in other Polynesian atoll lagoons : 300 to 500 mg m^{-3} at Mataiva, 50 to 150 mg m^{-3} at Moruroa (Renon, unpubl.), 47 to 61 mg m^{-3} at Takapoto (Renon, 1977). The confinement of waters only partially explains this phenomenon, since Takapoto, a closed atoll, is poorer in zooplankton.

Secondly, the scarcity of meroplanktonic forms characteristic of Mataiva's zooplankton might be related to the depauperate benthic fauna, hence to lighter grazing and may account in part for a rich biomass.

Finally, the nutritional basis of zooplankton populations remains difficult to define. The phytoplankton biomasses are not in equilibrium ith the zooplankton abundance, although the turnover rate of phytoplankton appears very high; however, the seston particles, which support bacterial development, may be directly used by the zooplankton.

Corals

As is often the case in closed atoll lagoons (Chevalier et Denizot,1979), the specific diversity of Mataiva lagoon corals is especially low. Only 28 species have been recorded in the lagoon (Table C). The areas of maximum diversity (12-14 spp.) have been found at stations on the N and S coasts of the atoll. This relative variety is related to hydrodynamic conditions, due to the nearness of the hoa and the general flow of the water across the northern and southern edges of the lagoon. In fact, only those stations removed from the hoa and the pass have a low population.

The cover rate by scleractinians is generally very poor. The colonies are mainly located on the tops of the lagoon partitions, along the edges of the pools. Porites lobata, forming microatolls on the shoals, and Acropora tortuosa, more generally covering the pool sides, are the 2 most commonly reported species. Other species, Montipora aequituberculata and Leptastrea purpurea, are widely distributed, but form a poor cover because of the smallness of their colonies.

The coral fauna's vitality seems to be very poor and dead colonies are numerous. The percentage of living corals, which is almost 30% near the hoa but tapers to 0 in the eastern part of the atoll, is directly connected with hydrodynamic conditions. However, the size of the dead colonies of Porites and Acropora indicates an accidental origin for this condition. The combination of several environmental factors, such as a low water level along with much rain or intense sunshine, is likely to induce, in certain parts of the lagoon, hydrological conditions incompatible with coral survival, thus causing massive death.

The inhabitants of the atoll reported the occurrence of such an event in November 1978, repeated in November 1980: water level at 52 cm, extremely strong sunlight and water temperatures close to 32°C for 10 days. The lagoon waters turned green-brown in certain parts and produced a nauseating odour. In May 1981, the live coral cover was low throughout the lagoon, exceeding 10% only near the hoa. Other measurements taken in October 1983 show a considerable increase in live cover. Such a situation is only possible as a result of oceanic inflows, allowing recruitment of larvae and a return to conditions favouring the growth of the surviving species.

The outer reef coral fauna is much more diversified than that in the lagoon (Figure 10). These colonies are often small or very encrusting. The eroded reef flat flagstone is little colonised by corals which mainly develop near the reef front. Acropora and Pocillopora are the 2 best represented genera.

Molluscs

The malacological fauna of Mataiva, with 222 species recorded (Table D), is very unequally distributed between the lagoon and the outer reef.

On the outer reef, 169 species (156 gastropods and 13 bivalves) have been recorded. This fauna is fairly similar to those of other Tuamotu outer reefs. Nerita plicata, Nodolittorina leucosticta and Littorinea

coccinea occupy the upper zone, where the scarcity of Tectarius grandinatus is rather surprising. The reef flat flagstone harbours nearly 30 species of which a large majority belongs to a carnivorous epifauna (Vasum, Conus, etc.). A wide variety of forms can be collected, although none is abundant except Cypraea moneta. The fauna of the forereef is dominated by Turbo setosus, actively exploited by the atoll's inhabitants. Live Drupa morum and Cypraea caput-serpentis are abundant there as well as numerous shells coming from the outer slope, evidence of its richness.

In the lagoon, 77 species have been collected: 55 gastropods and 22 bivalves. The species distribution is very uneven: the richest fauna occurs near the hoa in the S of the atoll. Here, the more abundant species belong to the epifauna (Cypraeidae, Buccinidae): up to 20 Cyprea obvelata per m^2 under coral blocks; on the sandy shoals, Cypraea moneta is the only macromollusc found. One boring species, Lithophaga cinnamomina, inhabits the Porites colonies, at the rate of several dozen individuals per dm^2 of the living surface. There is also a difference between the windward and leeward coasts of the same reef: Arca ventricosa, Pinctada margaritifera and Tridacna maxima are more abundant on the leeward side.

Moving away from the S of the atoll, there is a considerable decline in the malacological fauna. The sandy shoals are occupied by a few Cardium fragrum beds. A small oyster, Crassostrea cucculata, is particularly abundant on the branches of dead Acropora. The endofauna of bottom sediments is also unusual, consisting of many species unknown elsewhere in French Polynesia.

Along the lagoon and motu edges, the malacological fauna shows little diversity, only 3 species being found there. The absence of the Nasses, Mitres, Cones and Terebres usually found in this zone is surprising.

On the littoral fringe of the motu, 3 species appear in succession: Littorina coccinea, Nerita plicata and Clypeomorus brevis, whilst the Cerithidae and Cypraeidae usually present in the upper levels are absent. In the same way, the hoa contain an impoverished homogeneous mollusc fauna (8 species) which is characteristic of semifunctional hoa (functioning intermittenty).

Mataiva's malacological fauna, which includes about 1/5 of the species recorded in French Polynesia (Richard, 1982), appears to be, on the whole, fairly rich. However, the lagoon fauna is, on the whole, poor, especially away from the zones under oceanic influence. Only a few species (Lithophaga cinnamomina, Crassostrea cucculata) are really very abundant. However, this malacological fauna is unusual because of the uncommon species found in the sediments and on the reef flats and the wide heterogeneity of the populations.

Crustacean fauna

The crustacean fauna of Mataiva atoll includes about 100 species (Monteforte, 1984). Most studies have been carried out on crabs,

especially coral-associated species, and on mud-shrimps, which are very numerous on the sandy shoals.

Crustacea inhabit all environments in Mataiva. Land crabs (Cardisoma carnifex) are plentiful in the coconut groves, as are hermit crabs Coenobita perlatus. The coconut crab Birgus latro, on the contrary, is rare (probably because of over-collecting).

The sandy environments of the lagoon are densely occupied by the mud-shrimps Callichirus armatus living in permanent burrows. Densities up to 3 mud-shrimps per square metre were observed on the muddy bottoms of the basins; they are lower in the shallow waters (0.5 to 1 ind./m^2). For the whole lagoon, the estimated population of C. armatus ranges from 2.38 to 4.76 10^7 individuals, i.e. a biomass of 285 to 571 tons wet weight (100 to 200 kg per hectare). Callichirus armatus is a great sediment reworker, feeding on the mud which falls into its gallery, and generating considerable disturbance. It has been estimated that the upper centimetre of mataiva's bottom sediment passes through the mud-shrimps' burrows 4 to 9 times per year. Living also in a burrow, the stomatopod Lysiosquilla maculata ("varo") is common and much prized because of its tasty flesh. A crab Calappa hepatica inhabits these sandy surfaces, being well adapted to this biotope. The hard substrates in the lagoon, and especially Porites microatolls, shelter a reduced fauna, dominated by 2 Xanthidae, Chlorodiella nigra and Phymodius ungulatus, and 1 Portunidae, Thalamita admete, more numerous near the hoa.

The transition zones (hoa and pass) and the outer reef flats harbour a much more abundant and diversified population than does the lagoon. The hoa and the pass contain many species of the outer reef flat, which occasionally enter the lagoon: Chlorodiell cytherea, Liomera bella, Pilodius pugil. One also finds many juveniles of outer reef species: Etisus laevimanus, Thalamita and Leptodius. The Grapsidae and Paguridae are dominant in the slightly sumserged zones.

On the outer reef flats, the fauna is equally abundant and diversified, particularly on the reef front (Table E). Many species, such as the crayfish, Palunirus penicillatus, climb the outer slope at night and are found on the crest. The exposure of the reef flat modifies the crustacean fauna and its distribution; thus, Plagusia speciosa is abundant on the whole exposed reef flat but less commonly found on sheltered reefs and there limited to the reef front.

On these outer reefs, the presence of living corals induces the existence of a well developed symbiotic fauna. This constitutes up to 80% of the individuals associated with a living coral. The Xanthidae among the Brachyoura and the Alpheidae among the Natantia, are most abundant. In particular, crabs of the genus Trapezia (T. speciosa, T. bella and T. formosa) restricted to the coral Pocillopora, are particularly numerous in the frontal zones.

Other marine invertebrates

At present, only the major invertebrate groups have been studied. However, some interesting observations on other groups may be cited.

.The sponges are abundant in the lagoon under the empty Tridacna shells or covering the dead Acropora branches. Many species with brightish colours are present, but the colonies are usually small, except for one black species, sometimes over 20 cm high, which is found in the lagoon and on the outer reef slope.

The echinoderms include few species but some of them are very abundant. Such is the case, in the lagoon, of the black sea-cucumber, Halodeima atra, with densities reaching 1 or 2 individuals per m^{-2}. This species is known to prefer more or less confined environments (Salvat, 1975; Salvat et al.,1979). Another sea cucumber, Cucumaria sp., is often found near the hoa under empty Tridacna shells.

On the outer reef, one may find two other Holothurians, the thin, long Synaptes near the beach, and the rounded, white spotted Bohadschia argus on the reef flat flagstone. But urchins are more abundant there. Echinometra mathaei is present in the reef flat cavities; near the reef front, the pencil urchin Heterocentrotus mamillatus is often found at the base of the spurs, while the helmet urchin, Colobocentrotus pedifer, whose morphology is well adapted to resist wave action, is more abundant on the upper part of the spurs, especially the relict algal ridge of the swell-exposed southern reef fronts.

Ascidians form very discrete colonies and are not well known in French Polynesia. However, symbiotic ascidians, associated with green algae (Prochloron), are present in Mataiva lagoon on the dead Acropora branches, and at the base of the spurs on the outer reef.

Fishes

The ichthyological fauna of Mataiva lagoon is poor, not only in number of species, but also in number of individuals. Of the 115 species recorded (Table F), only 10 seem well established in the lagoon and are in evidence at practically all the stations. These are usually small individuals belonging to the Gobiidae (Amblygobius phalaena, A. nocturnus), the Pomacentridae (Chromis coerulea), the Chaetodontidae (Chaetodon auriga, C. ephippium), or juveniles of Mullidae and Scaridae (Scarus sordidus, Scarus sp.). Some species, common to the lagoons of more or less closed atolls, are not found in Mataiva: Arothron hispidus, Chromis dimidiatus.

Near the hoa and the pass, the number of species reported increases considerably (40-52 species). Generally, there is much heterogeneity in the distribution and abundance of the fish populations of Mataiva lagoon. More detailed studies (Bell and Galzin 1984, Galzin 1985), carried out in 1981 and 1983, have demonstrated the close relation existing between the abundance and diversity of the fish fauna (total number of species, number of species 250 m^{-2}, number of individuals 250 m^{-2}) and the live coral cover. Changes in live coral cover, estimated to be as small as 0 to < 2% and < 2 to 2 to < 5%, produced significant increases in the total number of species and the number of individuals 250 m^{-2}. On the other hand, the reef complexity, which is the same for dead and living coral colonies, is without any influence on fish populations.

In the pass and on the outer reef flats, the ichthyological fauna is much richer and made up of numerous species from the outside but which do not pass into the lagoon, such as triggler fishes (Balistoides undulatus, Pseudobalistes falvomarginatus, jacks (Caranx trifasciatus),emperors (Lethrinus mahsena), goatfishes (Mugil angeli, M. vaigiensis).

On the outer slopes, the fish population is dominated by the Acanthuridae family, mainly Naso and Acanthurus. Pomacentridae, Serranidae, Lutjanidae and Chaetodontidae are equally abundant. The specific richness is at its maximum between 10 and 20 m (70 species), whereas the maximum abundance is found between 3 and 10 m. The effect of the 1983 cyclones on the outer reefs, causing massive coral destruction, has brought about a slight decrease of the herbivorous populations, but, above all, a redistribution of certain species and a much higher density in the upper levels of 3 to 10 m.

CONCLUSIONS

Mataiva atoll has a singular morphology whose major characteristic is the partitioning of the lagoon into numerous pools. This is due to its peculiar geological history, during which several periods of uplift and subsidence occurred. During the periods of emergence, erosion processes resulted in the formation of a karstic relief, in the cavities of which phosphate deposits accumulated.

The present morphology, moulded onto the former one, has, as a consequence, created particular hydrological conditions in the lagoon: very high turbidity, considerable variations in water level, high nutrient concentrations.

The biological communities of the lagoon show the characteristics of a closed environment: few species are present, but some are very abundant. Mataiva stands out among atolls because of its high level of primary production, abundant zooplankton and a fairly poor, but very uneven distributed, benthic macrofauna. This latter, subject to strong variations in hydrological conditions, can suffer enormous mortality levels, affecting especially the corals. However, the evolution observed since 1981 seems to indicate that this is an accidental phenomenon and that the lagoon's biological communities retain the capability to survive and grow under difficult conditions.

Future research on Mataiva atoll must take into account the wide range of variation in the distribution and abundance of its lagoonal populations. This fact seems to be closely related to the hydrological environment and its long-term variations. Such research will mainly concern the hydrology, the primary producers and a quantitative evaluation of the benthic and ichthyological fauna.

Although Mataiva seems to be a very special atoll whose characteristics cannot be used as a model for the other Tuamotu atolls, it is a very interesting experimental field for some ecological studies, e.g. the relationship between live coral cover and reef fish populations. A fish survey, similar to those made in 1981 and 1983, is already planned for mid-1985, to follow the changes in the fish communities, as the corals recover from almost complete destruction in 1980.

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Table A : Distribution of the phytoplanktonic species in the different sectors of the lagoon.

	East	North	Pass	Hoa	Center
DIATOMOPHYCEAE					
Achnanthes sp.			x		
Actinoptychus undulatus		x		x	x
Amphiprora alata		x	x	x	
Amphora bigibba		x	x		x
Amphora exsecta	x	x	x	x	
Amphora obtusa		x			
Amphora ostrearia		x	x		
Amphora robusta			x		
Amphora sp.		x	x	x	x
Asterionella kariana				x	
Asterolampra marylandica					x
Biddulphia sp.					x
Caloneis liber		x			
Caloneis sp.		x	x		
Campylodiscus innominatus		x	x	x	
Chaetoceros sp.					x
Climacosphenia moniligera	x			x	x
Cocconeis sp.		x			x
C. placentula var.euglypta	x				
Coscinodiscus cf eccentricus	x			x	x
Coscinodiscus radiatus				x	
Cyclotella menneghinianna		x			
Diploneis bombus			x		
Hemidiscus cuneiformis		x		x	
Grammatophora marina			x		
Gyrosigma corallinum	x				
Gyrosigma sp.		x	x		
Lycmophora Ehrenbergii		x	x	x	
Mastogloia affirmata	x				
Mastogloia binotata	x		x	x	x
Mastogloia corsicana		x	x		
Mastogloia decussata		x			
Mastogloia erythrea		x	x		
Mastogloia fimbriata		x	x		x
Mastogloia horvathiana	x	x	x		
Mastogloia occulata		x			x
Mastogloia ovata				x	
Mastogloia ovulum	x	x	x		
Mastogloia cf pseudoparadoxa		x			
Mastogloia splendida		x			
Mastogloia cf tenuis		x			
Mastogloia sp.			x		
Navicula exigua				x	
Navicula granulata		x			
Navicula longa			x		
Navicula lyra		x	x		

	East	North	Pass	Hoa	Center
Navicula cf menisculus		x	x		
Navicula perobesa	x		x	x	
Navicula sp.			x	x	
Nitzschia acuta	x	x		x	
Nitzschia closterium		x	x	x	x
Nitzschia distans		x			
Nitzschia longissima		x	x	x	x
N. punctata var coarctata			x		x
Nitzschia sigma			x		
Nitzschia seriata				x	
Nitzschia ventricosa		x			
Nitzschia sp.		x			x
Plagiogramma atomus				x	
Pleurosigma sp.		x		x	
Podocystis spathulata	x	x	x	x	x
Rhabdonema adriaticum		x			
Rhizosolenia sp.			x	x	
Stauroneis salina	x		x		
Surirella fastuosa	x	x		x	
Surirella reniformis	x	x			
Surirella sp.	x				
Synedra ulna			x	x	x
Synedra undulata	x	x			x
Thalassiosira sp.					x
Trachyneis sp.				x	
Triceratium shadboltianum				x	
Tropidoneis lepidoptera	x	x	x	x	
DINOPHYCEAE					
Ceratium pentagonum				x	
Dinophysis sp.					x
Exuviella sp.			x	x	
Gonyaulax spinifera		x			x
Gymnodinium splendens					x
Gymnodinium sp.	x	x	x	x	x
Oxytoxum sp.		x	x		
Ornithocercus quadratus				x	
Oxytoxum sp.					x
Prorocentrum sp.			x		
Protoperidinium sp.		x	x		
CHLOROPHYCEAE					
Carteria sp.	x	x	x	x	
Chlamydomonas sp.	x	x			
Nephroselmis sp.		x	x		
Pyramimonas sp.	x	x	x	x	x
CYANOPHYCEAE					
Oscillatoria sp.	x	x	x		
Pseudanabaena sp.			x	x	
Spirulina sp.		x	x	x	
CRYPTOPHYCEAE	x	x			x
COCCOLITHOPHORACEAE	x			x	x

Table B: Distribution of the main algal species in the lagoon and the outer reef.

	Outer Reef	Lagoon				
		Hoa	Pass	East	North	Center
CYANOPHYCEAE						
Calothrix sp.		x	x	x		x
Hassalia byssoides	x	x				
Lyngbia majuscula			x			
CHRYSOPHYCEAE						
Chrysonephros sp.		x	x			x
PHEOPHYCEAE						
Dictyota sp.			x			
Lobophora variegata	x		x			
Sphacelaria furcigera		x				x
Sph. tribuloides		x				
Turbinaria ornata	x					
CHLOROPHYCEAE						
Acetabularia moebii			x			
Avrainvillea lacerata	x	x	x	x	x	x
Boodlea sp.		x	x			
Bryopsis sp.		x	x			
Caulerpa peltata		x	x			x
Caulerpa racemosa	x		x			
Caulerpa serrulata	x	x	x		x	x
Caulerpa sp.	x			x		x
Codium adherens		x				
Dictyosphaeria sp.	x	x	x	x	x	
Enteromorpha sp.		x	x			
Halimeda discoidea	x					
Halimeda opuntia	x	x	x	x	x	x
Microdictyon sp.	x	x				
Neomeris sp.	x					
Struvea elegans			x			
Trichosolen sp.		x				
RHODOPHYCEAE						
Centroceras clavulatum		x	x			
Ceramium tenerrimum		x	x			
Ceramium sp.		x	x			
Chevaliericrusta sp.	x					
Gelidium crinale	x	x	x		x	
Gelidium pusillum	x	x	x			
Herposiphonia secunda		x	x	x	x	
Hypnea sp.		x	x			
Jania sp.	x	x	x			
Liagora decussata	x					
Porolithon onkodes	x					
Porolithon craspedium	x					
Polysiphonia sp.		x	x		x	
Pterocladia media	x	x			x	

	OUTER REEF	PASS	LAGOON NORTH (J)	LAGOON SOUTH (B) (L)	LAGOON CENTER (G)	LAGOON EAST (C)
PSAMMOCORA CONTIGUA	+	+		+	+	
PSAMMOCORA SUPERFICIALIS	+					
POCILLOPORA DAMICORNIS	+					
POCILLOPORA EYDOUXI	+					
POCILLOPORA VERRUCOSA	+	+			+	
ASTREOPORA MYRIOPHTHALMA	+		+			
MONTIPORA AEQUITUBERCULATA			+	+		
MONTIPORA COMPOSITA	+		+	+		
MONTIPORA EDWARDSI				+		
MONTIPORA INFORMIS	+					
MONTIPORA TUBERCULOSA	+	+		+		
MONTIPORA TURGESCENS				+		
MONTIPORA VERRUCOSA			+	+		
ACROPORA DANAI	+					
ACROPORA HUMILIS	+		+			
ACROPORA LATISTELLA			+			
ACROPORA ROBUSTA	+					
ACROPORA TORTUOSA				+	+°	+°
ACROPORA VALIDA			+	+		
PAVONA MINUTA	+					
PACHYSERIS SPECIOSA	+					
FUNGIA FUNGITES	+					
PORITES (SYNARAEA) CONVEXA			+		+	
PORITES (NAPOPORA) IRREGULARIS	+				+	
PORITES LICHEN	+					
PORITES LOBATA	+	+	+	+	+	+	+
PORITES CF SOLIDA			+			
FAVIA PALLIDA			+			+
FAVIA ROTUMANA	+				+	
FAVIA STELLIGERA	+					
LEPTASTREA PURPUREA	+	+	+	+	+	+	+
LEPTASTREA TRANSVERSA					+		
CYPHASTREA SERAILA			+		+	+	+
PLATYGYRA DAEDALEA			+	+	+		
MONTASTREA CURTA	+					
ACANTHASTREA ECHINATA			+		+		
LOBOPHYLLIA CORYMBOSA	+					

° Dead Colonies

Table C : Distribution of the main species of Scleractinians on the outer reef and in the lagoon.

Table D: List of Molluscs catalogued in the lagoon and on the outer reef

CLASS GASTROPODA

SUB-CLASS PROSOBRANCHIA

Order Archaeogastropoda

HALIOTIDAE

Haliotis pulcherrima Gmelin, 1791

PATELLIDAE

Patella flexuosa Quoy & Gaimard, 1834

STOMATELLIDAE

Stomatella sanguinea (Adams, 1850)

Stomatella varia (Adams, 1850)

TURBINIDAE

Turbo argyrostomus Linné, 1758

Turbo petholatus Linné, 1758

Turbo setosus Gmelin, 1791

NERITIDAE

Clithon chlorostoma (Broderip, 1832)

Nerita plicata Linné, 1758

Puperita reticulata (Sowerby, 1832)

Order Mesogastropoda

NEOCYCLOTIDAE

Amphicyclotus sp.

LITTORINIDAE

Littorinea coccinea (Gmelin, 1791)

Nodilittorina leucosticta (Reeve, 1857)

Tectarius grandinatus (Gmelin, 1791)

TRUNCATELLIDAE

Truncatella sp.

VERMETIDAE

Dendropoma maximum (Sowerby, 1825)

Serpulorbis sp.

PLANAXIDAE

Planaxis lineatus (Da Costa, 1776)

MODULIDAE

Modulus tectum (Gmelin, 1791)

CERITHIDAE

Bittium cf. glareosum (Gould, 1861)

Bittium zebrum (Kiener, 1841)

Cerithium atromarginatum Dautzenberg & Bouge, 1933

Cerithium columna Sowerby, 1834

Cerithium mutatum Sowerby, 1834

Cerithium nesioticum Pilsbry & Vanatta, 1906

Cerithium rostratum Sowerby, 1855

Cerithium salebrosum Sowerby, 1855

Clypeomorus brevis Quoy & Gaimard, 1834

Clypeomorus moniliferus (Kiener, 1841)

Rhinoclavis diadema Houbrick, 1878

Rhinoclavis sinensis (Gmelin, 1791)

EULIMIDAE
- Eulima sp.

STROMBIDAE
- Strombus dentatus Linné, 1758
- Strombus gibberulus Linné, 1758
- Strombus maculatus Sowerby, 1842
- Strombus mutabilis Swainson, 1821

CALYPTRAEIDAE
- Cheila equestris (Linné, 1758)

TRIVIIDAE
- Trivia sp.

CYPRAEIDAE
- Cypraea caputserpentis Linné, 1758
- Cypraea carneola var. propinqua Garrett, 1879
- Cypraea cumingii Sowerby, 1832
- Cypraea depressa Gray, 1824
- Cypraea dillwyni Schilder, 1922
- Cypraea erosa Linné, 1758
- Cypraea fimbriata Gmelin, 1791
- Cypraea goodalli Sowerby, 1832
- Cypraea helvola Linné, 1758
- Cypraea irrorata Gray, 1828
- Cypraea isabella Linné, 1758
- Cypraea leviathan Schilder & Schilder, 1937
- Cypraea maculifera (Schilder, 1932)
- Cypraea margarita Dillwyn, 1817
- Cypraea minoridens Melvill, 1901
- Cypraea moneta Linné, 1758
- Cypraea nucleus Linné, 1758
- Cypraea obvelata Lamarck, 1810
- Cypraea poraria Linné, 1758
- Cypraea schilderorum (Iredale, 1939)
- Cypraea scurra Gmelin, 1791
- Cypraea serrulifera Schilder & Schilder, 1938
- Cypraea subteres Weinkauff, 1880
- Cypraea talpa Linné, 1758
- Cypraea tigris Linné, 1758
- Cypraea ventriculus Lamarck, 1810

NATICIDAE
- Natica galteriana Recluz, 1844
- Polinices melanostoma (Gmelin, 1791)

CYMATIDAE
- Cymatium gemmatum (Reeve, 1844)
- Cymatium hepaticum (Röding, 1798)
- Cymatium muricinum (Röding, 1798)
- Cymatium nicobaricum (Roding, 1798)
- Cymatium rubeculum (Linné, 1758)
- Distortio anus (Linné, 1767)
- Gyrineum roseum (Reeve, 1844)

BURSIDAE
- Bursa bufonia (Gmelin, 1791)
- Bursa granularis (Röding, 1798)

COLUBRARIIDAE
- Colubraria nitidula (Sowerby, 1833)
- Colubraria tortuosa (Reeve, 1844)
- Colubraria sp.

Order Neogastropoda

MURICIDAE
- Drupa clathrata (Lamarck, 1816)
- Drupa grossularia Röding, 1798
- Drupa morum (Röding, 1798)
- Drupa ricinus (Linné, 1758)
- Drupa speciosa (Dunker, 1867)
- Drupella cornus (Roding, 1798)
- Drupella fenestrata (Blainville, 1832)
- Drupella ochrostoma (Balinville, 1832)
- Homalocantha martinetana (Roding, 1798)
- Maculotriton serriale (Deshayes, 1834)
- Mancinella tuberosa (Roding, 1798)
- Morula granulata (Duclos, 1832)
- Morula margariticola (Broderip, 1832)
- Morula uva (Röding, 1798)
- Nassa francolinus (Bruguière, 1789)
- Pterinotus loebbeckei (Kobelt, 1879)
- Thaïs aculeatus (Deshayes & Milne-Edwards, 1844)
- Thaïs armigera (Link, 1807)

CORALLIOPHILIDAE
- Coralliophila cf. porphyroleuca (Crosse 1870)
- Coralliophila violacea (Kiener, 1836)
- Leptochoncus lamarcki Deshayes, 1863
- Quoyula madreporarum (Sowerby, 1832)

BUCCINIDAE
- Cantharus fumosus (Dillwyn, 1817)
- Cantharus spica (Melvill & Standen, 1895)
- Cantharus undosus (Linné, 1758)
- Engina incarnata (Deshayes, 1834)
- Engina sp.
- Pisania decollata (Sowerby, 1833)
- Pisania ignea (Gmelin, 1791)
- Pisania iostoma (Gray, 1834)
- Pisania truncata (Hinds, 1844)

COLLUMBELLIDAE
- Mitrella sp.
- Pyrene flava (Bruguière, 1789)
- Pyrene scripta (Lamarck, 1822)

NASSARIIDAE
- Nassarius gaudiosus (Hinds, 1844)
- Nassarius cf. pauperus (Gould, 1850)

FASCIOLARIIDAE
- Latirus sanguifluus (Reeve, 1847)
- Latirus sp.
- Peristernia chlorostoma (Sowerby, 1825)
- Peristernia nassatula (Lamarck, 1822)
- Peristernia sp.

VASIDAE
- Vasum ceramicum (Linné, 1758)

HARPIDAE
- Harpa gracilis Broderip & Sowerby, 1829

MITRIDAE
- Imbricaria punctata (Swainson, 1821)
- Mitra assimilis Pease, 1868
- Mitra coffea Schubert & Wagner, 1829
- Mitra columbelliformis Kiener, 1838
- Mitra cucumerina Lamarck, 1811
- Mitra fastigium Reeve, 1845
- Mitra ferruginea Lamarck, 1811
- Mitra litterata Lamarck, 1811
- Mitra paupercula (Linné, 1758)
- Mitra pellisserpentis Reeve, 1844
- Mitra stictica (Link, 1807)

COSTELLARIIDAE
- Thala mirifica (Reeve, 1845)
- Thala sp.
- Vexillum cadaverosum (Reeve, 1844)
- Vexillum crocatum (Lamarck, 1811)
- Vexillum cumingii (Reeve, 1844)
- Vexillum speciosum (Reeve, 1844)

TURRIDAE
- Clavus formosus (Reeve, 1847)
- Daphnella sp.
- Lienardia rubida (Hinds, 1844)
- Lienardia cf roseotincta (Montrouzier, 1872)
- Xenuroturris cingulifera (Reeve, 1847)

CONIDAE
- Conus auratinus Da Motta, 1982
- Conus auricomus Hwass in Bruguière, 1792
- Conus catus Hwass in Bruguière, 1792
- Conus chaldaeus (Röding, 1798)
- Conus cylindraceus Broderip & Sowerby, 1830
- Conus distans Hwass in Bruguière, 1792
- Conus ebraeus (Linné, 1758)
- Conus flavidus Lamarck, 1810
- Conus geographus Linné, 1758
- Conus legatus Lamarck, 1810
- Conus lividus Hwass in Bruguière, 1792
- Conus magnificus Reeve, 1843
- Conus miles Linné, 1758
- Conus miliaris Hwass in Bruguière, 1792
- Conus pertusus Hwass in Bruguière, 1792

Conus pulicarius Hwass in Bruguière, 1792
Conus rattus Hwass in Bruguière, 1792
Conus retifer Menke, 1829
Conus scabriusculus Dillwyn, 1817
Conus sponsalis Hwass in Bruguière, 1792
Conus tenuistriatus Sowerby, 1858
Conus textilinus Kiener, 1845
Conus tulipa Linné, 1758
Conus vexillum Gmelin, 1791

TEREBRIDAE
Terebra crenulata (Linné, 1758)
Terebra guttata (Roding, 1798)

Order Heterogastropoda

ARCHITECTONICIDAE
Heliachus infundibuliformis (Gmelin, 1791)

EPITONIIDAE
Epitonium sp.

JANTHINIDAE
Janthina ianthina (Linné, 1758)

TRIPHORIDAE
Triphora sp.

SUB-CLASS OPISTHOBRANCHIA

Order Entomotaeniata

PYRAMIDELLIDAE
Pyramidella sp.

Order Cephalaspidea

ACTEONIDAE
Pupa solidula (Linné, 1758)

HYDATINIDAE
Hydatina amplustre (Linné, 1758)

ATYIDAE
Atys sp.

SUB-CLASS PULMONATA

Order Basommatophora

ELOBIIDAE
Melampus sp.

CLASS BIVALVIA

Order Arcoida

ARCIDAE
Arca imbricata Bruguière, 1789
Arca ventricosa Lamarck, 1819

Order Mytiloida

MYTILIDAE
Lithophaga cinnamomina (Chemnitz, 1785)
Modiolus auriculatus Krauss, 1848

PINNIDAE
Pinna muricata Linné, 1758

PTERIIDAE
Pinctada maculata (Gould, 1850)
Pinctada margaritifera (Linné, 1758)

ISOGNOMONIDAE
Isognomon sp.
PECTINIDAE
Chlamys inaequivalvis (Sowerby, 1842)
Chlamys sp.
OSTREIDAE
Crassostrea cucullata (Born, 1778)

Order Hippuritoida

CHAMIDAE
Chama iostoma Conrad, 1837
Chama pacifica Broderip, 1834

Order Veneroida

LUCINIDAE
Anodontia edentula (Linné, 1758)
Codakia puncata (Linné, 1758)
Codakia divergens (Philippi, 1850)
CARDIIDAE
Corculum fragum (Linné, 1758)
TRIDACNIDAE
Tridacna maxima (Röding, 1798)
TELLINIDAE
Arcopagia robusta (Hanley, 1844)
Quidnipagus palatam Iredale, 1929
Scutarcopagia scobinata (Linné, 1758)
Tellina donaciformis Deshayes, 1854
Tellina obliquaria Deshayes, 1854
PSAMMOBIIDAE
Asaphis violaceus (Forskål, 1775)
TRAPEZIIDAE
Trapezium oblongum (Linné, 1758)
VENERIDAE
Gafrarium pectinatum (Linné, 1758)
Pitar prora (Conrad, 1837)

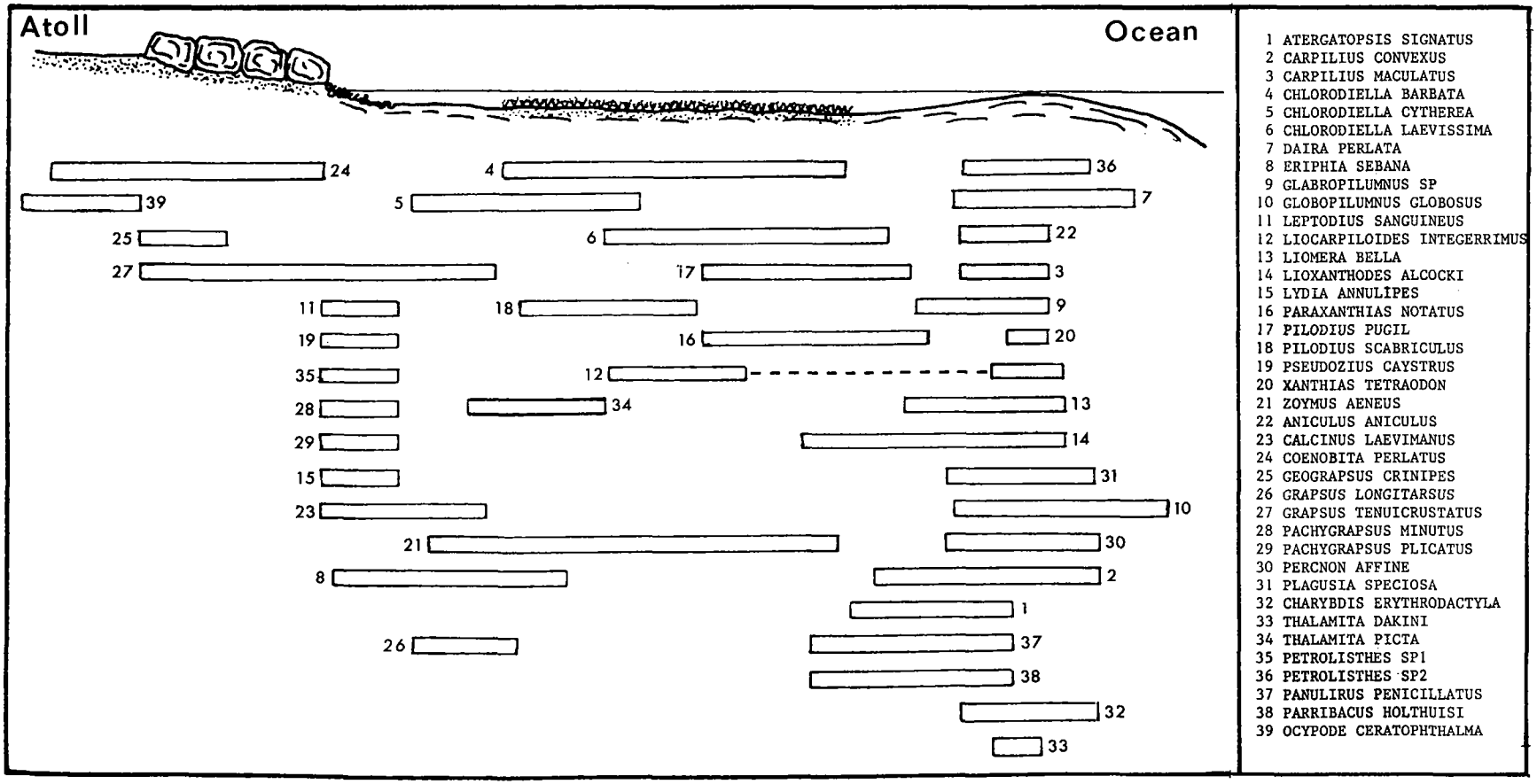


Table E : Repartition of the crustacean fauna on the sheltered outer reef.

Table F: List of fishes catalogued in Mataiva Lagoon (L) and the nearby ocean (O).

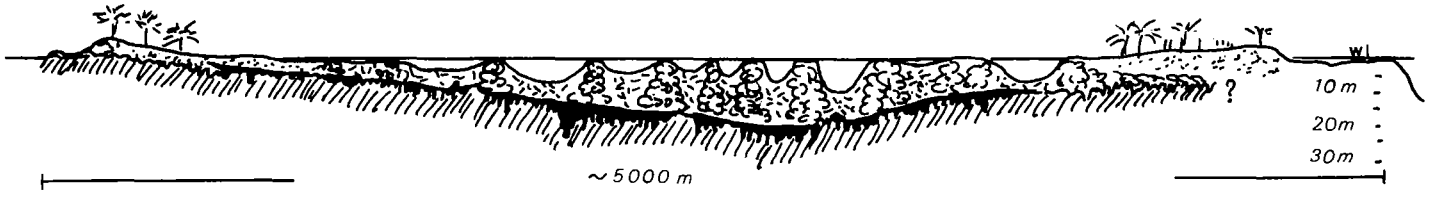
CLASS CHONDRICHTHYES	
Order Carcharhiniformes	
CARCHARHINIDAE	
Carcharhinus melanopterus (Quoy et Gaimard,1824)	L O
Order Rajiformes	
MYLIOBATIDAE	
Aetobatis narinari (Euphrasen,1790)	L
CLASS OSTEICHTHYES	
Order Anguilliformes	
MURAENIDAE	
Echidna nebulosa (Ahl,1789)	L
Gymnothorax javanicus (Bleeker,1859)	L O
Gymnothorax meleagris (Shaw et Nadder,1795)	L
Order Aulopiformes	
SYNODONTIDAE	
Saurida gracilis (Quoy et Gaimard,1824)	L
Order Gadiformes	
OPHIDIIDAE	
Dinematichthys sp.	L
Order Atheriniformes	
HEMIRHAMPHIDAE	
Hyporhampus acutus (Günther,1871)	L
BELONIDAE	
Tylosurus crocodilus (Lesueur,1821)	L
Order Berycyformes	
HOLOCENTRIDAE	
Myripristis kuntee Cuvier,1831	L
Myripristis murdjan (Forsskål,1775)	L
Myripristis sp.417	L
Neoniphon argenteus Bleeker,1849	L
Neoniphon opercularis Valenciennes,1831	L
Neoniphon sammara (Forsskål,1775)	L
Sargocentron caudimaculatum (Rüppell,1826)	O
Sargocentron microstoma Günther,1859	L
Order Syngnathiformes	
FISTULARIIDAE	
Fistularia commersonii Rüppell,1838	L
Order Scorpaeniformes	
SCORPAENIDAE	
Scorpaenodes guamensis (Quoy et Gaimard,1824)	L
Order Perciformes	
SERRANIDAE	
Anthias pascalus (Jordan et Tanaka,1927)	O
Anthias squamipinnis (Peters,1855)	O
Cephalopholis argus (Bloch et Schneider,1801)	L O
Cephalopholis urodelus (Bloch et Schneider,1801)	O
Epinephelus merra Bloch,1793	L
Epinephelus microdon (Bleeker,1856)	L
Gracila albomarginata (Fowler et Bean,1930)	O

GRAMMISTIDAE	
Grammistes sexlineatus Thumberg,1792	L
PSEUDOGRAMMIDAE	
Pseudogramma polycantha (Bleeker,1856)	L
APOGONIDAE	
Apogon exostigma (Jordan et Starcks,1906)	L
Apogon kallopterus Bleeker,1856	L
Apogon novemfasciatus (Cuvier,1828)	L
Apogon savayensis (Günther,1871)	L
Cheilodipterus lineatus (Lacépede,1801)	L
Cheilodipterus macrodon (Lacépède,1802)	L
Cheilodipterus quinquelineatus (Cuvier,1828)	L
Fowleria aurita Valenciennes,1831	L
Fowleria marmoratus Alleyne et MacLeay,1876	L
Fowleria sp.297	L
Genus sp.289 (juv.)	L
Genus sp.292 (juv.)	L
CARANGIDAE	
Caranx ignobilis (Forsskål,1775)	O
Caranx melampygus (Cuvier,1833)	L O
Gnathanodon speciosus (Forsskål,1775)	L
LUTJANIDAE	
Aphareus furca (Lacepède,1802)	O
Lutjanus bohar (Forsskal,1775)	O
Lutjanus fulvus (Bloch et Schneider,1801)	L O
Lutjanus gibbus (Forsskål,1775)	L O
LETHRINIDAE	
Lethrinus xanthochilinus (Klunzinger,1870)	L
Monotaxis grandoculis (Forsskal,1775)	L O
MULLIDAE	
Mulloides flavolineatus (Lacepède,1801)	L
Mulloides vanicolensis (Valenciennes,1831)	L
Parupeneus barberinus (Lacepède,1802)	L
Pseudupeneus bifasciatus (Lacepède,1802)	L
Pseudupeneus multifasciatus (Lacepède,1801)	L O
CHAETODONTIDAE	
Chaetodon auriga Forsskål,1775	L
Chaetodon bennetti Cuvier,1831	L
Chaetodon citrinellus Cuvier,1831	L
Chaetodon ephippium Cuvier,1831	L O
Chaetodon kleinii Bloch,1790	L
Chaetodon lineolatus Cuvier,1831	L
Chaetodon lunula (Lacepède,1803)	L O
Chaetodon ornatissimus Cuvier,1831	L O
Chaetodon pelewensis Kner,1868	O
Chaetodon quadrimaculatus Gray,1831	L O
Chaetodon reticulatus Cuvier,1831	O
Chaetodon semeion Bleeker,1855	L
Chaetodon trifascialis Quoy et Gaimard,1824	L
Chaetodon trifasciatus Park,1797	L
Chaetodon ulietensis Cuvier,1831	L O

Chaetodon unimaculatus Bloch,1787	L O
Chaetodon vagabundus Linné,1758	L
Forcipiger flavissimus Jordan et MacGregor,1898	O
Forcipiger longirostris (Broussonnet,1782)	O
POMACANTHIDAE	
Centropyge flavissimus (Cuvier,1831)	L O
Centropyge loriculus (Günther,1860)	O
POMACENTRIDAE	
Abudefduf sexfasciatus (Lacépède,1801)	L
Abudefduf sordidus (Forsskål,1775)	L
Amphiprion clarkii (Bennett,1830)	O
Chromis caerulea (Cuvier,1830)	L
Chromis iomelas Jordan et Seale,1906	O
Chromis vanderbilti (Fowler,1941)	O
Chromis sp.372	L
Chrysiptera leucopoma (Lesson,1830)	L
Dascyllus aruanus (Linné,1758)	L
Dascyllus trimaculatus (Rûppell,1828)	O
Dascyllus reticulatus (Richardson,1846)	O
Plectroglyphidodon dickii (Lienard,1839)	O
Plectroglyphidodon flaviventris Allen et Randall,1974	L
Plectroglyphidodon johnstonianus Fowler et Ball,1924	O
Pomacentrus pavo (Bloch,1787)	L
Pomacentrus coelestis Jordan et Starks,1901	L
Stegastes albifasciatus (Schlegel et Müller,1839)	L
Stegastes aureus (Fowler,1927)	O
Stegastes nigricans (Lacépède,1803)	L
CIRRHITIDAE	
Paracirrhites arcatus (Jordan et Evermann,1903)	O
Paracirrhites forsteri (Schneider,1801)	O
Paracirrhites sp.420 (juv.)	O
SPHYRAENIDAE	
Sphyraena barracuda (Walbaum,1792)	L
LABRIDAE	
Bodianus anthioides (Bennett,1830)	O
Bodianus sp.151	L
Cheilinus chlorourus (Bloch,1791)	L
Cheilinus oxycephalus Bleeker,1853	L
Cheilinus trilobatus Lacépède,1801	L
Cheilinus undulatus Rüppell,1835	L O
Cheilinus unifasciatus Streets,1811	L
Cirrhilabrus sp.58	O
Coris aygula (Lacepède,1801)	L
Coris gaimard (Quoy et Gaimard,1824)	L O
Cymolutes sp.	L
Epibulus insidiator (Pallas,1770)	L
Gomphosus varius Lacepède,1801	L O
Halichoeres hortulanus Lacépède,1801	L O
Halichoeres marginatus Rüppell,1835	L
Halichoeres ornatissimus (Garrett,1889)	O
Halichoeres trimaculatus (Quoy et Gaimard,1834)	L

Halichoeres sp.(juv.)	L
Hemigymnus fasciatus (Bloch,1792)	O
Labroides dimidiatus (Valenciennes,1839)	L O
Pseudocheilinus octotaenia Jenkins,1899	L O
Pseudocheilinus tetrataenia Schultz,1946	L
Stethojulis bandanensis (Bleeker,1851)	L
Thalassoma amblycephalum Bleeker,1856	L O
Thalassoma hardwicke (Bennett,1830)	L
Thalassoma quinquevittatum (Lay et Bennett,1839)	L O
Weltmorella nigropinnata (Seale,1900)	L
Genus sp.287	L
SCARIDAE	
Hipposcarus longiceps Valenciennes,1839	L O
Scarus frenatus Lacepède,1802	L O
Scarus ghobban (Forsskål,1775)	L
Scarus gibbus Rüppell,1828	L
Scarus globiceps Valenciennes,1839	L O
Scarus oviceps Valenciennes,1840	L O
Scarus psittacus Forsskål,1775	L
Scarus rubroviolaceus (Bleeker,1849)	L
Scarus sordidus Forsskål,1775	L O
Scarus sp.(venosus)	L
Scarus sp.106 (juv.)	L
Scarus sp.107 (juv.)	L
Scarus sp.329 (juv.)	L
Scarus sp.422 (juv.)	L
BLENNIIDAE	
Enchelyurus ater (Günther,1877)	L
Istiblennius periophthalmus (Valenciennes,1836)	L
Petrocirtes xestus Jordan et Seale,1906	L
CALLIONYMIDAE	
Callionymus sp.288	L
GOBIIDAE	
Amblygobius nocturnus Smith,1956	L
Amblygobius phalaena (Cuvier,1837)	L
Asterropterix semipunctatus Rüppell,1828	L
Callogobius sclateri (Steindachner,1880)	L
Eviota afalei Jordan et Seale,1905	L
Eviota infulata Smith,1956	L
Fusigobius neophytus (Günther,1877)	L
Gnatholepis cauerensis (Bleeker,1853)	L
Nemateleotris magnifica Fowler,1938	O
Priolepis cincta (Regan,1908)	L
Ptereleotris evides (Jordan et Hubbs,1934)	L
Ptereleotris microlepis (Bleeker,1856)	L
Vanderhorstia sp.(juv.)	L
Genus sp.290	L
Genus sp.324	L
ACANTHURIDAE	
Acanthurus glaucopareius Cuvier,1829	O
Acanthurus nigricauda Duncker et Mohr,1929	L O

Acanthurus nigroris Valenciennes,1838	L
Acanthurus olivaceus Bloch et Schneider,1801	L
Acanthurus pyroferus Kittlitz,1834	O
Acanthurus triostegus (Linné,1758)	L
Acanthurus xanthopterus Valenciennes,1835	L
Acanthurus sp.(juv.)	L O
Ctenochaetus striatus (Quoy et Gaimard,1824)	L O
Ctenochaetus strigosus (Bennett,1828)	L O
Naso brevirostris (Valenciennes,1835)	L O
Naso hexacanthus (Bleeker,1855)	O
Naso lituratus (Bloch et Schneider,1801)	L O
Naso unicornis (Forsskal,1775)	L O
Zanclus cornutus (Linné,1758)	L O
Zebrasoma rostratum (Günther,1873)	O
Zebrasoma scopas (Cuvier,1835)	L O
Zebrasoma veliferum (Bloch,1795)	L O
SIGANIDAE	
Siganus argenteus (Quoy et Gaimard,1824)	O
SCOMBRIDAE	
Katsuwonus pelamis (Linné,1558)	O
Order Pleuronectiformes	
BOTHIDAE	
Bothus mancus (Broussonnet,1782)	L
Order Tetraodontiformes	
BALISTIDAE	
Amanses scopas (Cuvier,1829)	O
Balistapus undulatus (Mungo Park,1797)	O
Balistapus viridescens (Bloch et Schneider,1801)	L O
Melichthys niger (Bloch,1786)	O
Melichthys vidua (Solander,1845)	O
Pseudobalistes flavimarginatus (Rüppell,1828)	O
Rhinecanthus aculeatus (Linné,1758)	L
Sufflamen bursa (Bloch et Schneider,1801)	O
OSTRACIIDAE	
Ostracion cubicus Linné,1758	L O
TETRAODONTIDAE	
Arothron hispidus (Linné,1758)	L
Arothron meleagris (Lacépède,1798)	L
Canthigaster bennetti (Bleeker,1854)	L
Canthigaster janthinoptera (Bleeker,1855)	L
Canthigaster solandri (Richardson,1844)	L



Reef rim sediments. Inputs by storms and high seas

Reef constructions; frame building

Bottom sediments rich in Acropora and Porites

Phosphate deposit

Carbonate basement

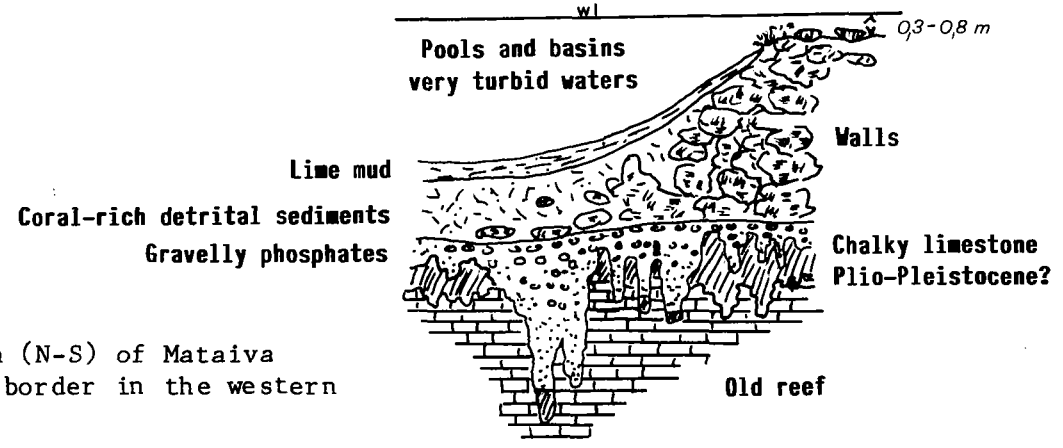


Figure 2 : Transverse cross-section (N-S) of Mataiva and detail of the basin border in the western part of the atoll.

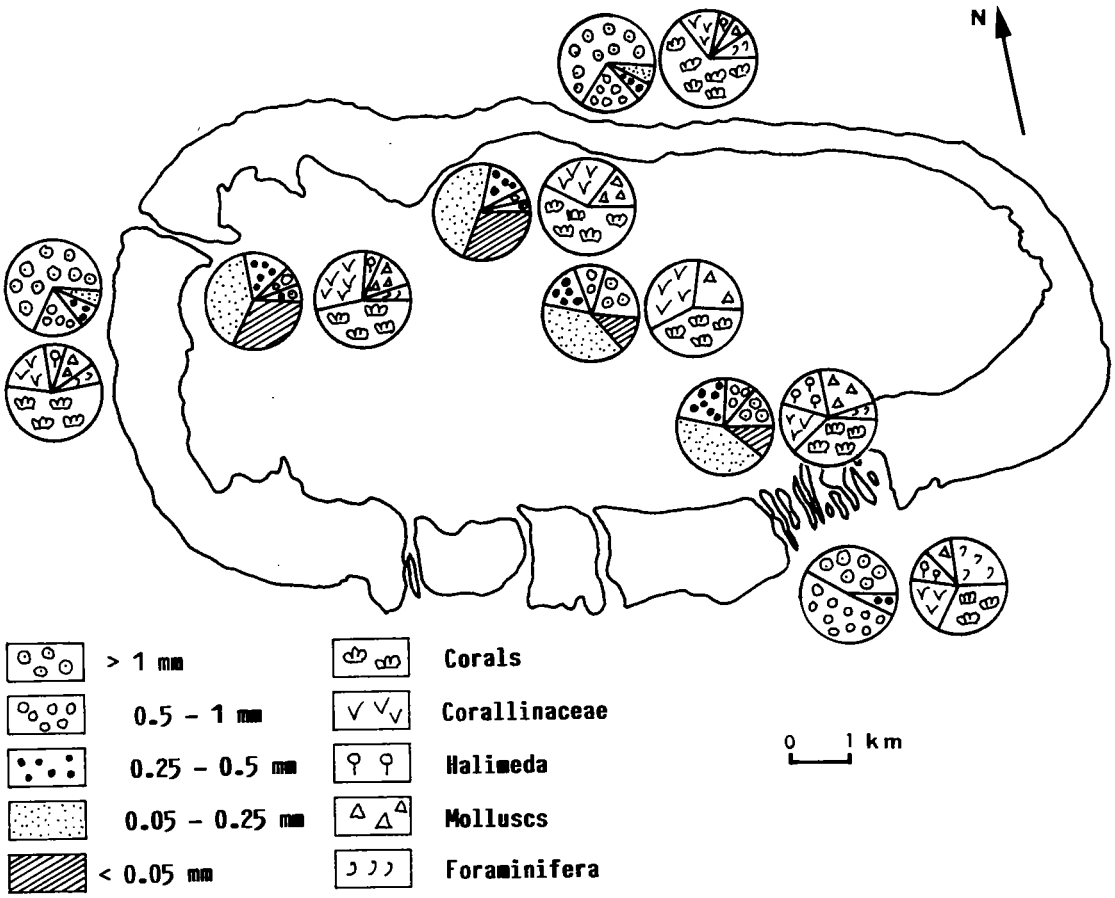


Figure 3 : Grain-size and components of lagoonal and outer reefal sediments

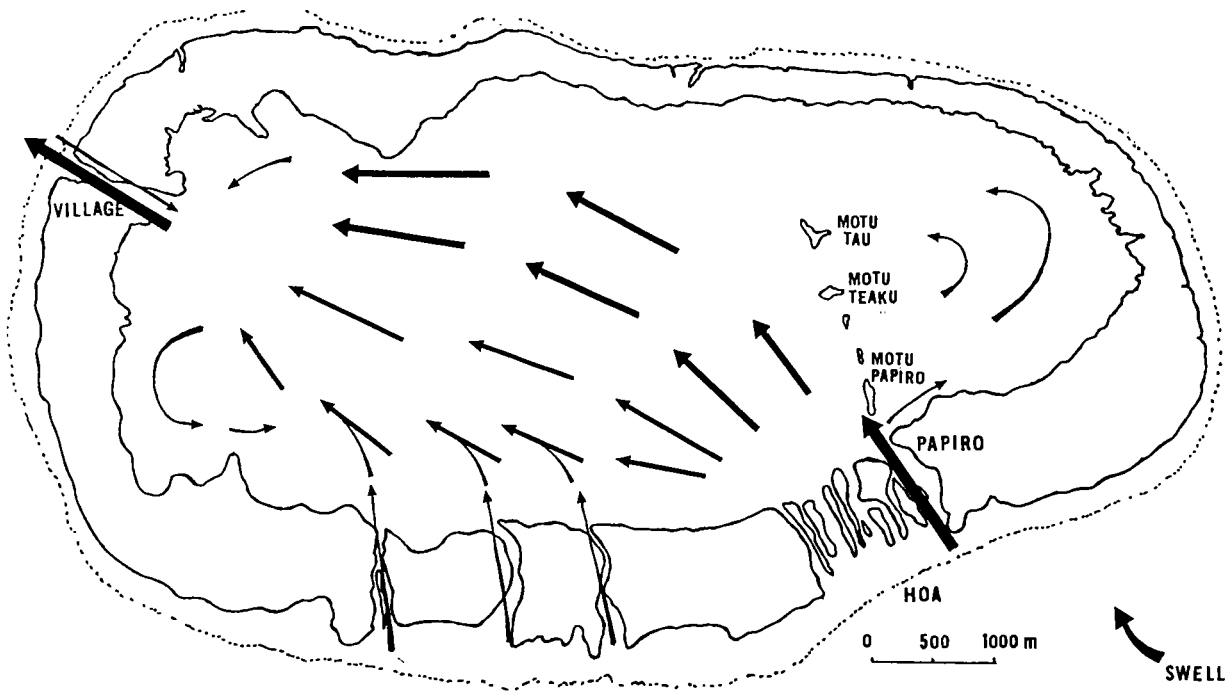


Figure 4: Surface circulation of lagoon waters (usual climatic conditions)

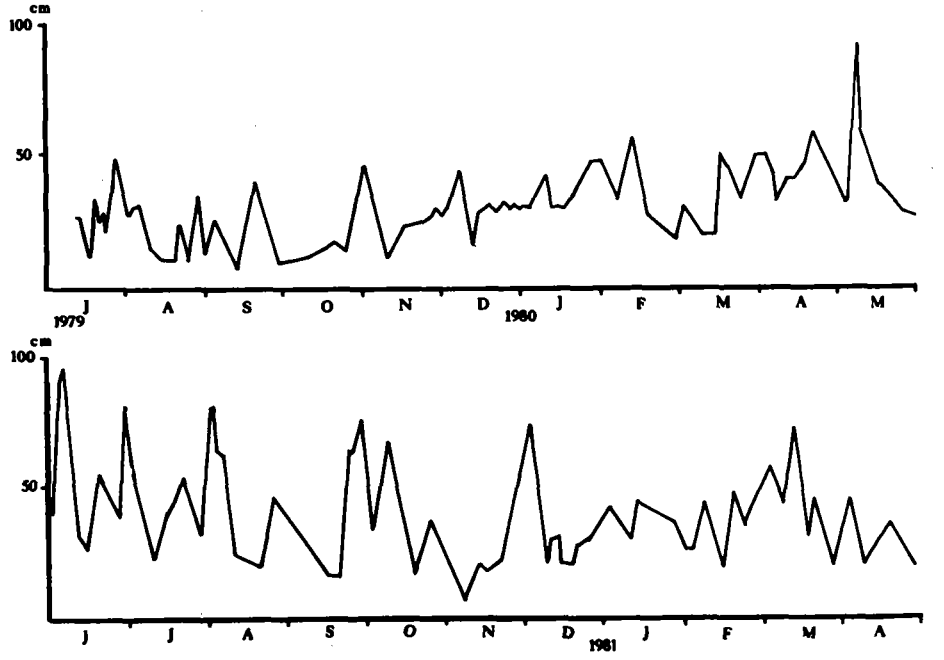


Figure 5 : Relative variations of the lagoon water level between 1979 and 1981.

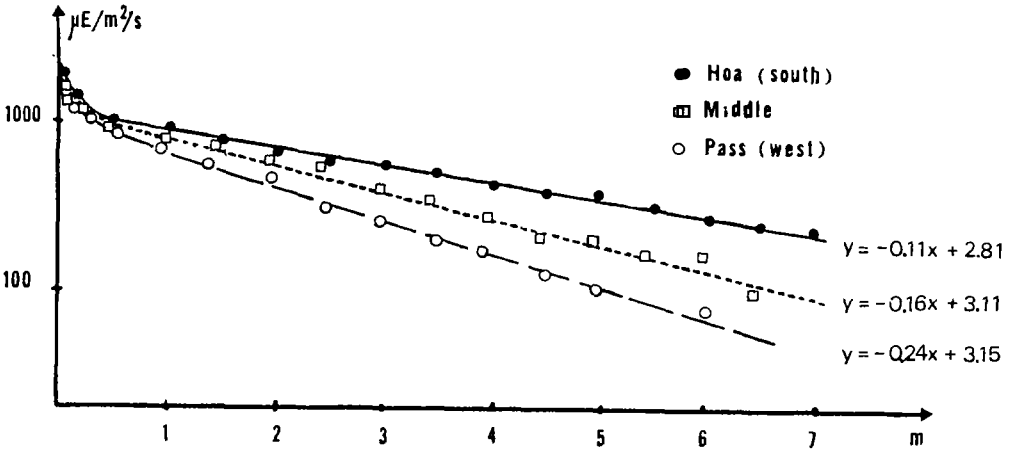
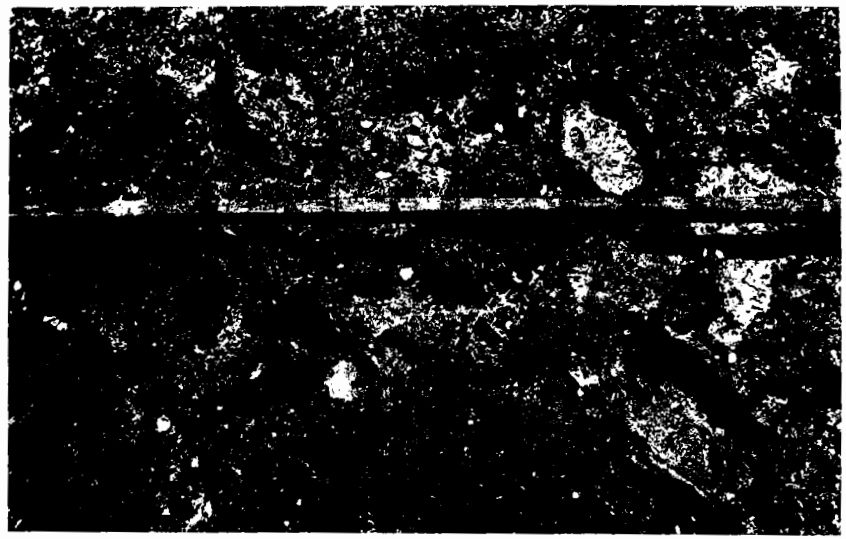


Figure 6 : Light penetration in 3 different points of the lagoon.

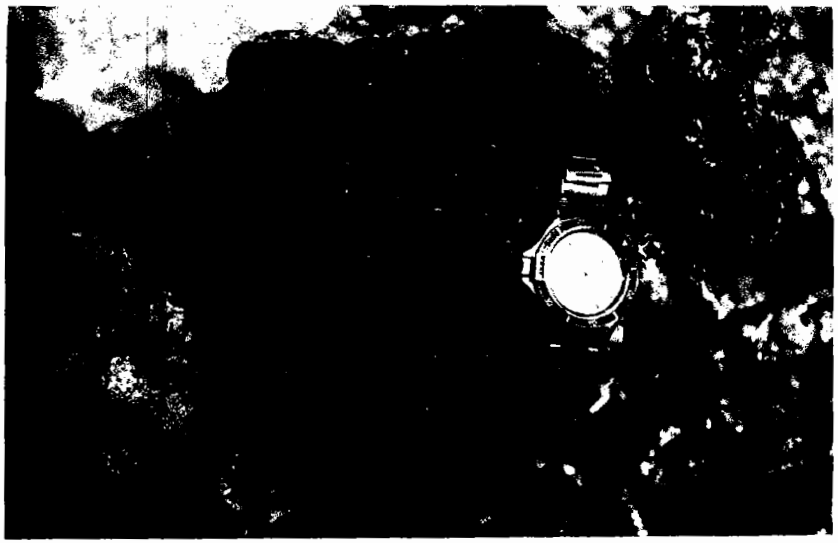
1. The village, damaged by the cyclone Reva in 1983

2. Aerial view of The Papiro-Aviu hoa.

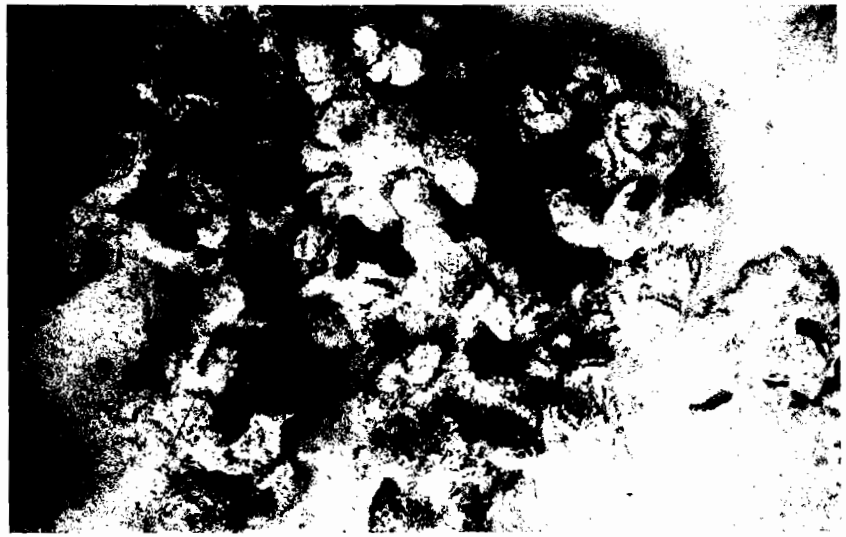
3. Dredged material including phosphates pebbles and coral fragments (Porites and Acropora).



4. The flagstone of Motu Tau, with Tridacna shells in growing position.



5. Bivalves, Litophaga cinnamomina, boring Porites



6. Small oysters Crassostrea cucullata on Acropora

7. Helmet urchins, Colobocentrotus pedifer, on the southern algal ridge (Papiro).

8. The north outer slope (20 m) damaged by the hurricane Reva (Teavatia area).