INTERRELATIONSHIPS OF THE ORGANISMS ON RAROIA ASIDE FROM MAN

by Maxwell S. Doty and J. P. E. Morrison

Having in previous sections of this report (Atoll Research Bulletins Nos. 18, 31-34) enumerated and given the geographic distributions of the individual kinds of organisms, and discussed the physical environment we can logically proceed to a more synecological discussion. At least we can report our major ecological observations and the syn- and autecological hypotheses derived from these observations.

To facilitate the gathering of information for this phase of our study of Raroia a number of areas (transects) were chosen for more intensive study. All of the members of the field team participated in these studies, and their aid is herein acknowledged. The locations of these transect areas on the atoll may be seen in Figure 1. In the transect areas a search was made for the living organisms present. These have been reported in Atoll Research Bulletins 18, 33, 34. Across each transect area a profile was studied in reference to the distribution of the physical and biological features of the transect. The profile positions in the transect areas are shown by the lettered solid lines within each area. The letters correspond to the profiles on Figure 2.

In this discussion reference is made to Figure 3. This is an idealized profile diagramming the typical elevational features met with in crossing the atoll ring. Essentially, it illustrates that which can be walked upon. This profile is a summary of Figure 2, the proportions are similar though no particular scale has been followed.

The description is organized as a discussion of the ecological units of the atoll under the following headings:

I. Sea Reef in general and pools

II. HOMOHOMO profile study

A. <u>Sea shore</u>

1. Spurs and grooves
2. Algal ridge
3. Amphiroa zone
4. Heliopora zone
5. Pool zone
6. Excurrent area
7. Intertidal and spray-wet shore

B. <u>Sea beach</u>

C. <u>Guettarda forest</u>

D. <u>Lagoon shore</u>

1. Lagoon shore above high tide line
2. Lagoon intertidal shore
3. Lagoon subtidal shore

III. A comparison of the other six profiles studied

A. <u>Sea shore</u>

1. Spurs and Grooves
2. Algal ridge
3. Reef flat
4. Intertidal and wave-wet shore
5. Spray-wet shore and sea ramparts

B. <u>Sea beach</u>

C. <u>Guettarda forest</u>

D. <u>Lagoon shore below high tide line</u>

IV. Reef patches

V. Vertical distribution

VI. Channels

I. SEA REEF IN GENERAL AND POOLS

The reef flats (Fig. 3) of Raroia are narrow (Fig. 2), usually less than 100 meters wide, and in general the pool of water on the reef flat was deepest near the shore. This, when considered in relation to the algal ridge, is in the position of the back-ridge trough of the much wider Marshall Islands reefs. The whole reef flat being only perhaps a hundred meters wide leaves little place as a rule for the inner area of reef flat characteristic of reefs having a greater width between the margin and shore.

The water comes in over the reef margin (Fig. 3) with each wave, except at low tide during calm weather. The water movements on the reef flat just as the tide began to rise (Fig. 4) were determined by watching the movement of dye spread on the surface. The water coming in over an algal ridge passes in toward the shore and to the right and left (Figs. 4B, C, D, E, F), and then out over the reef margin where it is low. This general pattern was consistent but at extremes of tide, and presumably at times of other extremes such as wind or the course of large waves, the details varied. As an example, at rising mid tide when a lot of water was coming in and out over the reef edge, a dye patch followed course "F" in Figure 4 rather than an <u>a priori</u> selected path parallel to "C".

The reef can be divided, by recognizing extremes, into <u>incurrent</u> and <u>ex-current</u> areas on this basis of direction of water flow after coming in over the reef margin. The excurrent areas are devoid of algal ridges. The incurrent areas usually have an algal ridge but this may be absent, the reef edge merely being higher here, or it may be a low cuesta in form. The leeward reef flats are such alternating incurrent and excurrent areas.

Excurrent areas rather consistently appear opposite the channels between the islands, but as the more leeward reef is approached, incurrent areas and excurrent areas alternate with one another even opposite island masses. Excurrent areas are much reduced as the more windward parts of the atoll are approached and in the most windward reef areas may be absent even opposite the channels, which are much more abundant (Fig. 1) here. In such cases the algal ridge is nearly continuous and the water normally passes across the atoll rim only in the direction of the lagoon. At least the water flows over the edges of the windward reefs and into the lagoon without the regular tidal reversal of direction characteristic of water flow in leeward channels.

The reef flat was far more intensively studied on the leeward transect north of the village of Garumaoa (Fig. 5). Locally speaking, the transect ran across the pieces of land known as Tomogagie and Homohomo. The profile of this transect (Homohomo) appears as figure 2G. Here evidence was gained that seems to indicate the reef may be divided into areas that become uncovered with the lowest tides and areas which do not become uncovered. The areas that become uncovered become uncovered rather quickly after the waves cease breaking over the algal ridge and once the tide rises so sufficiently that the waves again begin breaking over the algal ridge the whole tide flat is rather soon again covered with water from the reef ridge line inshoreward.

At high tide water does in part go back out over the ridge in incurrent areas even in regions having a rather high algal ridge. By standing at various distances out on the reef flat it was determined that the approximate point of division between where the water, at high tide, moves back toward shore after coming in over the algal ridge and where it moves back out over the algal ridge is the approximate location of the reef ridge line; though this varies out into the Amphiroa dominated algal-coral zone under some circumstances. Dyes dumped into the water on the reef flat at various stages of tide level revealed rather consistent circulation patterns over the reef flat. The water regularly moved as described, <u>in</u> toward the pool zone, <u>laterally</u> toward the excurrent areas, and <u>out</u> over the excurrent areas.

Water, in early July, coming in over the reef edge in the morning was near, or a little below, 26 degrees Centigrade. Twenty meters inshore, in an incurrent area the water would be between one half and one degree warmer and this warming of the water continued into the outer edge of the pool zone where the maximum temperatures were observed. In this case, they could be expected to be in the order of a degree to a degree and a half warmer than those obtained at the sea's edge.

Toward the inshore edge of the pool zone, the temperature dropped again. The lowest temperatures were measured in rills of water running out from the island conglomerate. In one case the temperature of a small pool near high tide line, but connected to the channel of the pool zone, was 29 degrees Centigrade in its central part, the inner edge, where the water was about 1 inch deep, was

27.8 degrees Centigrade, and with the bulb just covered in a sandy incurrent rill of water running into the pool from under the island conglomerate the temperature was 27 degrees Centigrade. Note in this connection the path of dye patch "A" in Figure 4.

As the channel along the inshore edge of the pool zone was followed toward the excurrent area, typically the temperature of the water was observed to increase in temperature about one degree. Then as the reef flat was crossed again, following the excurrent area out to the sea again, the temperature increased perhaps another degree, until at the most the temperature was about 30 degrees Centigrade. It was just in this area of maximum temperature that a certain soft coral was found. Beyond this point the repeated inwash of cooler water with each wave quickly lowered the temperature to that of the sea beyond and outside the reef.

There are essentially two kinds of pools associated with sea shores, both of them are calm ever-submerged habitats. The simplest is the classical tide pool with its continuous rim. Such pools may be thought of as being constant-level tide pools in consideration of the fact that when exposed by the receding tides, waves or spray, their level remains constant, except as it may change through addition of rain water or by evaporation. The second type consists essentially of areas with a restricted drainage. The surfaces of this type, when exposed, slowly lower and may be thought of as a non-constant-level type. Around the former of these two types there is often a sharp change in the biota associated with the surface level. Such a change is absent at the high water level in the latter type.

Tidepools are convenient places in which to make observations. They attract biologists for they are often centers of considerable biological activity. Recently, for the reason that this biological activity is of geological importance, the interest of the geologists (e. g. Emery, Bull. Geol. Soc., 1946) has been attracted. All of the tidepools can perhaps be differentiated to a certain extent by their position in respect to tide level, as supralittoral, littoral, and sublittoral tidepools.

The constant-level pools of the island conglomerate are supralittoral pools often of low salinity or of high salinity. These have been discussed at length under the blue-green algae in Part 2 of Atoll Research Bulletin No. 33.

Littoral pools are nearly absent except for the reef flat and the channels both of which are non-constant-level type pools. They are discussed below in greater detail.

Sublittoral pools of the constant-level type are nearly absent, unless one wants to consider the whole ocean as one pool. The concentration of biological materials around the shores of the sea favors this classification. Certain surge channels, the incomplete channels between the islands and especially the lagoon, itself, are essentially sublittoral tidepools of the non-constant-level type. However, on downwind lagoon shores where there is a reef, the gross aspect, like the littoral shore of the ocean, is that of a constant-level tidepool.

II. HOMOHOMO PROFILE STUDY
(Figures 2G, 4 and 5)

A. Sea Shore

1. Spurs and Grooves. The so-called "surge channels" and "ridges" received considerable, but entirely superficial, attention. Classically it is here that the atoll rim is growing upward and advancing the surface of the atoll outward. Newell has seen the same features in limestones which were of an oolitic sort formed inorganically. In Hawaii, on the basaltic materials under water where these are partially covered with sand, the sand and basaltic material show to an observer in a plane or boat as radially arranged elongated areas. Thus must be eliminated the explanation that the spurs and grooves have formed entirely as ridges growing between the now present channels. All of this points to an erosional origin of these spurs and grooves as Cloud (Bull. Amer. Assoc. Petroleum Geologists, 1952) has claimed.

At Raroia the spur and groove area appeared (Fig. 5) to be a mass of *Porolithon onkodes* with only traces of other coralline algal species. Coral animals were few. In the heads of most of the grooves there were to be found colonies of a *Millepora*, which extend down about one foot and out from approximately the outer edge of the algal ridge and the level of the reef flat inside the algal ridge. These *Millepora* colonies form their own small pools by their reticulate pattern of upgrowth. (See Figure 2 in Tracey, et al, Bull. Geol. Soc. Amer. for 1948.) *Centroceras clavulatum* coated many of the highest parts of the spurs beyond the algal ridge. Rarely were other than coralline algae present; however, among these rarities was a *Caulerpa* (a variety of *pickeringii* or an undescribed species) and *Microdictyon okamurai* Setch., and spots of blue-green algae. In a very few places rather well under even the lowest tide levels there was an increased abundance of *Pocillopora* on the tops of the spurs.

The grooves beyond the algal ridge at Homohomo dip sharply (Fig. 3) or may even be somewhat overhanging at their heads. Often the heads of these grooves are broadened and filled with what might be referred to as huge algalated lumps. While no effort was made to determine more than the nature of the superficial material of these it appeared that they might be fragments of reef rim broken off and lodged in the heads of the grooves and then cemented in by the growth of such algae as *Porolithon onkodes* and *Lithophyllum* species. From the rounded shapes of the groove bottoms and their containing rounded boulders and pebbles as well as their generally very smooth regular contours it was assumed that in the grooves there was a lot of abrasion. This was insinuated further by the frequency of spherical clumps of algal materials (*Microdictyon okamurai*) found there. Around these irregularly arranged huge algalated lumps in the channel heads the broadening seen appeared to be what one might expect from the abrasive action of particles being washed around their sides. In some cases the heads of grooves were nearly confluent as though by extensive overgrowth of the lodged reef fragments by coralline algae. A prostrate *Gelidium* and an extremely fine partially corticated *Ceramium*, recalling *Ceramium avalonae* Dawson but with longer nodes and more slender throughout, grow in small concavities of the *Porolithon onkodes* along with *Herposiphonia tenella* (C. Ag.) Naegeli (Male thalli were found displaying the assymetrical nature described by Boergesen).

It should be emphasized again that there was little macroscopically visible on the walls of the grooves. The actual surface was usually covered with a characterless pink layer of coralline algae, which insofar as we could tell, was always morphologically undeveloped.

Here at Homohomo the opinion was developed that perhaps Porolithon onkodes is different from other crustose species of coralline algae in being able to develop rapidly, stand the brilliant illumination (other crustose corallines were usually restricted to cavities or shaded areas) and a certain amount of emergence with its attendent elevated temperatures and the osmotic changes inherent with desiccation. Furthermore, since this species was apparently extremely important in the life of the reef it was interesting to entertain for a time the idea that such a species suddenly arising and spreading very rapidly would aid in explaining some of the uniform characteristics of coral atolls.

2. Algal Ridge. The algal ridge at Homohomo was discontinuous (Fig. 4), being highest in what are being called incurrent areas and absent in what are being called excurrent areas. The surface of the reef, however, was a uniform pink coating of Porolithon onkodes throughout. Seaward the algal ridge descended from its maximal heights of eight or ten inches by a gradual slope (Figs. 2G and 3) onto the spurs and into the heads of the grooves. Inshoreward similarly it descended to the reef flat by a gentle slope, often a bit steeper than on the seaward side.

But few animals were to be found on the algal ridge. On the sea side, the most conspicuous of these was Turbo setosa, which as a substitute for a good breakfast was certainly reason for the relative scarcity of this species near the village. In numbers the animals on the surface here were principally a limpet (Acmaea, Siphonaria, or Helcioniscus sp. 11067*), a small barnacle (Balanus sp., 11068) and various worm or gastropod tubes which protrude through the algal cover which tends to overgrow all these animals. Microdictyon okamurai is the most conspicuous non-coralline alga and appears on both faces of the algal ridge. Particularly on the inner face of the algal ridge, but on the outer too, small spots of a blue-green alga appeared.

The inshore side of the highest part of the algal ridge at Homohomo was deeply pitted with many of the pits being occupied by pencil urchins (11088). These holes which the urchins were in were holes such as are "typically bored by sea urchins".

The smooth Porolithon onkodes cover of the algal ridge extends horizontally inshore from the base of the algal ridge from a few inches to a few feet ending in a rather definite border. This border, which usually could be located within a few centimeters, was called the reef ridge line (Fig. 3). It was one of the most consistent marks on the sea reef. Even opposite relatively large excurrent areas where no ridge was to be found this reef ridge line could be identified. In Figure 3, the algal ridge is shown in its full expression. Beneath the ridge four dotted lines are labeled a, b, c and d. These indicate the contour of the algal ridge in relationship to a groove bottom as one progresses from a strongly incurrent area to a less decidedly incurrent area, a, where the algal ridge is an almost level topped cuesta. Further along toward an excurrent development, such as the large excurrent area at the sea end of the Homohomo transect, successively profiles b, c and finally d could be expected.

*Doty & Newhouse collection numbers.

Throughout the algal ridge area one gained the impression that Porolithon onkodes was dominant, overgrowing everything. At its outer edge there were a few boring urchins (Echinometra species) but the holes on which these urchins were found were often nearly overgrown. The sea edge of the algal ridge was often cavernous in structure when broken into; as though the Porolithon had overgrown whatever was previously there and then the material had disappeared perhaps by solution. Perhaps, the superficial reef ridge material in time itself may disappear through weakening by such solution or boring and break away during storms. The cavernous areas were the habitats for a host of different species of fish and of crabs and other invertebrates rarely seen out on the reef in the daytime.

3. Amphiroa Zone. The reef ridge line is the position distinguished by a transition from the smooth Porolithon onkodes surface dotted here and there by patches of a blue-green alga to a surface dominated by an Amphiroa. This Amphiroa (11103, 11061) is similar to Amphiroa annulata Lemoine, but is somewhat larger. From observation this zone (Figs. 3 and 4) has three major characteristics: 1) form and position; 2) structure; and 3) its peculiar biota.

In form the Amphiroa zone is a flat that is quite like a turf and consists principally of but this one species. It formed a zone about five to fifteen meters wide.

It was observed that at low tide the Amphiroa community was out of the water. The remainder of the reef flat or reef pool area constantly submerged. At high tide the water coming in over the reef edge "divided" here. The water inside the inner edge of the Amphiroa zone passing on in over the reef flat and that over the Amphiroa and outside the reef ridge line surging back outward. Essentially the feeling was gained that this was the highest growing form insofar as tide level is concerned on the reef flat away from the high tide line at the shore itself. It was widest inshore of incurrent areas and most narrow, absent (or nearly so) across excurrent areas.

There was in a few places some development of this association to the seaward of the algal ridge on the largest and flattest topped spurs. For a series of such flat topped spurs see Figure 5 opposite the third island from the right, Kumekume, and just outside the line of breakers.

In structure the Amphiroa zone is a turf about three centimeters deep over a room and pillar structure (diagrammed in Fig. 3) about ten or fifteen centimeters thick. The cavities are the habitats for a myriad of invertebrate species and small fish. The important inhabitant insofar as the solid structure of the reef is concerned appeared to be a black "boring urchin", Echinometra (11095). This urchin can be postulated as being responsible for boring the holes in which it is found and thus causing the removal of algal material. Whether it consumes this material or not is unknown but should be looked into. The tops of the chambers or rooms of this portion of the reef are open to the surface. However, this opening is increasingly closed by Porolithon onkodes which tends to convert the reef flat here into a smooth pavement like that of the algal ridge area. The Amphiroa grows on top of this perforated algal pavement.

This zone is perhaps distinct vertically but is not so distinct horizontally. The biota here beyond the Amphiroa itself is not seemingly restricted to this zone, except for Caulerpa urvilleana which appeared with some frequency opposite incurrent areas as green patches in the otherwise pink Amphiroa turf. Corals such as those more abundant in the next zone inshoreward were present here with lower frequencies. Especially opposite incurrent areas Heliopora appeared most frequently. The Porolithon beneath the Amphiroa and especially the animals in general in the cavities below the active growing level of the Porolithon are essentially those of the next inshoreward and lower zone.

Turbo argyrostoma was rather sharply limited inside the reef ridge line and the major distribution of this species on the Homohomo transect was in holes near the surface of the Amphiroa zone. It did, however, occur in much lower numbers in the next zone shoreward. In the Amphiroa zone the boring urchins (Echinometra) were predominantly black urchins and in the more inshore zones a similar pink urchin became predominant. A most interesting association between the shrimp, Crangon frontalis, and the alga Lyngbya sordida, discussed with the other blue-green algae, (Atoll Research Bulletin No. 33), was most abundant in the cavities under the Amphiroa though occurring both out in the grooves and more inshore in the next adjacent zone.

4. Heliopora Zone.* At Raroia there was only what might be said to be an analogue of the Heliopora zone (Fig. 3) reported by Ladd, et al., (Jour. of Geol. 58, 1950) at Bikini. At Raroia, Heliopora (11107) was nowhere conspicuous and was found with any frequency at all only on the sea reef at Homohomo and there with regularity only inside the most incurrent areas. Perhaps, it would be better to term this a coral animal zone, without being too specific as to whether or not a hyphen should be placed between coral and animal.

This coral animal zone or Heliopora zone (Fig. 3) was essentially a band inshore of the Amphiroa zone achieving its maximal breadth opposite the incurrent areas and being absent opposite excurrent areas. On the Homohomo transect this zone was about 20 meters broad at its broadest.

In general the lowest levels in this region were fifteen or twenty centimeters below the level of the highest levels. The whole zone could be thought of as a series of holes with more or less incomplete rims. At the seaward margin the holes were smaller and more nearly closed over as the Amphiroa zone was approached. Inland, the holes were larger and the rim portions less conspicuous. Rim portions that reached the level of the Amphiroa zone were populated above with species of the Amphiroa zone. Essentially, perhaps, this coral animal zone extended right under the Amphiroa zone at least to the reef ridge line (Fig. 3).

The depressions or holes in this area were connected so as to drain toward the shore. Toward the seaward edge of the zone these drainage chains were inconspicuous. Inshore the holes were deeper, larger and more conspicuously continuous and almost no solid material reached the elevation of the Amphiroa zone. The impression gathered was that the rim material of the holes was more in the nature of the remains of coral organisms that had grown and died there, rather than being of the nature of material such as island conglomerate that has been removed by one process or another.

* [This is the "Montipora belt" of Newell, Atoll Research Bull. 36. Ed.]

The organisms identifying this zone by their distribution are Diadema (11093), Pocillopora (11069) and Acropora. Abundant, but less conspicuour are the same black Echinometra (11095) and such gastropods as Drupa ricinus (11069) and Cypraea moneta (often in pairs in small holes).

Essentially this zone is not exposed to emergence at low pool water level. The organisms in it extend upwards to the lowest water levels. Those which are mobile move so as to remain submerged. As an example, Diadema became rather active as soon as the spines became emergent. The spines were actively tilted this way and that until they came under the water surface or nearly under it. In correspondence with this observation is the observation that the size of the specimen is as a rule no larger than the depth of water at the lowest level in the particular pool area in which organism is stationed. That is to say the height of the animal was equal to the depth of water at low pool level. Seaward the specimens are smaller in correspondence to the smaller holes, which we presume to be due to the greater rate of algal replacement of the material removed by the boring of the urchins and other forces.

A rather interesting series of observations on the relation of the non-mobile animals, e. g. Pocillopora, Heliopora and Acropora, was made. These organisms apparently grow upward during periods of higher low tides and the corresponding higher low pool levels. On July 7 and 8 there was at Raroia, in correspondence with favorable weather, a series of exceptionally low pool levels (and tides). At this time, it was noted that the Pocillopora (11101) were more damaged by the exposure of their uppermost parts than were close by Acropora colonies (11101). The effect is one of killing the more exposed parts of these colonies. In correspondence with the direction of the prevailing wind and the sun the more northern edge appeared to be killed to a greater extent than the southern edge. Thus, one could find what appeared to be the dead base of the coral animal colony extending away along the reef to the north and at the southern end a crescentic living edge. This is illustrated in our specimens and photographs of Pocillopora (12168) and Acropora and another as yet unidentified coral animal (12169).

Not only are the animals killed at times when the pool water level is low but inducement of the turf-like nature of the algal cover over the highest portions of this zone is encouraged by the killing of algal tips. Caulerpa urvilliana, as well as the Amphiroa of the next seaward and elevationally higher zone appeared the next day after one such exposure with all the longer tips yellow or white and presumably dead.

It was in this coral animal or black urchin zone that the only living Fungia was seen on the sea reef. In this zone the black boring urchin, Echinometra, gives way in predominance to a very similar pink one (11905, 11130). This led to some discussion as to the distribution of these small boring urchins. To gather more information the transect method was resorted to and the populations of these small urchins in meter squares were counted. The results were, in brief, at the innermost meter square 2 black boring urchins and 13 pink ones (11131). At station #72, in this coral animal zone, there were 48 black ones to 9 pink urchins (11130). At this point the counting was discontinued for counting further out into the Amphiroa zone revealed the fact that the pinker boring urchin there had shorter thicker spines than the similar pink one discussed from nearer shore. Whether this was a third species of Echinometra, or a color form or an ecological form could not be decided and the most our results gave us was the information that there is only a gradual change in numbers across coral animal zone and added support to the idea that the area under the Amphiroa zone is closely related to the present area.

5. Pool Zone. Between the coral animal zone and the low pool level at the seaward edge of the land is the deepest part of the reef flat. In this region, there are few objects that protrude at low pool level. Essentially, this pool zone (Fig. 3) is a shallow channel fifty to sixty meters wide gradually deepening inshoreward to within a few meters of the shore and then further deepening gradually as it passes along the reef from behind the incurrent areas toward an excurrent area. The water flows downhill (Fig. 4) toward the excurrent areas. At low tide, the water is warmest in central regions of the pool zone (by about a degree on the Homohomo transect). It is colder at the inshore edge in correspondence with the cold water percolating out of the shore at low tide and again colder at the sea edge, but not usually as cold there as at the inshore edge. At high tide the water temperatures over the reef flat are rather uniform. The bottom is covered with a generally pink sandy layer. This, as at Bikini, was predominantly coralline algal material, mostly juvenile crusts, and sand. The sand itself consisted of foraminifera and clastic fragments presumably of the organisms living further out on the reef flat.

There was little in the way of algae sufficiently mature that could be identified, with the exception of some few clumps of Caulerpa urvilliana (11094) despite the fact that the pink color of the region seemed to result from a predominance of coralline algae. As sand increased, and the areas became less pink, it was pointed out by Morrison that there was a corresponding increase in microspecies. And in such sandier parts Strombus sp. became perhaps the most abundant of the larger gastropods. In less sandy parts where the corallines were more developed, perhaps the best molluscan indicator of this region was to be found in Drupa grossularia. This species of Drupa was quite distinct by its low form and yellow lip. With it, especially as these two species occurred nearer the excurrent areas or down the channel, Goniolithon sp. (11106) appeared as an epizootic coralline alga on top of this Drupa. Similarly this same Goniolithon appeared in the centers of the small (30 cm or so) microatolls resulting from death of the center of coelenterate coral heads.

It is of interest to list some of the other animals of this region. They all appeared to obtain their food from the algal species directly or indirectly. Heliopora (11107) was present in small numbers. Diadema (11093, 11092) was present in larger sizes and lower numbers. The largest appeared in the deepest parts of the pool very near the shore, there being fewer, however, in the middle of the pool zone. Perhaps, this was related to the distribution of water temperatures. Pocillopora and Acropora appeared here but in lower numbers. Near the seaward border, but very indefinitely so, there occurred a brain coral the colonies of which were so scattered that its distribution was very difficult to determine. Thais, a species of the armigera-group, was found here. Cypraea moneta, perhaps a better indicator of the next zone out was also abundand here. Cypraea helvola and C. caput-serpentis were here. Naria irrorate, a wee speckled "Cypraea" was suspected of living here, but its shells were usually always found empty and cast up with the coarser sand or in with little gravels in holes in the island conglomerate. Cypraea schilderorum in various forms or sizes was perhaps most typical of this pool region. Various cone shells such as Conus miles, C. debraeus and C. miliaris and a couple of others were most easily found here too, but were probably in more seaward regions equally but there harder to find at least in the daytime at low tide.

Toward the inner edge of the pool zone a tawny Porites thrived even in the rock basins in the island conglomerate where sand predominated, but always at least just below the lowest pool level. This species was so consistently placed that it was used along with a black Holothurian as an indicator on the shore of low pool level. Several other animals were conspicuous just below this lowest pool level too; such as two gastropods, a Vasum sp. and the very interesting small red marked Conus sponsalis. A pipe fish, which seemed to be an undescribed species of Corythorichthys was typically found here, especially in the larger of the pools at the edge of the island conglomerate.

As this inner edge of the pool zone is reached the color of the bottom becomes more brown and is more sandy in nature but is still definitely pinkish in contrast to the brown of the intertidal regions above.

6. Excurrent Area. Logically a discussion of this region (Fig. 4) follows the discussion of incurrent areas which have predominated this specific discussion of the sea end of the Homohomo transect so far. The largest excurrent area studied can be approached, for the sake of description, most logically by continuing our discussion as though passing along the pool zone, following the course of the water which flows through the pool zone and out through this excurrent region. As one moves from the pool zone opposite an incurrent area toward the lip over which the water pours out of an excurrent zone the bottom becomes increasingly smooth and toward the lip becomes longitudinally furrowed as though by gravel scouring.

We speak of little else other than bottom for the shores of excurrent areas are the incurrent areas to each side and the intertidal island shore area to be described below. This bottom is a pink pavement of what seems largely to be undeveloped Porolithon. It is, especially seaward, a bright pink; though inshore it is more buff to brownish. The low pool level of the excurrent area is marked with the same species of Porites and the deeper areas with Diadema.

It is the relatively inshore portions of the excurrent areas that we found the greatest development of Heliopora in formations termed by other atoll workers, microatolls. The centers of these microatolls were covered as a rule by coralline algae which are of the genus Goniolithon. Unfortunately the thalli are so oddly developed, or underdeveloped, that these knobby crusts could hardly be identified to species as specific determination demands not only fertile material but "normally developed" thalli.

Thus far, we have been discussing what might be called the "pool zone" of the excurrent area and it has in it all the organisms characteristic of the pool zone elsewhere but they are for the most part much less abundant. The little association of Goniolithon and Drupa grossularia, however, is more conspicuous here.

At what we considered the "pool edge" the bottom (Fig. 3 at "e") was quite flat and just beyond began dipping more sharply toward the sea. On this lip was a sea-facing arc of yellow soft coral colonies (Zoanthids) in a single series, spaced about eight or ten meters apart. And here the water level was least, even zero at lowest pool levels, and the water temperatures were highest. Beyond this level, there was rather constant mixing with insurging waves and the temperatures were measurably lower.

At the pool edge, the increase in slope toward the sea was accompanied by the longitudinal grooving described above. These grooves were various in size and while coursing in a general way parallel to one another they were to a small degree tortuous and anastomosing. As a rule, they were neither more than a foot broad nor a foot deep. Their bottoms were broadly rounded like pot hole bottoms. In the bottoms of these grooves, there was little other than the pink of coralline material. The ridge tops often had the same Amphiroa as described for the incurrent areas or a few of the other species of incurrent areas arranged in the same general serial order inwards from the sea.

Aside from the organisms mentioned already, Porolithon aequinoctiale appeared in such excurrent areas on the ridges between these grooves. It was very characteristic of such places and might be said to have been the best indicator organism. While not strikingly developed at the sea end of the Homohomo transect it was much more developed at the sea end of the large excurrent area associated with the channels at Kukina Rahi, at the south end of the same island and the islands called Kukina and Rare. Here it tended to close over the tops of some longitudinal grooves entirely. At Homohomo the thalli of this species were rarely more than mere undeveloped buttons perhaps four centimeters in diameter at best and two or three centimeters in height. Those in similar positions at other stations developed from bases of similar diameter but specimens returned to Honolulu were up to twenty centimeters tall and twenty-five to thirty centimeters in diameter at the flat top.

At the seaward end of the reef pool lip just discussed, the bottom pitched deeply and abruptly into the groove heads with little in the way of the overhanging development found so often in incurrent area groove heads.

No study of one of the channels between the islands (Fig. 5) was made in connection with the Homohomo transect. Channel information is collected in section VI.

7. Intertidal and Spray-Wet Shore. The intertidal region (Fig. 3) proper is approximately 22 centimeters high.* The solid conglomerated material is brownish in color, contrasting with the pinkish sandy, otherwise similar shore slope of the pool zone. This region varied in width as the slope of the beach changed all along the shore of the island and transect at Homohomo. Otherwise, it was relatively uniform in character. Thus, it and regions inshore of it were at times considered separately as an "onshore area" in contrast to the "incurrent" and "excurrent" areas. The surfaces here were in general rounded and convex in contrast to what they were in other places.

This approximately 22 centimeter band was usually a gently sloping shore rather continuous in slope with the pool floor. It was terminated inshore by

* /According to Newell's measurements 35 centimeters. Ed./

a steeply pitched step or bench of island conglomerate (loosely speaking "beach rock").

In some places there were outliers of island conglomerate or pools cut to pool zone levels in the seaward edge of this island conglomerate bench. The outliers were in some cases apparently of the island conglomerate, but in other cases they were very obviously, from the uniform orientation of the fossils in them, fragments of reef. The outliers were found in various stages of undercutting with this 22 centimeter zone recognizable physiographically and biologically. In general as one moved up them vertically their surfaces were similar in biota to the shore.

Continuing inland and upwards above the intertidal zone above what may be mean high tide line the rock rises almost vertically for about two feet. The surface then levels off at about 100 centimeters above the low pool level. When rather dry, at times of low tide, this area is blackish and appears from the air (Fig. 5) as a black line around the island. It provides a good point of departure in interpreting aerial photographs (Fig. 5); as the seaward edge may be taken as high tide line.

The organisms insofar as algae are concerned were microscopic forms mostly unstudied yet. Those studied and identified have turned out to be blue-green algae, with some exceptions, and for the most part forms of Entophysalis crustacea (see discussion under Myxophyta in Atoll Research Bulletin No. 33). This organism was spread all over the general area under discussion and was responsible for the black coloration of the rocks.

Between the low pool and level and about three fourths of the way to high tide line the common gastropod Morula granulata with another gastropod, Thais hippocastaneum, occupied the remainder of the intertidal region up to the mean level of high water.

Migrating so as to remain just above the water's low surface between waves and especially conspicuous at night was Nerita plicata. This species could be expected as the predominant living organism of macroscopic size upwards for perhaps forty centimeters above the water where it overlapped the lower levels of the range of a Tectarius. Just below the levels of the Nerita a carnivorous gastropod, Cronia cariosa, fed on the Nerita. The ecological implications here, especially in reference to migration of the Nerita, are most interesting.

Tectarius did not seem to be a species which migrated with the tides and its intertidal range was rather high. In fact, it was what might be called a spray zone, or low spray zone, habitant. It ranged at the sea end of the Homohomo transect about thirty-six centimeters above the ordinary wave splash line with the general lower level of its distribution being about thirty to forty centimeters lower.

Perhaps the most conspicuous feature of the supralittoral zone, or the shore just above high tide line, is the blackness of the island conglomerate induced by a heavy growth of blue-green algae. Both Nerita and Tectarius appear to feed by ingestion of this blue-green algal material. The animals living directly or indirectly upon this material were to a large extent migratory.

As discussed in greater detail in the floristic report on Myxophyta these blue-green algae appear to have several very important roles in the determination of the nature of the edge of this island conglomerate shore. Briefly, though one should consult the section mentioned for the details, these roles seem to be such as: softening of the limestone rock; inducing rasping by the snails; elevation of temperatures; protection of the rock from rain; protection of the rock from the buffering action of sea water while shifting the pH locally; and locally affecting the solution or deposition of calcium carbonate through their metabolic activities.

Inshoreward over the island conglomerate the black line so sharply distinct at the sea edge of the island conglomerate in the aerial photographs (Fig. 5) fades to a grayness over the exposed surface of the rock. That this is superficial was determined by breaking out fragments. The fragments were white where not previously exposed to the light. Similarly the undersides of stones lodged or laying on the surface of the island conglomerate were gray on the exposed surface, this faded to green just under their edges and the remainder of the under surface being white. For a discussion of this phenomenon see under Entophysalis in the section on Myxophyta.

The island conglomerate on the sea shore of Homohomo was a bench (Figs. 2G and 3) about two feet above high water line and sloped, with ridges parallel to the sea, somewhat toward the island mass. The Tectarius population dwindled soon inshore of the seaward edge of the rock and there was nothing found in the way of macroscopic life for a distance of perhaps fifteen meters. Inshore of this in crevices, shaded places and under rocks for the approximately twenty meters of the more-inshore remaining portion of the exposed island conglomerate what was taken to be Melaraphe coccinea, a littorine, was abundant. The same Entophysalis crustacea was abundant in the regions where the littorine was abundant, along with other blue-green algae, but there was nothing else macroscopic in the way of living material other than the larger transient animals such as man and birds.

B. Sea Beach

At the seaward extreme one saw only sand, at the landward extreme only bushes (Fig. 3). At first glance, one is inclined to distinguish two zones, one of beach and one of shrubs or bushes.

The edge of the vegetation on the Homohomo transect sea shore is not what was expected. There was no Ipomoea pes-caprae at all and Scaevola frutescens, so common on sea beaches on atolls elsewhere, did not extend out onto the beach. Indeed, though a search was made for it, Ipomoea pes-caprae was found on neither Raroia nor Takume. Superficially there appeared a zone of sand as a gently sloping beach extending inshore about 20 or 25 meters and rising about two feet. This is, perhaps, the area of which Wm. R. Taylor (Plants of Bikini 1950: 162) says "on the upper beach there was nothing" in the Northern Marshalls Island areas he studied.

A vegetation of Suriana maritima, Pemphis acidula and Messerschmidia argenta bordered this sand beach (Fig. 3) which was apparently so barren of living things. However, the small tropical lizards we know as geckos were to be found under the larger rocks that sat on the sand where its seaward edge ran out onto low places in the island conglomerate. Minute Suriana plants were to be found in surprising abundance growing scattered about on this sand, but were only found upon close observation. The surface of the sand was a buffy white near the sea edge and more gray at the inshore edge. It was indeed superficially apparently devoid of life. However, around footprints in the sand, a pale green edge could be seen about two millimeters under the apparently sterile surface. This proved to be a layer of blue-green algae (largely Anacystis montana and Entophysalis crustacea) two millimeters thick.

There seemed to be little else in this sand until one dug down about two more centimeters, where the sand was found to be damp, and where one was confronted with a maze of rootlets one to two millimeters in diameter. After digging one of these for a half hour and following it many meters one of our helpers, Tetohu, was put at following the root. After exposure, the irregular course of that particular root was from within two meters of the sand's seaward edge to the tree some forty-four meters away. From sampling of the sand area, it was decided that the roots of this particular tree, Messerschmidia argentea, occupied all the nearby sand area. This led to the postulation of root dominance of Messerschmidia over the many minute Suriana plants. This was an amazing dominance of the area for the roots spread over 40 meters, radially, while the tree top was only about two or three meters at most in diameter and height. The depth and diameter of this root and distance from the base of this tree are given in Table 1.

Table 1

Distance from tree in meters	Depth of root in centimeters	Diameter of root in centimeters
0.15	25	6.5
1.0 (?)	20	17
4.	29	3.5
10	25	2.8
22	18	1.8
30	14	1
35	8	0.6
40	-	0.4
44	2	0.1

Temperatures in the sand were measured and the coolest area in the sand was some few centimeters below the surface. The sand was hotter at the surface and at about sea temperature below this level. Table 2 is a resume of temperatures measured at different depths in the beach where Messerschmidia was growing.

Table 2

Position of thermometer bulb	Temperature in degrees Centigrade
Air above sand	29.5
Just covered with sand	33.5
Below the surface 2.5 cm	30
Below the surface 12.5 cm	26
Below the surface 21 cm	25
Below the surface 120 cm (pushed into wall of well dug one day previous)	25.5
Below the surface 90 cm (pushed into wall of well dug a few hours previous)	26.5 & 27

Temperature and related phenomena may be significant in controlling succession in the sere leading to what one finds on an atoll islet. Thus it is of interest to learn something of the temperatures tolerated by such pioneers among the bushes and trees as Messerschmidia, Suriana and Pemphis. According to Wm. H. Hatheway (personal discussion) Messerschmidia may be the only tree-like plant to occur natively on Canton in the Phoenix group. It seems likely that it may be the pioneer of this sort elsewhere as well. Thus we are prone to attach some significance to the lower temperatures found at about the level of the largest Messerschmidia roots. Certainly their significance, as well as the significance of such factors as water (set sand) and oxygen should be taken into account in studies of root biology in such beaches as this. Our apparatus, laboratory grade thermometers, did not justify any more detailed study of this possibly very important aspect of the environment.

The vegetated area at Homohomo and generally elsewhere too, was bordered by what could be called a bush zone. Actually extending over the bare ground between and even beyond the bushes in some places was Heliotropium anomalum but this was infrequent here. The bush first found upon approach from the sea was certain to be Suriana. It even extended out onto the island conglomerate at the end of the island. It extended over the sand of the beach, often as plantlets only a centimeter to two in height, to the inland edge of the sea shore island conglomerate (Fig. 3 and 5). In a short distance from the vegetational margin, but often this was hard to determine, one was certain to find Pemphis. Often a bush of Pemphis would occur surrounded by several bushes of Suriana.

Inshore of the Suriana and Pemphis one often found an almost exclusive zone of Messerschmidia. Again the Messerschmidia was diffused among these bushes or the most seaward other large plants.

The observed relationship of these two plants at Raroia appears to contrast somewhat with the observations of Fosberg (Atoll Res. Bull. No. 23) and Hatheway (op. cit. 16), but it may be that at Raroia the exposed conglomerate is a remnant exposed by hurricanes and the situations are only superficially comparable. Apparently Suriana could develop under rather rigorous conditions, in the sand and on the island conglomerate and tolerate the high temperatures, salt and lack of water experienced in such locations. However, it did not seem to be able to develop in the presence of viable roots of Messerschmidia. Indeed, on the beach where Messerschmidia was present there was apt to be no small nearby Suriana, only mature large plants. Thus, on the beach Suriana tended to be clumped separately from the Messerschmidia. Since we rarely found Pemphis isolated by itself, we gathered the impression that perhaps it or the seedlings were not tolerant of the high temperatures of the open sand and island conglomerate and was, thus, not such a pioneer. Apparently, there was not the antagonism between Pemphis and Suriana roots and the Pemphis may have been favored by the shade and lack of competition with Messerschmidia roots found in Suriana areas.

As the upper part of the beach was reached the particle size of the sand increased to that of small pebbles (IRIIRI) and gravel (KONAU KOREREKA). At the same time, there was a change in color from the buff color of the surfaces nearer the sea to grey and blackish near the trees. The color was not uniform, however. In the shade, as for example under bushes, there was less darkening and out in the open the sand was in places completely bound into a blackish cake by Entophysalis crustacea. The temperature here under the midday sun was 33.5° C. just under the algal mat. This was at least 1.2 meters above high tide line and far into the bush zone, thus, not one of the phenomena of beach rock formation, though perhaps related. Gravels and rocks in the sandy open areas in the Suriana belt tend to be whiter on top than those from further inshore and the sand between them was greenish below as in the case of the beach sand. The coloring material in all these cases seems to have been derived from Entophysalis crustacea with others, such as Calothrix scopulorum, Mastigocoleus testarum and Fischerella ambigua, contributing lesser amounts.

At the inner edge of the bush zone on the seaward end of the profile at Homohomo there was a gap covered by gravel and then various areas of Messerschmidia and finally the next to be discussed zone of Guettarda. The barren rocks from just out from under these trees and bushes are black-topped in general. Again the blackening was algal, and again in this case, Entophysalis crustacea and Calothrix scopulorum.

An interesting variation of this situation was studied on the leeward (sea) side of the Guettarda. The further from the Guettarda, the less black the rocks. This appeared to be like the reverse of a rain shadow. Perhaps, it was due to the protection from wind and thus lessening of desiccation in the "rain shadow". That it was not entirely an effect of exposure of the rock surface itself was indicated by the distribution of greenness on subsurface rocks. Under the blackened rocks near the Guettarda, rock surfaces were greenish to a depth of about seven centimeters, about four centimeters halfway across the (ca. 15 meter broad) area and only two centimeters at the seaward edge of the area, where the surface was but grey. Collections of these rocks were uniformly soaked in the laboratory to make sure the color differences observed were not due to immediately local field conditions.

Messerschmidia argentea, where bushes or small trees were present, arbitrarily was accepted as the innermost limit of the sea beach. The soil, such as it was, was the blackened gravel described above. This small tree was in general most dense near the Guettarda forest boundary and less dense toward the beach where it was irregularly scattered as isolated bushes. In this connection it is to be noted that on the transect area at Raroia Messerschmidia not only sprouts readily from stumps but layers readily from decumbent branches. The relationship between this zone and the next is described with the Guettarda forest.

C. Guettarda Forest

The greatest elevation of the Homohomo transect area was about eight and a half feet above high water line. In general the transect area was covered with Guettarda speciosa from just seaward of the highest part of the island to within perhaps five or ten meters of the high tide line on the lagoon shore, or perhaps more truly almost to the lagoon shore high tide line. This area (Figs. 2G, 3, 5) is the area supporting coconuts where planted. It should be noted that this area was a main source of Guettarda as structural timber for houses, outriggers, etc., in the village. However, the Economics of Raroia (see Danielsson in Atoll Research Bulletin No.32) is another chapter and can not be taken up here.

Upon rare occasions Messerschmidia trees of relatively enormous size (one foot trunks and tops 25 feet high) were found in the Guettarda forest. More often mere skeletons of such trees were found. Around the edges of the Guettarda forest on the Homohomo transect while investigating the soil under Guettarda we found rotten prostrate stems of Messerschmidia. These were at a stage easily disintegrated by foot: similarly-rotten roots bound them to the ground. Such stems could be followed towards the edge of the Guettarda thicket, a distance of over twenty feet, and as the stems were followed they became less rotten and finally alive and revealed themselves to be the living though prostrate trunks of the Messerschmidia bushes that so tightly and characteristically here underly and protrude from the edge of the Guettarda vegetation. Undoubtedly the Messerschmidia is very intolerant of shading and it is this that results in its beachward displacement by Guettarda though the Messerschmidia grows best inland away from the beaches. Furthermore, since the Guettarda is further from the sea shore than from the lagoon shore and only on the highest ground one is led to the conclusion that it is not very tolerant of salt water.

The large leaves of Guettarda accumulate under the trees for a time, though there was little in the way of humus. Since they are cupped they often hold small pools of rain water. Having constantly in mind the mosquito and elephantiasis problems of the Society Islands (though these were respectively, neglegible and absent at Raroia) a great many of these small pools were investigated as possible breeding places of the mosquitoes. No mosquito larvae were found in the large number of such pools looked at. Similarly there seemed to be little in the way of pools formed by empty coconut husks or in the bracts of coconut inflorescences.

The profile (Fig. 2G) of the transect indicates a low spot in the center of the island. This corresponded to what was apparently a partially filled channel crossing the island mass and transect at this place. There was essentially little change in the vegetation other than a quantitative reduction though the rocks forming the soil were larger here on the surface. The bottom of this trough of gentle profile was covered with stones largely three to eight inches in major diameter. All were heavily covered with algae (Entophysalis crustacea, Fischerella ambigua and Schizothrix longiarticulata, 11292). Much of the gravel surface under the more dense stands of Guettarda was covered with leaves of this plant with occasional larger boulders (up to 2 feet in diameter) protruding through the leaf cover. The rocks at ground level, or perhaps more properly gravels since they were usually less than three inches in major dimension, were in these areas rather barren as were the tops of the larger boulders protruding through the leaf cover. However, on the vertical sides of some of the larger rocks black rather nostocaceous lumps appeared, probably due to Anacystis montana 11302 and 11304 with the algae apparent nearer the ground as browner patches of this algae and Anacystis montana, Schizothrix giuseppei, Entophysalis crustacea, and Scytonema crustacea, 11305. In less shaded and less leaf covered regions the rocks forming the surface layers of the soil and the sand had more in the way of discoloration by Calothrix parietina, Fischerella ambigua, Entophysalis crustacea, and a fungus (11290) but still the discoloration was nothing like that found nearer the shores.

The seaward beach consists of foraminiferal sand at its seaward edge. At the inshore edge it is coarser and has much fine gravel in it. Just inside the bush zone on the seaward edge the sand may be bound by an algal coating as described. Inside this region the sand is gone as though it had been washed out of the gravel. The gravel is coarser at this seaward edge and becomes increasingly fine as the lagoon shore is approached. At least there is, toward the lagoon shore, an increasing predominance of sand and smaller gravels; the larger gravel is perhaps there too. However, the sandy material toward the lagoon shore above high water line has a different appearance from that on the sea shore. This lagoon shore appears to be of clastic material, largely broken coral fragments in the broadest sense. The foraminiferal sand type is found in abundance toward the center of the island lagoon shore and below high tide line, but not toward the end of the island and the channel which separated the island across which our transect ran from the next island. In Figure 5 this change is indicated by the breadth between the trees and dark intertidal zone.

The sandier soil toward the lagoon shore was beset with pebbles closely placed on the surface. Blue green alga of rather gelatinous consistency (Entophysalis crustacea, Schizothrix longiarticulata, Anacystis montana, and Scytonema crustacea, 11302) coated the soil. While grey at the surface below about a depth of about 2 millimeters, where not covered with pebbles or rocks, the sand is green down to about the 2.5 centimeter level. This appears to be sheath material of Symploca kieneri (?), Entophysalis crustacea and Scytonema hofmannii (11285). The pebbles which cover the sandy soil in certain small discontinuous areas were thoroughly algalated with Scytonema hofmannii and Entophysalis crustacea (11303), often so much so that they appeared black.

Inshore of the lagoon storm ramps and around the nearest dug well shown (Fig. 2G), occasional nearly buried stones were exfoliating either from natural causes or because fires had burned over them. The exfoliated chips were uniformly covered with such algae as Entophysalis crustacea, Fischerella ambigua, Schizothrix longiarticulata and Scytonema crustacea (11284) on their outer surfaces. Perhaps these algae play some role in the breakdown of land laid rocks, e. g. in "boring" into the rocks and inducing softening or increasing the water-permeability of the rock. Other rocks that protruded in an otherwise more or less algal sterile area of soil that had been burned over were heavily covered with Entophysalis crustacea, Scytonema crustacea and Schizothrix guiseppei (11304). In fact these were the most heavily algal-covered rocks on the land. Rotten woody debris found here was heavily covered with Scytonema ocellatum (11297).

The soil on the Homohomo transect has been described in its superficial aspects above. Humus could be distinguished toward the lagoon shore. Even toward the center of the profile in a small rather dense coconut grove an upper A-1 zone of humus could be distinguished in which the only living things detected were fungus filaments (11288) and a lower brown sand zone, an A-2 zone, of little or no humus with the same fungus filaments (11287). Toward the sea the plants seemed to grow just as well without such humus, the surface being covered with the relatively coarse gravel described to a depth of a foot or more. The geological members of the party pointed out that this was very likely due to the finer material having been washed out by the hurricanes. It was suggested that the remaining algal covered coral fragments may substitute for the "A" soil zone. Roots were not found in the superficial few inches of gravel which were discolored by algal material but there were lots of them below a depth of about fifteen centimeters where pinkish-buff sand fills in between the coral fragments. Perhaps the essential products of this rare type of "A" zone was dark and about three centimeters thick.

A considerable amount of time was spent attempting to estimate the specific distributions of the various smaller plants along the Homohomo profile and in this transect area. The area had apparently been burned over repeatedly through the years, with the various irregular burned areas overlapping. This was both an advantage and a disadvantage in attempting to devise tentative explanations for the distributions observed. Perhaps the most clear observation was that Microsorium scolopendria, the ever common Polypodium-like fern, was coextensive in range with Guettarda, often growing on it and all about under it. It seemed to grow as well with the coconuts.

Other plants were less clear in their roles and distribution. Scaevola frutescens, which one normally expects on beaches and the common Euphorbia atoto, grew throughout the burned-over areas, with the Euphorbia apparently appearing first and perhaps being restricted to the Guettarda area. The Scaevola did extend beyond the limits of where Guettarda grew, especially toward the channel between the island across which the transect was studied and the next island, Tomogagie.. It did occur in numerous forms with different flower colors and leaf shapes and as large shrubs with 4 cm stems up to ten feet high. The forms in dense shade seemed more attenuated and viney and weak, while the best development was toward the more brightly illuminated margin of the Guettarda zone, where the Guettarda had been removed by burning or cutting, and in the inner areas where Messerschmidia could be expected to be most prominent otherwise. Morinda citrifolia was most dense in an irregular zone 30 meters broad, the lagoonward edge of which was about 30 or 40 meters from high tide line. Portulaca johnii occurred on this transect area where there was the most humus.

D. Lagoon Shore

1. Lagoon shore above high tide line. On the lagoon beach (Figs. 3 and 5 (between trees and first lagoonward dark line)) of the transect area it seemed clear that other things being equal there would be a condensed version of the transition from Guettarda to Messerschmidia to the bushes Pemphis and Suriana. However here local variations in the composition and form of the beach were more pronounced comparatively as this whole transition appeared to be restricted to a band about five to fifteen meters broad. The lagoon shore (Figs. 3 and 5) appeared here to be one that was building up and extending into the lagoon for there was loose material accumulated in front of the vegetation and an active reef below low tide line. Messerschmidia was present, however, only near the end of the island.

Morphologically the surface covered by flowering plants sloped gently toward the lagoon from an elevation of about three feet. This surface was rather solidly of the clastic sand and small gravels described above. While under the edge of the Guettarda or Messerschmidia the gravels were blackish and the sand dark grey, toward the lagoon the surface became lighter grey. This was due to a coat of Mastigocoleus testarum and Entophysalis crustacea (11286). The individual pebbles are darker on their upward facing surfaces with increasing prominence of Scytonema hofmannii (11303) and lighter on their surfaces facing the lagoon ridges and facing down.

The most inland rampart or lagoon beach ridge (Fig. 3) is flat topped and sloped uniformly down on both the landward and seaward faces. The top of the rampart is whitish in aspect and consists of mixed gravels mostly smaller than three centimeters in their largest dimension. The lagoon facing side of this upper storm rampart above the whitened gravels below high tide line are grey in gross aspect. Individual gravels are grey on their long exposed surface, brownish on their edges and greenish under their edges, fading away to white in the center if the lower surface is sufficiently large. Such stones were turned over just above high tide line and left in order to determine if this typically-grey coating would appear during the approximately two months we were to be there. These stones remained in appearance quite as when turned over.

The top of this major lagoon beach rampart (Fig. 6) is as uniform as though it were a small man-made grade and is the principal walkway along the lagoon shore. Below the lagoonward base of this rampart were two or three smaller ramparts of whitish gravels. The surfaces of these 2.5 cm minus gravels are harder than those of the grey gravels above when tested with a knife. It was observed that these gravels are worked over vigorously at times of high tide coincident with onshore winds at the lagoon shore. Thus it was concluded that the algae and any surfaces softened by weathering are kept ground off. There was little in the way of algae apparent here other than minute brown patches in cavities in some of the pebbles. Melaraphe, however, is common to such lagoon gravelly beaches just above high tide level.

2. Lagoon intertidal shore. The intertidal region (Fig. 3) of the lagoon shore on the Homohomo transect consists of a gentle slope of centimeter-minus gravels about 3.2 meters broad. Its extent was recognizable by the brown color induced by blue-green algae. It appears as a narrow dark irregular band in Figure 5 in the transect area, the inner sharp margin of which is separated from the trees by the light colored beach area. Away from the end of the island the size of the gravels was much less and Nerita polita migrated back and forth over it just landward of the usual wash of the waves as the tide rose and fell.

Behind each embayment in the lobed lagoon reef the intertidal area and lesser gravel ramparts above it were concave in form.

The only fishes seen here over this part of the shore were mullet at high tide. One red and brown shore crab was common here in the intertidal region. These crabs were often poised just outside the reach of the waves. The scientists and children delighted in their response to being tossed into the water. The crab, hesitating a moment and then orienting with the wave motion, would hurriedly scramble back up on the beach out of the water.

3. Lagoon subtidal shore. Along the lagoon shore, except where there was a gravel bank opposite a channel opening into the lagoon, there was a reef bordered by active coral animals. This reef shows as a linear irregular dark area opposite the island lagoon shores in Figure 5 between the intertidal region and the lagoon bottom. For the sake of discussion this reef can be divided into a number of zones, enumerated here as "A" through "G" and illustrated in Figure 6. They are taken up here as they were most extensively studied in conjunction with our study of this transect.

Geographically and morphologically "A" regions (Fig. 6A) are intertidal, and have been described above.

"B" regions are very variable and consist of a coralline algal pavement (Fig. 6B), coralline algal nodules or gravels. If unconsolidated the "B" regions consist of an even more gently sloping slope than "A" regions and are covered by gravels. Here, however, there are more small and more flat pieces and the gravel is coral chunks covered with coralline algae. This area was six meters broad on the profile. Other "B" areas to be noted are the Porolithon (11357) algal pavements which are quite flat (see below) in nature.

In this "B" area Cypraea obvelata was found in association with the coralline algae. Latirus sp. was found active on the rocks at night in both the "B" and "C" zones. It was not found on the sea reef. Mullet on occasion swam over such areas as the "B" area and over the more lagoonward areas as well. Just below low tide line a holothurian was especially common in cavities in the coralline algal pavement and the coralline algae covered, fragment areas (Fig. 6B "N" and "O"). Under the rocks in this area is a white Isonomon along with an Arca (of the A. noae group (turkey feather ark shells)). Perhaps here hypo- and epibioses should be considered separately. Most of the animals found here are hypobiotic.

"C" regions are sand dominated flats (Fig. 6C) and are essentially the bottoms of reef pools. They show up in Figure 5 as the lightest colored region on the lagoon reef. A few living corals are found on rock chunks with a few holothurians (11361, 11363). This region on the profile is about four meters broad. This is the deepest part of the lagoon reef flat, but rarely over a foot deep at low pool level here at Homohomo.

Often Halicaries (a small wrass) hides among the coralline nodules or coralline covered rubble. Perhaps these fish are truly characteristic of this "C" region for the other fishes seen here occasionally are largely species much more abundant elsewhere.

While on the outer reef Strombus maculatus is common in the sandier parts of the pool channel region, in the sandy pool region or reef flat (Zone "C") of the lagoon shore two different species are common. These are Strombus varabilis and S. gibberulus. S. variabilis is quite similar to S. maculatus differing in having only obscure striations and these only in the central portion of the outer lip. In S. maculatus this striation is rather uniform and distinct all along the yellowish outer lip. Conus tulipa was collected alive in the deeper parts of the "C" region which were in connection across to the sand beyond the reef edge at about the "D" or "E" level, horizontally speaking. Conus eburneus is found with the two Strombus species mentioned above.

Beyond the "C" area one stepped up abruptly onto what we may call a "D" area (Fig. 6D) of dead coral the upper surfaces of which were often silt covered. This area was 2 meters broad and dominated by sandy patches, the coral occupying less area than the sand. In Figure 5 the "D" area is the light grey shoreward edge of the grey lagoon reef margin.

This was followed by an "E" zone (Fig. 6E) that was essentially an eight meter belt of the same Pocillopora (largely) as in the "D" and following "F" zones. Sand bottomed areas between patches of Pocillopora are minor in area covered. Living Porites was found around the edge of each Pocillopora patch. The aspect was often that of the inside of a microatoll top with many small Tridacna specimens and a general surface veneer of algal material. It is over this heavily "algalated" inner reef edge that Acanthurus triostegus (the convict surgeon fish) is most abundant. It does appear commonly both inshoreward and further offshore but in reduced numbers. It seems to feed on the non-calcareous algae that cover dead Pocillopora branches with a brownish coating. These algae are fine reds and Zonaria. In the sand-bottomed channels between the larger patches Acropora was common but the heads were small.

An "F" zone is to be distinguished (Fig. 6F) as a dense mass of coral fingers, again the same Pocillopora, alive at least on the lateral upper edges and not closed over at the surface. However the tops were veneered with algae, often of filamentous Rhodophyta. No sandy areas are to be seen in this three meter broad region. The spaces between the coral animal fingers were often plugged a few inches down with algal material, often Zonaria or Rhipilia.

Finally the very dark and narrow (Fig. 5) irregular edge of the lagoon reef was distinguished as a "G" area. While about 0.5 meters broad (Fig. 6G) the living coral was largely distinct heads on the reef margin and gently sloping downward from the level of "F". There was no algal veneer on the surface.

In the corals here there was found an Anomia-like clam boring like a Lithophaga. Leather urchins (related to the sea stars, Asteroidea, because of their ambilacral grooves) can be reported from here. On the reef patches these were found further in from the reef margin; perhaps in what is referred to as the D-zone above. Over the edge on protruding lobes of the lagoon reef the drop-off was vertical or even locally overhanging, but in embayments in the reef the drop-off was at about forty-five degrees to the sand or sediment covered bottom six to ten feet below.

The numbers of Acanthurus and Pomocentrus common inshore and on top of the lagoon reef are considerably reduced as one drops over the edge of the nearly vertical reef edge. This is ichthyologically the most varied habitat in the way of species and the most productive in the way of numbers. Surgeon fishes cruise along with the large parrot fishes audibly nipping off chunks of coralline algae. Accompanying them are often various large wrasses which, while they feed with the parrot fishes, have small teeth and seem to search for invertebrates among the algae. Unlike the parrot fishes, which always dash for open water or herd along the shore when disturbed, the wrasses may hide in caves or under overhanging ledges. The surgeon fishes common in this area too will hide in such places. They are frequently seen to swim along the face of the reef above a cave or overhanging place and right on under the roof or ledge. The observer is bound to be somewhat disturbed by the picture of the several different kinds of surgeon fishes then swimming along the overhanging surface wrong side up, or on their sides.

A cave fish fauna appears here of fishes which more or less continuously occupy these places in which the wrasses and surgeon fishes merely hide. Most conspicuous of these are the brotulids and large sea basses. Along with one of these sea basses there often moves a trumpet fish, an Aulostomus or a Fistularia. The unwary observer may swim down to take a close look at a brightly colored yellow trumpet fish and upon very close approach suddenly become aware of the very large well tooth dark colored fish alongside which the trumpet fish was hiding. Often just at that moment one is inclined, though the sea bass are harmless, to go to the surface for air.

A perhaps even more interesting association of two fishes is seen in the case of a blenny and the large parrot fish (TINGATINGA). Now most proper blennies are residents of the bottoms or piles of rubble, but this one accompanies the parrot fish swimming in an odd leaping fashion, shomewhat like a finch in flight. This blenny (commonly called a tick fish) is furthermore unusual in having broad longitudinal stripes of blue, black and red. When the parrot fish feeds the blenny presses alongside the parrot fish and cleans off its larger companion's beak-like jaws, teeth and head area.

In all there are more fish in the way of numbers and species here than on all the other parts of the lagoon end of the transect put together.

The edge of the lagoon reef, the "G" areas, drop abruptly (Figs. 3 and 6) to the fine white gently sloping lagoon bottom three to seven meters below. This lagoon bottom shows in figure 5 as a white area dotted with brownish (black in the figure) patches of coral and coral rubble. There was little in the way of life on this white surface.

In the sand bottom of this region fish rarely seen by others than ichthyologists dominate. These are fish which are quite peculiar to this region such as burrowing gobies and eels (Echidnidae, Moringuidae and Echelidae). In places of seclusion in coral rubble are many small blennies and the young of the larger wrasses and of the various eels, such as the unpleasant morays. Perhaps some of the most characteristic forms of the whole flat sand area are the lizard fishes. The water area of this region is characterized by many kinds and large numbers of transient forms most of which are apt to move out of the area as one approaches. This habit of the inhabitants makes them difficult to obtain by any but very careful placement of fish poison if they are to be taken at all by poisoning.

The area between the reef edge and the first lagoon patch reef (Fig. 3H) is essentially a channel frequented near the upper surface by the needle gars and half beaks which are also common to the areas further lagoonward. These forms are unusual shoreward of the reef edge. Further down in the water cruise various sharks. An occasional remora causes the swimming observer to look around nervously for its normal and more voracious shark buddy. Nearer the bottom characteristically there cruise carangids and large lutjanids.

One of the more ludicrous ichthyological wonders available to the swimming observer in this area is Dascyllus, a small black and white fish of the Pomocentridae. This fish swims in schools about the occasional branched coral heads at the bottom of the reef edge and out on the fine sand bottom. When some danger is anticipated, as from a suddenly thrust outward set of fingers on an arm, the whole school dashes into the seclusion of the branched coral mass only to drift out almost together in a few seconds cautiously and ready to sink into the coral should the pretended danger still threaten.

Along the vertical face of the coral patches and lagoon shore reef there is a bright blue small (4 cm long) fish, Chromis, which in small schools behaves in somewhat the same manner, but is more venturesome...getting as much as six or eight meters out in the lagoon.

A consideration of the distribution of variations on the lagoon reef as one might see them from the air (Fig. 5) is most valuable here. As seen from this Figure 5 the lagoon reef is not a regular band along the shore but a series of irregular lobes with, in the transect area, the lagoon face flattened and the flat face tending to face the wind. One of these is diagrammatically illustrated both in profile and as seen from above in Figure 6. This same lobe shows in Figure 5 as the third from the north end of the island. Even a very brief study of these regions and the reef in the lagoon reveals great similarity between the two. The individual lobes of the lagoon shore reef may best be considered as patch reefs of which the island shore forms one edge. As one goes toward an embayment between such shore-bound patch reefs, or lobes of the lagoon reef, there is a conspicuous change depending upon whether one is moving toward the end of the island (and the channel there) or along the shore toward the island center. The "C" areas are essentially separate pools and in line with the wind induced surface currents these drain out toward the center of the island lagoon shore over what is essentially a "D" area. The "C" area is closer to this down current edge of the shore bound patch reef, e. g., here the "D", "E", "F" and "G" areas are narrower or absent.

The "A" and "G" regions were the most consistent in composition and general character. The other areas varied widely from place to place, and cannot be characterized by any single profile study. In all positions in reference to these shore bound patch reefs the "A" zone remains approximately the same except for the change in particle size noted. The most conspicuous difference is in the qualitative character of that region termed here "B". At upcurrent sides of the reef patch (Fig. 6B "O") the "B" area is largely coral fragments covered with a coralline algal coating (11357 (but also see 11352)) and there are many holothurians between these fragments. Even further upstream, or between adjacent shore bound reef patches, there is a pavement (Fig. 6B "M") of coralline algal material (11364) just below low pool level. This pavement is about one meter or a meter and a half wide and nearly horizontal. Usually bordering this pavement on its offshore side and downstream side was an area (Fig. 6B "N") of close-lying coralline algal nodules (Porolithon 11366, 11365 and 11364). In Figure 5 the lagoonward margin of this pavement shows as a very faint dark line across the shore edge of the second reef lobe south from the channel north of the transect area. Usually over the upstream "D" and "C" areas there was a pink sandy layer over the tops of fragments, coral heads and microatolls that may be the same coralline algae (11361) as that forming the pavement in the "B" area, but very much less well developed.

Algae were found, further, under stones in the "C" areas where they were usually forms such as completely prostrate crustose Peysonnelia species and Ectocarpoid species such as (11353, perhaps really from "B" sandy areas). Spots of Sphacellaria were obtained here as well. Apparently such algae form the food for certain of the fishes, but no exacting food chains were worked out. Rhipilia, probably R. geppii Taylor, was common both under such boulders in the "C" zone and between the phalanges of the Pocillopora of more lagoonward areas "D" to "F". This species seemed active in trapping and binding sand in crevices and holes and may play an active role in solidifying of the reef material below the surface: the corallines being far more active, however, than Rhipilia right at the surface. Zonaria species, again, play a role if nothing else in overgrowing the sides of the coral animals and perhaps killing them by cutting off their food supply.

Along the lagoon shore further from where the active reef is near shore, that is near the center of the island shore where the "A" and "B" areas are sandy and indistinguishable from the "C" areas, there are little sandy points upon occasion. These (Fig. 5) are usually in line with reef edge configurations or beach rock outliers or other offshore features. The bases of these points while sandy themselves are often accompanied on each side by patches of Jania (11351 (see also 11350)). Where further offshore the consolidated reef flat was not so strongly overlain by sand there was a coating of Gelidium (11029) everywhere. Characteristic tufts of Lyngbya majuscula and Caulerpa serrulata (11010) are about the only macroscopically recognizable subtidal algae on the lagoon shores otherwise. Above low tide line on rocks are recognizable what appeared to be Ectocarpus indicus and some of the little ubiquitous but almost unidentifiable tropical Enteromorpha species.

Only about ten species of fish were to be found from the high tide line to the outer edge of the shore reef. This is a generally non-fishy area. Over the coral edge of the shore reef or as one approaches the edge there is a great increase in the number of the little (10 cm) black Pomocentrus nigrigans which with its head protruding from almost each hole in the coral greets the observer with a pair of very cold dark eyes. This small four-inch fish is common in fewer numbers outward and down over the face of the reef as well.

III. A COMPARISON OF THE OTHER AREAS STUDIED

To avoid needless repetition of observations the differences between the seven transect areas studied are recorded below in one series of sections rather than putting in descriptions of each transect area. The location of these areas and the profiles through them may be found in the diagrams, figures 1 and 2.

A. Sea Shore

Animal coral was not a conspicuous element anywhere visible from the surface of the reef. In general the Village or Raro reefs were the sea reefs having the most coelentrates on them. The sea reefs of other areas had far fewer. Nowhere were they apparently dominant and leading to increase in mass of the reef flat or reef margin; this seemed to be an algal activity. However, it appeared that a majority of the gravels and stones making up the islands were coelenterate coral material. Foraminifera were major contributors of the coarser sand found.

1. Spurs and Grooves. Flying just offshore along the windward reef from Kaea to Tahuna Maru provided the only opportunity of seeing much of the windward spurs and grooves. Occasional fleeting observations were made from the top of the algal ridge but these gave us at best but a qualitative appraisal. The reef flat, perhaps in correlation with the higher general surf level, seemed higher in elevation than that on the lee side of the atoll. The spurs in our photographs and from the shore at Tahuna Maru and Kaea appeared to be relatively broad and flat. Often they appeared to be narrowed toward their inshore end and thus the grooves between widened. They pitched on a rather even slope into the sea from the seaward edge of the algal ridge. Between the lowest wave trough levels aerial photographs indicate a rather rough and broken pasture of small coral knolls and very irregular channels.

The view obtained by swimming seaward down the gradually widening grooves was very different on the sea shore of Motufano (Tokerau), Homohomo (Fig. 5) and Oneroa. In these latter places at least for fifty yards seaward the grooves gradually widened and deepened. The surface of the spurs seemed to be sloping more steeply than the floors of the grooves. This gave the impression that these two features would blend into a coral plane a few hundred yards off shore.

While little sampling was feasible, the surfaces of the grooves and spurs everywhere seen were pink as though covered by Porolithon. Certainly those of Tokerau, Raro and the village area investigated by swimming were covered by this genus. In a very few places Pocillopora was found on the inshore tops of the ridges below low tide line.

While almost all the Porolithon observed appeared to be P. onkodes in one place on a ridge top below low tide line a specimen of P. aequinoctiale was obtained. This is an interesting record, though considered anomalous at the time, for this species appears to be a dominant species in similar areas at Johnston Island (Novelty shoal).

At Gake and in a few other places the spurs in addition to P. onkodes had Amphiroa (11488) on them if their shoreward end was broad. There are rare patches of poorly developed P. ?gardneri (11485) on these ridges and what appears to be the same species still more poorly developed occurs behind (inside) the algal ridge.

The surge channels in places extend through the first of the ridges of "beach rock." In places they are very broad (10M) between the algal ridge and the exposed island conglomerate and they are ca ½ to 1M deep. Their bottoms are scoured but wide places have corals in them. Coral were not conspicuous otherwise on this transect area. Essentially the same situation prevailed at Kaea, but here the algal ridge was less often cut through by the grooves. The grooves themselves left us with the impression of being shallower and more numerous, and from the aerial photographs, more irregular in their courses.

2. Algal Ridge. The reef ridge area was defined on the profile as the surfaces of the reef margin above low pool level. The ridge as a whole protruding from the pool bottom level might be an at least equally useful unit. It is felt that at Garumaoa, the level of the reef ridge line and the upper level of the boring urchins or the seaward edge of the Amphiroa zone (Fig. 2E) is at the base of any reef ridge that may exist as defined in the field. Perhaps the pool impounded by a well developed algal ridge changes the habitat so as to favor the urchins which seem to be the most active agents in destroying especially the inshore edge of the algal ridge.

At Gake, and Gagieroa there seemed to be a so-called "backridge trough" rather than the flat Amphiroa zone recognizable elsewhere (Fig. 3) at Raroia. This was often true elsewhere in Kereteki and to some extent at Gake, Takume. This seems to imply that perhaps the reef ridge should be defined as the seaward raised area on the reef which impounds a pool and gives the reef flat the characteristics of a tidepool.

As one proceeds along the reef ridge at Gavarivari (Fig. 1), the general level of the top of the reef ridge changes. Centrally along the island shore on the profile (Fig. 2A) the ridge was about 30 cm high (above low pool level). That opposite the northern half of the island, while not sharply lower than opposite the southern half is about a foot lower. This lower reef ridge is more thoroughly "algalated" from its pool edge to below its seaward edge. Still from a distance it is uniformly pink in appearance.

The outer half of the Gavarivari reef ridge is covered with P. onkodes (11926). Microdictyon okamurae and a fine Jania sp. are characteristic epiphytes on the P. onkodes. A Laurencia-like alga (11926) is common in small hollows and holes. The more eroded inner half of the ridge is higher than the outer half and appears to be more actively covered (11925) by non-calcareous algae at the surface than by P. onkodes. Cypraea depressa (11927) and C. mauritiana (11927) were found on the inshore slope of the reef ridge down to within 15 cm of the pool level. The genus Drupa was represented by numbers of D. morum and D. ricinus. Many vermetids (11919 = J.P.E.M. 2221) were seen. It seemed that even Turbo setosa was much more common on these inshore slopes. The latter delightfully comestible species as well as the purely scientifically interesting species were not searched for diligently on the seaward slope of the reef ridge for the usual reasons applicable to research on windward reefs.

The higher reef ridge generally opposite the south half of Gavarivari, was in correlation with somewhat different appearance. The inshore half of this ridge was yellow brown in color. This coloration is given by what appears to be blue green algae, at least in part Rivularia polyotis (11919) on erect spines of rock left by the erosion of the ridge material. In places the algal coating is sufficiently developed to look not unlike that covering the sometimes similar spines of rock just above the pool level at the inshore side of the reef flat or inshore margins of the reef pool.

There was little or no general algal cover of the rock here. The only algal materials at all common were isolated tufts of a Dictyosphaeria and a Microdictyon (11919). On the larger Drupa shells and dead Vermetus shells there were obviously fine algae but these forms did not cover to such an extent that the ridge appeared to be dominated by non-calcareous algae (and different species were involved) as on the inshore part of the reef ridge further north at Gavarivari.

Similarly there were few living animals in sight. Drupa ricinus and Drupa morum were found only on reef ridge pot hole bottoms and on their sides.

Low on the inshore edge of the ridge the reef is pink with various algae, but predominantly P. onkodes. (Amphiroa (11917) is not a meadow hereabouts but is found in frequent patches or tufts irregularly two to four centimeters across. This is the only area on the atoll where Centroceros was recognized in the field as a consistent dominant and these areas were small bright red patches of uniform appearance. Laurencia formed skimpy coatings and small tufts in the hollows and holes of the general P. onkodes cover.

The seaward half of the higher ridge area is, at most, perhaps 9 to 12 centimeters lower than the inshore half. This outer reef area was bright pink in area and a priori appeared to be a suitable area for the surf dwelling P. gardneri and related forms. However, in no place at Gavarivari or Gagieroa was there any trace of living Porolithon gardneri or similar species. On Gavarivari, however, were found the greatest concentration of boulders in the island structure which were fossil remnants of such species.

One "clump" of what appeared to be P. aequinoctiale was lost when pried loose in a surge channel bottom. Turbo setosa was common on this higher ridge as elsewhere. No living Cypraeas were seen on this higher part of the ridge either on the inshore or offshore half. A medium sized dead vermetid (11919 = J.P.E.M. 2220) was abundant coiled flat on the reef ridge pavement. It was different from the vermetid (11927) on the lower reef further north.

The algal ridge at Gake (Fig. 2E) has large (25 cm) pits that are interpreted as evidence of erosion by solution.* The outer high part has fine algae (Laurencia 11487, 11491) and arches or domes of P. onkodes (11486). The algal ridge at Gagieroa was not only pitted on top but it appeared as though it had been a rather high ridge now truncated by erosion.

In general as the Garumaoa village area was approached from Gake through Tokerau the algal ridge became less ridge-like and more of a cuesta. While still more often little other than a cuesta, as one proceeded southward to Oneroa a ridge was often present. This ridge when present was very often deeply pitted on the inshore side by holes often occupied by pencil urchins. There was little algal cover in such places beyond a general pink calcareous coating taken to be undeveloped P. onkodes.

The sea reef in front of Tetou (Figs. 2B and 2C) is covered with non-calcareous filamentous algae. While it seems to possess an impressive algal ridge the only calcareous alga in sight that appears alive is a fine Jania intermixed with the non-calcareous filamentous algae.

As one progresses along this ridge northward there are some clear but inconspicuous changes seen. Firstly, there is an increasing abundance of Bryopsis pennata (in 11851-11852) until it forms conspicuous turfs of a square meter or so in area. This then gradually became less conspicuous and a branched matted Codium (11860) became common only to disappear as there came into prominence in turn Neomeris (11857 etc.). While at first found only in holes, a tenth of a kilometer further on it lined many of the larger cavity rims. This species was small and ringed and when small hardly calcified. A half kilometer further along the Codium was gone and Neomeris is scarce. Then a Dictyosphaeria (1 cell thick and hollow) became common. At about this point almost 3 km. north of Tetou, there were the beginnings of a conspicuous display of P. onkodes (11859). This was first seen around low edges of excurrent channels, but further on, it extended to local algal ridge prominences. The P. onkodes was never conspicuous though and possibly because of extreme erosion here it was on its way out (i. e. here there was merely a less dead Porolithon ridge than directly opposite the village of Tetou).

One kilometer south of Tetou the algal ridge has P. onkodes (11846) showing in about the same degree as 2 or 3 kilometers north described above.

At Kaea the reef ridge area and more seaward areas were pink with P. onkodes. Turbo setosa was common. Little else was visible. In one of the deepest of the excurrent channels through the algal ridge a few coelenterate corals were to be seen; none was seen on the reef flat, the algal ridge or elsewhere. The algal ridge (Fig. 2D) was sloped very gently into the pool on the reef flat. A few miles south, at Tetou, the reef ridge was much the highest seen and there covered with a coating of non-calcareous algae and sharply distinct from the reef flat area. Here at Kaea the inward edge of the algal ridge area was hard to locate because of the gentle even slope and the lack of macroscopically distinct indicator organisms. The rather uniformly high edge was cut into from the seaward face by numerous low surge channels, only a very few of which extended through.

* [Considered by Newell to be mainly an effect of gravel scour. Ed.]

At Mataira and in the same geographic area of Takume Atoll the margin of the reef gradually sloped upward resembling "Reef type II-B-(1)" at Bikini as depicted by Tracey in his figure 1 (Bull. Geol. Soc. Amer. 59, 1948). Here likewise were found the only good cases of grooves extending into the reef flat and overgrown at the surface to any extent. One of these into which we could dive was perhaps 20 meters long, five meters deep and from 0.1 to 2 meters broad.

3. Reef flat. The reef flat (Fig. 3) is considered to be a tidepool biotically related to the sublittoral region. The seaward edge of the black coating of blue-green algae seen in aerial photographs is the inshore margin. This margin is broken (Fig. 5) by the complete channels between the islands. The seaward wall of this pool is the algal ridge.

The narrow heads of grooves frequently extend from the sea through this wall on the windward shore. These are, then, related to small localized excurrent areas. More generalized larger excurrent areas connect the reef pool to the sea as the village and pass area are approached. It may be the single pass rather than the leewardness of the village area that is responsible for this difference in connection between reef flat and sea on the windward and leeward shores.

At Gavarivari there is no division of the reef flat into Amphiroa, or boring urchin zone, etc. The whole reef flat is characterized by the lightly sanded pink pavement and black holothurians to be expected in channel pool areas. This outer part of the reef flat at Gavarivari could be interpreted as a situation where there was a poorly developed back-ridge trough. No corals at all were seen on the reef or reef flat there. Only two Diadema specimen were found and a very small black shrimp was found under circumstances that led us to believe it had come from around the bases of the Diadema spines. The common black-tipped sharks so timid near the village would move right in head on when they first sighted (smelled) something. They were relatively easily repelled, however, if one jumped on them.

In this zone at Tetou, just inside the reef ridge Symploca hydnoides was found as soft wisps with gelatinous centers.

At Gavarivari the inner part of the reef flat was distinct from what has been described above as the pool area. Under rocks near the shore edge of this area are many large boulders 30 to 100 centimeters in diameter and usually rather thin proportionally. Under these there is an aggregation of small gravel and even sand. These particles were found to be variously cemented to the large boulders, to the reef pavement, and to each other. These shaded surfaces are often coated green and often supported various non-calcareous algae (11922) which seem to be but poor developments of those species found on the reef margin or algal ridge.

As animals perhaps the most abundant macroscopically was Morula granulata (M. tuberculata in Tinker's very useful book). Under rocks was a variety of small Cerithium-like gastropods among which Planaxis? zonatus was the most common of these "smaller than usual collecting size" shells. One shell of Morula uva (called M. nodus in Tinker's book) was obtained. One shell of Imbricaria punctata was found. This was unusually plain white but the appertture had the violet anterior tip to the columellar surface characteristic of this species. One small specimen, about one centimeter long, of Conus miliaris was found under a stone. The above six molluscs (MD 11923) are in the U. S. National Museum under the number JPEM 2218.

Locally near the shore at Gavarivari and Gagieroa there were clusters of Chama half-shells protruding from the reef pavement. No living Chamas were seen here. Few of the other characteristic animals of such regions were seen alive. For example, after some searching, a few Conus sponsalis were seen but of the shells found only one was alive. Few other gastropods were found here (11923).

Drupa grossularia, common in leeward reef pool zones at Raroia was not found at all on the windward reefs of Raroia. This species was also uncommon on the windward reefs at Bikini, only about a half dozen specimens being found according to Morrison.

As hermit houses (11931 = JPEM 2222) Bursa bufonium, Thais hippocastaneum, Vasum sp., Strombus gibberulus, S. mutabilis were common. Both Strombus gibberulus and S. mutabilis normally at Raroia are lagoon specimen but Morrison found that at Bikini S. mutabilis occurs with S. maculatus on the sea reef flat. Cronia, Tectarius, Nerita, Cerithium, Polia, Morula and Mitra litterata occurred. The last four, while hermits, are characteristic when alive of the inshore portion of the reef pool area. Cronia, Tectarius and Nerita are characteristic of the shore between tides or above the tides in the case of Tectarius. Vasum and Bursa are probably characteristic of the more seaward pool areas.

On both the Mataira (Figs. 1 and 2F) and the Gake (Figs. 1 and 2E) transect areas the inshore edge of the reef flat was, in general more shallow than the outer part. The bottom near high tide line was conglomerate rock with large shallow pits on the surface. In these there was very often a flattened stone. As the observer moved seaward these pits were more and more frequently fused forming chains of pools through which the water drained as the pool level lowered. Toward the seaward edge of the system the walls of the individual pools gradually were reduced to merely sharp pinnacles a decimeter or two high. At Mataira, these disappeared about halfway across the reef flat. The outer part of the reef being smooth to its sea margin.

At Gake the inner half is so irregular in elevation that one has the effect of a series of incomplete small reef pools 25 to 60 cm in diameter. The bottoms tend to display the reef pool characteristics of being covered with a fine coating of sand and what is taken to be juvenile encrusting coralline algae. On this bottom there were to be found many specimens of such species as the Strombus maculatus, Conus ebraeus and C. sponsalis characteristic of the pool area of the sea end of the Gavarivari transect. Cypraea moneta and some of the characteristic Drupa species (and D. grossularia as hermit shells) were also seen. The walls of these pools and the lowest of the ridges by their color and general appearance seemed to represent the shore between high tide level and low pool level.

In contrast almost the whole reef flat at Kaea was a pool zone with little other than a smooth coating of coralline algae visible. At Kaea there were many relatively small reef boulders, but they were not as numerous as they were at Gavarivari where there were larger ones as well.

4. Intertidal and Wave-wet Shore. This area is divisible in general into a lower yellow zone and an upper black zone. The junction between them was considered after observation to be high tide line. In general on solid shores the intertidal or yellow zone was a gently sloping consolidated shore about 20 or 30 centimeters high and two meters broad. The black zone above was usually a precipitous drop of 115 centimeters (Matajra, Fig. 2F) or so over the edge of a consolidated rock bench (PAKOKOTA). The black zone also extended as a coating inshore over the upper surface of this bench for a variable distance.

At Kaea (Fig. 2D) this yellow intertidal zone was largely coated (11900) with Entophysalis crustacea and Plectonema nostocorum. At Tetou (Figs. 2B and C) this yellow zone was coated with the same Entophysalis and in addition Calothrix aeruginea (11321). At Tetou the yellow zone rocks were in places covered by a fine brown fuzz (11322).

On the transect area at Gake the walls of the pools dominating the shoreward part of the reef flat protruded from the low pool level water surface. The algae (11483), Entophysalis crustacea, Rivularia polyotis, Plectonema nostocorum, Calothrix scopulorum and C. crustacea, coat this protruding rock a yellow brown. Thus, these protruding points and pool walls were listed as intertidal. The presence of a few specimens of Thais hippocastaneum as hermit homes on the pool bottoms and the presence of Morula granulata support this hypothesis. The bottoms of these pools were the sandy pink of reef pool areas.

On the Oneroa transect (Figs. 1 and 2H, I, J), while there was no specific or definite "high tide line" fish fauna otherwise at Raroia, there was in the splash region on the reef boulders a species of blenny during low tide periods. This blenny was loath to return to the aquatic environment even when disturbed. Perhaps the restriction of this fish to such a region is an indication of a different species of algal food though a priori it might as well be some other restrictive factor.

The fauna in the intertidal regions was perhaps richest in the village area (Garumaoa) and poorest at Oneroa. Gake held an intermediate position, for example, the blennies and gobies were those of the above stations, but some species were absent...i. e. the fauna was attentuated from that at Garumaoa but richer than Oneroa, both in reference to numbers and species. No fish were found intertidally in the Gake sea reef region other than the common white spotted rather innocuous Gymnothorax picta which moves in and out with the tide as did Acanthurus triostegus. However, rare this eel was, it was definitely more aggressive or curious here and at Kaea. It would follow a passerby and go so far as to bump its nose into a proffered shoe sole before scurrying for a rock to hide. At Gake none of the "splash zone" blennies could be found. On bolder sea and channel shores a sea slug (Onchidium sp.) and a greenish half-shelled tectibranch are to be found in the lower part of the intertidal area above the pool level near shore. While seen only at Oneroa and Garumaoa it is presumed that these two occur in similar places all around the atoll.

At Mataira (Fig. 2F) the large pits of the reef pool gave way to small pits with relatively blunt topped walls in the intertidal zone. These were the sizes thought bored by the resident gastropod species. Above high tide line, in the black zone, the wall tops on these holes were sharper.

Above high tide line the black or spray zone may be recognized by its color when dry. On Oneroa (Fig. 2H and I) this was largely algal material (11675), Entophysalis crustacea and Brachytrichia quoyi, that is dark brown when wet. Here at Raroia (11675), in Massachusetts (7273) and in the Philippines (10937) and elsewhere this Brachytrichia appears just above high tide line, often with the ecologically related Calothrix species.

Three phenomena are notable in relation to the "black zone". 1) At Mataira there were numerous pools of fresh water on the surface, often about forty centimeters broad and four to six centimeters deep. These were fresh water at the time of observation, though within ten meters of the sea edge of the rock platform. 2) Many large reef fragments, up to 100 cubic meters in size, were strewn on the rock platform here. Some had several kinds (Timonius polygamus, Portulaca johnii, Boerhavia diffusa, Heliotropium anomalum) of flowering plants growing on them. Inshore from each there extended a bar of small gravel. 3) From the sea edge the platform so sloped down toward the lagoon that it would have about reached the lagoon level at the lagoon shore. At the sea edge of the unconsolidated island material the surface of the platform was leveled and found to be 30 cm lower than the sea edge. This slope was commonly, but not always, observed in other areas of Raroia.

The highest protrusions of the inshore reef flat pool walls at Gake, often only the size of a fist, above a certain level were colored black. Such black "algal" material was collected (11484) and proved to be Entophysalis crustacea, Rivularia polyotis and Plectonema nostocorum. This same black algal material, predominantly Entophysalis crustacea and Calothrix scopulorum (11439), covered the so-called spray wet zone (Fig. 3) on both the beach boulders and gravel (Entophysalis crustacea alone 11437) near the shore. This was accepted as evidence that these protrusions were in essence above high tide line.

The blackness of the black zone at Tetou (11318, 11320) is a coating, in addition to the dominated Entophysalis crustacea, composed of Calothrix pilosa, C. scopulorum, Mastigocoleus testarum, and Plectonema terebrans.

At Gake only a few specimens of Nerita were seen; too few to decide upon their zonal affinities. Tectarius was observed only on the beach boulders in the upper part of the black zone. The shore was a gravel ridge and this nature of the shore in the vertical range of this species (and perhaps as well as Nerita) might be cause for the apparent absence of the species there. Much of the splash zone gravel is white at the seaward foot of the high gravel ramps, probably due to movement with each wave that washes this high.

An interesting habit was noted at Gavarivari and elsewhere, among the hermit crabs. One is puzzled by local accumulations, often of one species of empty gastropod shell. Often these are of but one size. They are found on rocks a few centimeters above high tide level. There were many such accumulations at Gavarivari. But here it was found that many of the shells had hermit crab occupants and many of these were aperture side up. Just what the explanation is is not clear, but it did seem that the hermits had crawled up themselves, perhaps just to sun themselves. It is to be noted in passing that the common red land hermit crabs similarly accumulate.

The black zone at Gavarivari (Fig. 2A) and Kaea (Fig. 2D) is very broad and the surface, while plane, slopes gently toward the high tide level down about seventy centimeters. The grey beach-rock flat inshore is essentially level. The black zone here instead of being essentially the outer edge of a consolidated beach rock platform as usual, is composed largely of loose and semi-cemented-in-place flat stones embedded in sand, each of which tilts into the sea. The blackened material (11928) appears to be Entophysalis crustacea. The stones tend to be green around their sand embedded bases and on their undersurfaces when loose. The whole is apparently seated on a consolidated platform of homogeneous rock at about the pool channel bottom level. This is revealed in the exposure of such material in the frequent small pools in this black region. The basement rock, though, instead of being pink and sanded over as in the pool channel is blueish and rather clean. The blueishness is about the same blueish color as that to be seen around snail borings in the black zone, for example, in the PAKOKOTA at the sea end of the Garumaoa transect. At Kaea much of this boulder covered flat extended up to levels where the rock was only grey.

While their shells were found elsewhere no living Tectarius, Nerita or Melaraphe were found at Gavarivari; though a brief fruitless search was made for them. Tectarius was found 4.5 feet above the pool level on the reef boulders though and these specimens (11931) were turned in to Morrison (JPEM 2222) for identification. Various gastropod and pelecypod shells (11931 = JPEM 2222) were found in this region and on them were various small algae (11930). On the rocks at and just above the high water level were found (11932) Rivularia polyotis along with the ubiquitous Entophysalis crustacea.

Above high tide line in the black zone at Mataira and also at Oneroa (Fig. 2I) exfoliation was common. The exfoliated pieces coming off were from a few centimeters to almost a meter across. Exfoliation was noted elsewhere along the lee atoll shore but was not recorded from the windward shore.

At Gake and occasionally elsewhere on windward or exposed shores the black zone was bordered inshore by a gravel rampart. These were most interesting. The sea facing base of the gravel rampart was filled with sand. This sand in the uppermost part of the black zone was bound by Mastigocoleus testarum, Plectonema terebrans and, as might be expected, Entophysalis crustacea (11446). This growth was permeated by numerous fungus filaments. Flat areas of beachrock seaward of the gravel ramparts, where these curved shoreward at their ends, were often covered by fine sediment bound into pinkish crusts. These were quite stony when nearly dry. The algal material (11436) which was the biological part of these crusts was largely Schizothrix longiarticulata, Entophysalis crustacea and Calothrix scopulorum.

5. Spray-wet shore and sea ramparts. Arbitrarily the areas (Fig. 3) between the algally blackened spray wet region and the vegetated areas are biologically treated here as "sea beaches." These differed greatly in nature from place to place from loose gravel ramparts to boulder fields to conglomerated rock benches bordered shoreward by sand or fine gravel. In the aerial photographs (e. g. Fig. 5) the beaches appear white, sometimes dotted with black indications of shrubs. The rock benches appear as radially striated greyed areas just shoreward of the black zone.

In the Tetou and Gake transect areas the sea beaches were gravel ramparts at their seaward edges. This was also true of the more southern more exposed ends of Garumaoa and some of the larger islands in Raro. As an example note the successive profiles J, I and H in figures 2 and 9 of Oneroa. Figure 2J represents the profile at the exposed part, the bend, of the island. Figure 2I a mid region further north. Figure 2H a profile across the northern protected end of the island. As this series was passed through (Fig. 3) the sea beach became less gravelly and at the seaward edge it became a conglomerate bench (PAKOKOTA).

The top of the gravel ridges, or ramparts, everywhere is grey and there was (except at Tetou) only a gently curving slope inshore to the tree-covered area. The whole beach area was dominated by unconsolidated grey gravel to inshore areas where Suriana became dominant. Only one flowering plant was ever found on the gravel ramparts. This was Ipomoea tuba at Tetou. The local people insisted that some of these trailing plants had blue flowers but none other than the typical I. tuba was seen. Ipomoea pes-caprae was not found on either Raroia or Takume and a special search was made for it.

South of Tetou at Gagieroa and Gavarivari, a large amount of the sea beach was small (25 to 50 cm) boulders. These were cemented at lower levels onto the consolidated platform described above. At higher levels they were loose. A large proportion of those (e. g. 11845) far inshore had the appearance of a Porolithon of the P. gardneri type. No such forms were seen on the reef margin even after repeated search. Such algal boulders were not at all conspicuous on the lee shores (Tokerau, the village area, or Raro).

The black zone organisms spread over the consolidated bench (PAKOKOTA) to variable distance shoreward. Splash from waves was seen to wet this area upon occasion. During rains the area is washed quite free of salt and small pools of fresh water accumulate (determined by taste). In the vicinity of the sea edge these pools last noticeably longer than those formed further inland where the PAKOKOTA is merely grey. Whether this is due to greater porosity of the rock, higher temperatures or lower humidity or some other cause as the sea edge is left behind was not determined. The floor of the pools near the sea edge at Mataira were coated by a black soft scum called KOPARA (11372, Calothrix scopulorum B. & F., Entophysalis crustacea (J. Ag.) Dr. & D., Anacystis dimidiata (Kutz.) Dr. & D., Schizothrix lacustris Gom.) or a floating soft mat. Around the pools at the landward edge (Q in fig. 9) of the beach rock, at Oneroa, the surface was grey when dry and black when wet with Entophysalis crustacea. The blackish coloration of the alga found on seaward edges of the rock surface (R in Fig. 9) was the ubiquitous Entophysalis crustacea and Brachytrichia quoyi.

Occasional boulders on the shore were sometimes sufficiently large that land vegetation occurred on them. At Mataira one such boulder attracted attention in particular. It was about five meters high, six meters wide at right angles to the shore and six or seven meters long. This boulder (KONAU TOREU) was at least 100 meters inshore from the reef edge. It must have taken a tremendous wave to break it out of the reef edge and carry it up that far. On its gray top there was growing Timonius polygamus, Heliotropium anomalum, Portulaca johnii and Boerhavia diffusa. A most odd observation was that the upper half of this boulder appeared to be composed of Pocillopora faced upward and the lower half of Porolithon onkodes faced downward. Nowhere did anyone on the team see either of these organisms growing in any other position than facing upward.

While no loose gravel was seen on the sea edge of the PAKOKOTA or in the "rain pools", further inshore increasing amounts of loose gravel appear. This gravel is in general of smaller size as one proceeds shoreward. Nearest the sea it was almost all either on pool bottoms or in bars behind large boulders. Inshore it formed a general litter obscuring the surface of the PAKOKOTA, e. g. at Mataira.

At Gavarivari there was an extensive black-zone boulder field extending up, inshoreward, into the grey zone or PAKOKOTA levels. At Kaea the similar boulder field was much more in the grey zone. These boulders were found in varying degrees of cementation to the solid reef material. Perhaps if covered by sand they could have become cemented into the island conglomerate benches seen. These benches where we saw them were exposed by hurricanes ripping the vegetation and much of the islands away.

B. Sea Beach

The vegetational margins and the sandy areas between the spray zone PAKOKOTA (island conglomerate) and trees seem to be related. This was decided after a study of root areas at Homohomo. In general Pemphis acidula and Suriana maritima were the plants associated with PAKOKOTA areas and Messerschmidia appeared with the presence of sand.

If the present extensively exposed island conglomerate was at one time productive land, then about ten times as much productive land was present at one time at Raroia. Local history records a great deal of destruction of land but we do not know how much. A reduction of the human population by a factor of ten is related in the history correlated with European civilization of the area.

There was little to be found in the way of sea beach biotic elements on the PAKOKOTA other than for an occasional bristle-like tuft of the grass, Lepturus repens. At Tetou Lepturus repens appeared on both the PAKOKOTA and the sand. As at Homohomo and each place where this point was investigated the sand for the first three millimeters below the top one millimeter of whitish sand is greenish near the sea edge of the beach (Fig. 9I) with various blue-green algae. However since they cannot be distinguished even as to genus with the unaided eye and because some of them grow well further seaward they do not serve as indicator organisms.

While at first glance the sea beach seemed to be rather barren, close investigation always revealed roots or seedlings or the tufts of Lepturus or other plants (in one case geckos) and this seaward limit of such macroscopically recognizable biotic elements became accepted as the seaward limit of the sea beach beyond which was the spray wet zone. This was essentially true also at Oneroa where Pemphis and Suriana became dominant. Under the Pemphis in particular the sand is solid and well packed, i. e. not the loose sand of the sea beaches. From the seaward edge of the bushes, some 45 meters from the beach rock where the sand was less packed to the inshore edge of the bushes essentially the same blue-green algae were found as were found at the sea edge of the beach. This seemed to indicate there to be no real difference in the surface soil conditions between what might be called the sandy beach and the bush-covered areas.

At Tetou Ipomoea tuba was also found growing at the edge of the Guettarda area on the sand and often growing as a climber into bushes of Pemphis, Suriana and young Guettarda. The largest patch, about 20 meters long and 4 meters broad, occupied the inner surface and top of the gravel rampart illustrated in Figure 2B. This was the only thing like the expected growth of I. pes-caprae seen on Raroia. I. tuba is apparently the only species to be found; though our local resident assistant thought this particular patch of Ipomoea to be blue flowered until shown differently.

The bristle-like Lepturus became abundant inshore and Suriana became more frequent and larger until it dominated the landscape at Tetou.

While Messerschmidia was common at the landward edge, and indeed on one profile it was conspicuous at the outer edge of the "land" behind the gravel rampart (Figure 2C) it was not what one could call a strong element in the population from a purely observational standpoint. Inland one can draw on a map an arbitrary line between the seaward edge of the Guettarda and the inland edge of the bush zone coordinately dominated here by Suriana and Pemphis. One element (Hibiscus tiliaceus var. sterilis, 11833) found only at Tetou appeared in a very narrow zone just seaward of the Guettarda. This species was a bush usually just less than two meters tall with rather stiffly erect or patent branches. It was interesting to note that the young, more terminal, leaves wilted at a much greater rate than the old leaves...and to note also that the leaves apparently did not remain on the stems very long. This was evidenced by their appearance in clusters at the tips and the great frequency of leaves at the bases of these clusters with "autumnal" foliage coloration, as well as the accumulation of leaves on the ground.

It should be noted that Messerschmidia is to the local people a very valuable mulch forming plant. In this connection it was noted that leaves of Suriana and Pemphis accumulate to a considerable degree under their respective bushes. Along with the leaves of the above Hibiscus these are all probably very active plants in the humification of gravel platforms such as that here at Tetou inasmuch as humus is formed.

With the region outlined to the seaward by the Hibiscus at Tetou and by the bristly form of Lepturus, the ground is covered by stones (5 cm) that are blackened (Mastigocoleus testarum and Entophysalis crustacea, 11877). On transects elsewhere than at Tetou one could expect a coincidence of the successful coconut plantings and outer, seaward limit, of Guettarda. In windward areas under the Guettarda there was little Euphorbia atoto or Scaevola frutescens in comparison to other areas studied. These two plants were far more abundant on the leeward side of the lagoon. Similarly on and beneath the coconut trees Microsorium and mosses were common in windward areas but not as abundantly so as on the leeward side of the atoll.

As in the case of other islands along the windward side of the atoll Gavarivari displayed (Fig. 2A) a broad area between the vegetated area and the sea. There were also several gravel ramparts in the structure of the seaward part of the vegetated area separated from the lagoonward gravel ramps by low areas most of which were swampy. The more seaward gravel ramps (Fig. 1) tend to be strongly covered by gravel that is coarser than that which covers their seaward uppermost and lateral (exterior) faces.

Various of the islets north of Tetou were investigated as to their flora. Lepturus repens and Heliotropium anomalum appeared alone on many of the islets that were hardly more than sand spits. These were the smallest vegetated islets at Raroia. On islets that had a fair cover of these plants there were coconut trees but nothing else was to be seen in the way of flowering plants.

There seemed little transition between islets having the aforementioned vegetation and those having additionally Pemphis, Suriana, and Guettarda. However, there were a number of flats which were little other than Pemphis-Suriana thickets without Guettarda. This latter genus appeared only on islets where there were elevations distinctly higher than the usual levels at which Pemphis and Suriana were to be found.

It appears that these beach edge plants are thus pioneers and that a water supply is available under their cover that will at least support Cocos. Cocos is planted. Since Cocos does not bear and do well in the above places it is not normally planted in regions supporting only the Messerschmidia seral stage. It can be postulated that the reason for the absence of Messerschmidia from such islands at Raroia is the length of time required for Messerschmidia to become distributed to such areas, germinate and grow naturally.

A preliminary assumption is that Cocos will grow in sand with little or no humus if there is a satisfactory water supply. Similarly, it may be that Guettarda, which seems to follow Messerschmidia, requires the water suitable to Cocos but in addition more soil or shade during development of its younger stages. The absence of Guettarda seedlings in some of the burned Guettarda areas at Opakea substantiates this. Perhaps Messerschmidia growth sets the stage, serally, for Guettarda.

Kaea (Fig. 2D) presented another case of Suriana and Pemphis, and also Timonius polygamus, on the island conglomerate and beach gravels. Hedyotis romanzoffiensis was there too, but as most common it was more conspicuous as the channel shores of the island were approached.

C. Guettarda Forest

Skeletons of large Messerschmidia trees (7 meters tall) were found on Kukina. At Opakea (Figs. 1 and 2K) in central regions relatively recently destroyed by fire, among the skeletons of fire-killed Guettarda, seedlings of Messerschmidia had appeared in profusion. At Garumaoa and generally elsewhere Guettarda appeared on islands, on the sea side, about 2.2 M above high tide line. That it does occur lower, for example, was observable at Oneroa (Fig. 9) where on the lagoon shore, one trunk was based on the sand sloping to the water's edge. It was perhaps a foot above high tide line, but dead roots protruded into the sea water of the lagoon at high tide.

The Homohomo transect area, upon which so much time was spent, was a very muchly disturbed area and not so desirable for an analysis of the vegetation as Oneroa. Oneroa too is a coconut plantation, but it is an old one in which somewhat of a balance between the pre-plantation conditions and plantation conditions may have become established, and it appeared to be typical of what we found in coconut plantations at Raroia. Three profiles across this area were leveled with a hand level and paced. These three profiles were through an exposed part of the particular island (see figure 1J), through a moderately exposed part of the island (Figure 1I) and through the least exposed part, that is the part most protected from windward influences (Figure 1H). These profiles are illustrated in detail in Figure 9. A sample of the distributions of the species can be had by study of Figure 9 and reference to the species found at each of the locations indicated by the letters A through R. The relative abundance of the species is indicated by its position in the lists of species... the most abundant being given first. The taxonomy and certain specific information on these organisms is given in Atoll Research Bulletins No. 33 and 34.

Fine sand dominates the sea edge of the Cocos area at Oneroa and this is largely covered by algae (Fig. 9G) binding it into stony moss-like tufts. Suriana and other bushes appeared with the most seaward coconuts at Oneroa. The coconuts had been planted further seaward here than they are usually planted, and the most seaward trees had not developed well and did not seem to bear nuts. In this area (Figure 9F) at one or more places fragmentary channels show as depressions in the surface of the island. In these depressions sometimes Suriana dominated. The sand under the shrubs was either covered with a layer of Suriana leaves or the complement of algae indicated in Figure 9 at F. These algae form an almost continuous series of dark lumps, 0.5 to 1 cm. in diameter, over the surface. Further toward the center of the island and at higher elevations (Figure 9P) boulders of 1/3 to 1/2 meter in diameter were frequent. These were quite black on their upper surfaces when wet but only plain grey when dry. This algal layer of Symploca kieneri and Schizothrix (?) longiarticulata was particularly developed in surface depressions on the boulders and diminished on parts more exposed to the air. While we did not turn over the larger boulders the smaller rocks and gravel near the center of the island tended to be more completely white beneath and grey on top, or blackish if wet. They had the same complement of algae (see list on Figure 9 for N and O, though not listed some Schizothrix longiarticulata and Nostoc muscorum was present at this latter site) as found on similar gravels on the lagoon storm ramparts (beach ridges), and a more or less green line around the margin of their white under surfaces. Toward the center of the island the surface is in general buff gray and while the sand and small gravels are not bound together or cemented they are certainly well packed. After a rain algae (figure 9E) cause these same surfaces to become greenish.

At Gavarivari, Guettarda appeared on the nearly level top of the outermost ramp and continued on all but the lowest areas across the island. Even on the outermost ramp some of these were as much as 0.6 meter or more thick toward the base below the major limbs. Most of these large Guettarda trees had light grey bark. Our measurements indicate about 920 hectares of Guettarda forest area on the atoll about 580 of it planted to coconuts.

The trees on the seaward edge of the vegetation at Tetou were coated on their windward faces with Trentepohlia (11842). This green alga formed a bright yellow orange coating on the tree trunks and limbs as it does elsewhere in the world in such habitats. The larger limbs of Guettarda on this seaward face were coated beneath with a whitish coating of fungus material (11841).

Morinda citrifolia was most often more abundant just within the edge of Guettarda areas. It did occur at Garumaoa rarely outside this cover on the seaward side of the island in a muchly disturbed area. On the atoll of Anaa, it similarly was seen seaward of the major tree covered area on a raised area. It was most frequently seen along the lagoon shore, but one usually walked near the lagoon shore or along the algal ridge. There is no central road or, in fact, much of any regular trails at all at Raroia. At Tetou within the seaward edge of the Guettarda area there is an unusual amount of Morinda and this extends, largely as seedlings without much in the way of branching and less than 3 meters tall, to "x" in Figure 2C where they stop rather abruptly. Grass in this area is only spotty and the soil is largely obscured by the grey algal-coated small gravel (11876) discussed above. Morinda seemed to be well able to grow in the shade but only away from the salt water. In the southern Marshalls, Morinda is about the only tree reputed to survive under the dense shade of Artocarpus (breadfruit). Artocarpus seems to grow well only far away from salt water at Raroia.

Special note should be made of the hermit crabs (Coenobita brevimanus and C. perlatus) found on the highest parts of the islands. One comes upon fifty to a hundred clustered about the base of a single tree and there will be no others in sight for fifty meters or so in any direction. The tree is sometimes a small one or an odd one. One aggregation at Gavarivari was on the ground around where a downward growing Guettarda limb touched the ground. The limb then curved upward so that it touched the ground only in this one place. In the occasionally occupied villages these same hermit crabs may accumulate almost entirely in just one of the abandoned houses. A human occupant, if wise, will confine all his decapod contenders for the period of residency to a bucket or box...throwing them out of the house only being the stimulus setting them in motion to a noisy return.

In passing, it should be noted that Birgus latro, the coconut crab, was a highly prized article of food found rarely in unpopulated Guettarda areas. The only specimen shot was from Kahogi where it was molesting a Pandanus fruit. This island was just north of the pass, and was an island visited infrequently. It had the only large Pisonia trees seen at Raroia.

Pandanus was a most variable entity in form. In habitat it was found on the highest parts of the islands. Usually it was surrounded by Guettarda. However, some of the small, yet highest, islands such as Kaea on the windward side of the atoll and Temari, just south of the pass, had this tree growing in exposed situations. At Gavarivari Pandanus occurred on some of the high windward ramparts and was there quite unprotected by other vegetation. The trees in this habitat were nearly a solid leaf-filled masses and thus most typical in appearance.

Though little such land was available for study the coconuts were in general not growing above a level (determined with a hand level) of 3.2 meters above high tide line. The surfaces above such levels were of coarse gravel and occasional flattish boulders (up to 0.75 meters in diameter).

Essentially it is in the Guettarda area that most all the flowering plant species are to be found. The aerial photographs well illustrate the extent of this area on the individual islands. This is the stippled area on the map accompanying the report by Newell on the geological work at Raroia. In going from Garumaoa northward toward Gake the flora in general became increasingly depauperate; though the general situation as described for the Garumaoa transect area persists. After leaving Homohomo one can almost count each individual tree of any species other than Cocos, Guettarda, Messerschmidia, Pemphis acidula and Suriana maritima.

Scaevola frutescens nowhere at Raroia grew out onto the beaches as it does in Hawaii, in the Marshalls and elsewhere. As a rule it was a plant of the inland Guettarda dominated end areas but appeared to be much more intolerant of shade. When growing in the shade Scaevola developed as a viney plant with slender parts and creamy flowers having no purple wavy petal edge or corolla base.

Euphorbia atoto seemed to be more shade tolerant than Scaevola and was the predominant herb (isolated and usually approximately 30 cm tall) in most coconut groves. It likewise may either have a shallower root system or be more tolerant of salt than Scaevola for it extended nearer the lagoon and often nearer the hurricane-disturbed island ends than did other members of the Guettarda forest community and even Scaevola.

While discussing shade it should be pointed out that under the Cocos and Guettarda cover there were usually many small saplings of Guettarda. The possibility that these might shoot up quickly and fill an opening in the forest canopy comes to mind.

At Raroia it was Suriana maritima rather than Pemphis acidula that seemed the most hardy pioneer form on sand and rock. This is in contrast to reports from other atolls and it may be that at Raroia this apparently unusual situation was due to the hurricane-disturbed nature of the northern part of the village area where this relationship was observed. In some places at Oneroa (Fig. 9) Suriana did grow in abundance well inland on a sandy area as described above. Inophyllum calophyllum was present only as a single small tree at Vaituke outside the village, Garumaoa.

In the village area only one tree of Cordia subcordata, a small one, was found. This was at Kumekume. North of the pass on Kopuano there was one Cordia, a small tree along the southern edge of the coconuts not far from the water in the channel. On another island, also called Kopuano, the name essentially of the estate to which it belonged, were two rather large Cordia trees (TOU) and many small ones forming a small grove.

On Kahogi the largest Pisonia grandis, GATAE, was seen. This was some 0.8 meters in diameter (but not DBH) and fourteen meters high. There are several trees just slightly smaller and many very small trees. It, thus, appears that this species was reproducing. Though there were no guano deposits identified on the ground there were red-footed boobies nesting in the trees. Terns similarly made the area their home. One tree about 0.3 of a meter in diameter was found in the eastern part of the Gake region. At Paparoa there was one other Pisonia (11506). No reproduction of this tree at Paparoa was seen and neither bird nests nor guano were seen to be associated with it or its environs. No seeds were to be found though flowers were collected. Except for perhaps a dozen or so trees of uniform size with small ones underneath at Opakea no other Pisonias were found.

While rare, south of the pass, except in the village, Lepidium bidentatum was scattered along the islands to the north. Here it was withered beyond the fruiting stage or juvenile, no fruits or flowers being seen. On the windward side of the atoll fruits and flowers were common, e. g. at Kaea.

Timonius polygamus was rare north of the village to the pass. One plant being found on Tomogagie and two on Takeke. North of the pass this species was common; as it was in Raro and Kereteki.

Hedyotis romanzoffiensis, like Timonius, was most commonly found along the channel ends of islands, the former often on rather thinly covered consolidated rock and the latter usually on the more gravelly soils. Hedyotis was found occasionally in widely different forms. As a vine it resulted in tangles near the sea beach at Oneroa and near the lagoon beach formed rather tall spindly plants. These two with the bushy plants of island ends were so different that they were thought at first to be different species.

North of the pass mosses and ferns soon became insignificant and were not found at all from Mataira through the Gake area.

Such plants as Fleurya ruderalis grew in profusion on some of the long undisturbed Guettarda areas of, e. g., Kaea, where no coconut trees were growing. Portulaca johnii here seemed most succulent and with the largest flowers. The land area of Kaea appeared to have been reduced about nine tenths by a hurricane in 1903 but since had vegetationally quite recovered so as to be a somewhat open Guettarda forest. There were on the island many whitened remains of pre-hurricane trees, probably Guettarda. The seaward remnant high portion of Kaea (Fig. 2D) had a generally vigorous growth of Guettarda. Suriana and Pemphis were present around the margins but Messerschmidia was little in evidence. The highest portion of the island, that end nearest the lagoon, in addition to Guettarda, as is often true of the islands at Raroia, was largely populated by Pandanus distinctus. Lepidium bidentatum formed the major ground cover with a grass (11896).

Ximenia americana (RAMA) was scattered along the midline of the large island at Opakea as about six bushes, Forsythia-like in their viney habit. This was in general a shady habitat in the freshest ground water area of the island. It had the same position at Kopuano (Tokerau), where it was identified only as a burned dead stump with nuts scattered about on the ground.

Without analyzing it further there was an increase in floral variety in reference to approaching long islands near the southern end of the atoll.

To this point we have been discussing the Guettarda vegetational area essentially of the highest part of the island. As one approaches the lagoon the land consists of finer particles. On short islands the island surface in the Guettarda area may be entirely of gravel. Toward the lagoon the surfaces of long islands are of sand that is finer toward the midpoint along the lagoon shore. In both cases there are usually traces of storm ramparts of essentially these beach materials near and parallel to the lagoon shores. The lagoon base of these storm ramparts is essentially high tide line and is identifiable by a shift in color, slope and biota.

Perhaps in correlation with the finer particles and lower permeability, coconuts and Guettarda grow closer to the high tide line along the mid lagoon shores of the islands. Toward island ends the storm ramparts were gravelly in nature and occupied by, essentially, the bushes. Of these Messerschmidia, drops out first as the center of an island is approached, then the Pemphis and Suriana, leaving Guettarda, Cocos and grass on the sandy ramparts in mid-shore areas. Sometimes where the lagoon beach ramparts were broad as at Gavarivari (Fig. 2A), this was the only area thoroughly planted in coconuts.

Between the lagoon and seaward storm ramparts there is (Fig. 2) often a low area (Fig. 3), a swale. In southern Kereteki (Fig. 2A) often there was a series of these low areas. Elsewhere (Fig. 2) there was usually but one. This has been termed here "swale". In some places the swales had been in the past used as taro pits. No taro was found at Raroia and it is believed to be extinct there.

At Tetou the swale proper was a muddy area thickly beset by coconut trees. At Gagieroa and Gavarivari, Suriana and Pemphis were common in these troughs between the ridges. In these swampy areas Pemphis dominated the picture, Guettarda being absent. Likewise in these swampy areas Pemphis and Suriana formed cane-like trees up to 16 feet tall, the trunks of which were only six or eight centimeters in diameter. At Tetou in the swale a very shallow well (APOO KOMO) had been dug (Fig. 2 C, "y") about 48 cm deep in which at high tide there were a few inches of water. The water had a salinity of 4.1 parts per thousand salt at high tide and the surface of the water was about 20 centimeters below ground level. On the mud bottom of this well the unicellular green alga, Gloeocystis grevillii (11901), formed a delicate coating.

The seaward slope up to the crest of the island was of coarser material than the lagoonward margin of the swale. At Tetou this was covered by Lepturus repens of the same form as that found on the downslope to the mud flat from the lagoon. Actually this cover extended over the beach ridge to within a few meters of the lagoon. Portulaca johnii of low stature and occasional tufts of Eragrostis amabilis were intermixed with the Lepturus. Many of the partially burned pieces of Cocos trash had the blue-green alga, Scytonema hofmannii on them. On soil swept bare here there were occasional developments which in mass appeared to be green algae (11884).

The beach ridge was bordered with an irregular zone about 3 meters wide, the ground of which was grassless, relatively loose, sand or fine gravel. The sand (11864) and fine gravel (11865) were somewhat greenish when damp and grey when dry. This color was induced by the presence of the blue-green algae Entophysalis crustacea, Scytonema hofmannii, Mastigocoleus testarum, Coccochloris stagnina and Plectonema calothrichoides.

The very plane surface of the beach ridge sloping gradually toward the central swale region at Tetou is very variable in shape. Rather consistently it is a slope covered with complete cover of Lepturus repens (11866). This form of Lepturus is soft and in loose spreading tufts which do not run conspicuously. The highest density of Vernonia cinerea was seen here. The tallest plants were often 0.7 meter high.

Out on the swale flat itself at Tetou toward the center of the island, Pemphis and Suriana were essentially absent. The surface was level and of mud. On this mud surface the general color is "blackish". The temperature was found to be 26° C. about 3 cm beneath the surface. The surface had the same temperature as the air. Temperatures of the nearby lagoon water were 26 to 26.5° C. Over the surface were strewn large numbers of Strombus gibberulus characteristic of the lagoon. They were present here in rather larger numbers than would have been expected just from hermit crab carrying. On this surface, too, there are localized scatterings of small stones which are quite yellowish green with a mixture of the Gloeocystis grevilli and fungus filaments (11874). In some intensely lit areas the surface of the mud could be seen to be greenish and covered by a thin coating of Hapalosiphon pumilis (11870). On the flatest surfaces there were two sorts of raised areas. One, while very low, was arched upward and while solid was rather dry and non-stony internally. This brownish surfaced material was a dense development of the same Hapalosiphon pumilis (11844). The other sort of raised surface was black and plain as to contour. Such areas were out two or three millimeters raised and were in texture adjudged to be nearly the same in texture as the nearby Hapalosiphon-covered mud or black and higher (3/16") and often quite stony. This stoniness was that of dry mud and probably the area was not stony beneath its somewhat dry surface. This material (11871) proved to be the Hapalosiphon and a mixture of Entophysalis crustacea, Microcoleus acutissimus and Mastigocoleus testarum. There was a rock formation around the roots of many of the coconut trees on this mud. No biological materials other than the roots were seen to be associated with this hard material.

Here in this central region of Tetou there was an aggregation of cryptogams growing on the trunks of coconuts (11872, 11873, 11868, 11885, 11886, 11887, 11888, 11889). Physcia sorediosa, P. integrata and Antracothecium ochraceoflavum were the lichens. Blue-green algae such as Nostoc commune, Scytonema hofmannii, Plectonema calothrichoides and the green alga Gloeocystis grevillii were found. The moss Calymperes tenerum was common on these trees as well. Outside of this swale area these cryptogams were far less abundant.

The lowest swampy areas had the best developments of soil. By measuring the elevation of the surface above the level of the water-saturated sandy soil in land crab excavations at Gavarivari it was estimated that such swampy areas were about 0.5 meter above the upper level of the Ghyben-Herzberg water lens.

The lagoonward rampart ridges at Gavarivari were at least covered by sand and small gravel, e. g. covered with materials consistently smaller in size than those which covered and seemingly composed the seaward ramps or ridges. Algal growths here bridged between the individual particles and thus more of a soil was simulated. Under the coconuts in this area Lepturus repens formed a meadow but for burned areas and leaf trash. This situation at Tetou prevailed lagoonward to within a very few meters of the sandy lagoon beach edge where the grass dropped out and the land surface was more definitely sandy. Coconuts thrived right to the edge of the lagoon beach on windward and Raro shores where land and beach graded together without an erosional bank showing. In contrast at Tetou and Oneroa, where coconut trees were being washed into the lagoon an erosional bank showed. From Kereteki (Fig. 1) through the village area and northern Raro, downwind lagoon shores, the coconuts were not as conspicuously close to the water's edge as they were on the more windward shores.

While the lagoon side of the beach ridges in sandy intertidal areas are of clean well washed sand rather devoid of any conspicuous vegetation the sand of the inshore sides of these ridges at Oneroa is often bound algae (Fig. 9B). These generalized bound areas are interspersed with loose sand areas and areas bound more or less distinctive in one way or another. One such different area type is smooth surfaced and rather light grey. This (Fig. 9C) was found to be largely a binding by fungus filaments. It extended with considerable frequency far into the coconut area. Behind and on top of the lagoon beach ridge much of the bound sand over relatively large areas was brownish grey and somewhat lumpy on the surface. A long list (Fig. 9D) of algae was found intermixed here with the same dominant Symploca keineri, as dominated the generally bound "B" areas.

On the slope (Fig. 9N) from the lagoon beach ridge into the swale most of the gravels and rocks become very black after a rain. They are more strongly grey when dry and most darkly colored near the sand line with what may be a typical island "large gravel" association of algae. The unbound sand (Fig. 9A) of the lagoon beach ridge crest areas assumes a greenish cast from the activities of the largest variety of algae found closely intermixed on the atoll. Occasionally about the village of Oneroa and on the ridges (Fig. 9M) some stones were green even when dry. These were found to be coated with Mastigocoleus testarum and Entophysalis crustacea.

D. Lagoon shores below high tide line

In general the upwind atoll lagoon shores, such as those of Gake and Kereteki, were of sand (GAERE) or fine sediments. As one approached the village area through Tokerau and Raro more and more gravel was to be found on lagoon shores and the particle sizes and high tide storm ramparts were larger.

A major exception to this rule was the lagoon shore of the longer leeward islands. Toward the midpoint of such shores the intertidal region, as well as the supratidal region above it, became a sand or sediment beach. Nerita and the ghost crabs mentioned above were the major biological forms of these beaches as well. Stones low on the intertidal shore at Tetou were coated with Symploca hydnoides (11863). The small gravels or stones to be found at low tide line, at high tide line and just above high tide line (Fig. 9J, K and L respectively) were similarly grey green at Oneroa. Because of the constant submersion of the low tide stones, the intermittent regular submersion of the high tide stones and rare wetting by rain or spray of the above-high-tide stones we were surprised to find in general the same algae predominating on them.

In a few places beach rock was observed. Biotically this was interesting for it, with the town wharf, provided about the only stable areas on which intertidal zonation could be studied. This topic is expanded below in section V.

The lagoon beach at Gavarivari was for the most part typical of agrading lagoon beaches on the windward side of the atoll. There was lots of foraminiferal brown sand in the upper intertidal region. The beach between tide levels was large plane in profile between extreme tide limits. Upward it rounded off gently into the lagoon ridge. Below it rather abruptly changed pitch to the plane even more gently sloping lagoon shallow water flat.

At Kaea the brown sand (11897, a Calcarina?) or small pelecypod shells formed the beach. In any case there was little in the way of macroscopic algae on the lagoon shore other than an occasional patch of Caulerpa urvilleana near channel mouths and certain corallines (11334-11338) on coelenterate coral fragments. Here at Kaea the lagoon terrace, while of the usual slope, had perhaps more Acropora and less Porites than other Gake or Kereteki lagoon beaches. There was no evidence in this region of any lagoon reef or beach rock at all.

Ghost crabs appeared on such sandy shores at low tide at night. These were not to be seen in the daytime. The land hermit crabs appeared to make some regular visits to these shores. Algae were essentially absent.

Subtidal lagoon shores can be readily divided into reef regions and unconsolidated shores. The reef regions have been described as to major variations in our description of this area at Homohomo above. The unconsolidated shores are almost continuous through Kereteki and Gake as an almost flat sandy area. At Gavarivari, Tetou, Kaea and Gake the sandy flat was occasionally interrupted by a mill-stone-like colony of Porites. At Gavarivari on this flat there was more coral development than elsewhere in Kereteki or Gake. However, there was no intimation of a coral lagoon reef on windward lagoon shores. In one embayment at Gavarivari there was a rather broken up example of an algal reef pavement like the "B" zone on the lagoon shore of the Homohomo transect. This (11916) was seemingly the same alga as collected at Oneroa (on the flat south of village) forming a flat pavement or growing up around Vermetus (11915 = JPEM 2219) tubes in such a way as to stimulate a branched Porolithon in form. A number of species of shells were collected (11915). Cypraea moneta was found both on the sea reef and on the lagoon reefs in this same "B"-zone association with a Porolithon species. It was not found at Oneroa, however, in essentially similar places, but may have been overlooked. At Gavarivari two Isonomon species are found, the black one from intertidal regions on beach rock and the white one from beneath rocks below low tide level. Very small shells of Arca turned up in the same collections, and a fragment of the shell of Conus pulicarius was found filled with cemented lagoon rock material. Rhinoclavis sinensis was found alive below low tide line but near shore. Shells of the clam Asaphis were common but perhaps had come from nearby channels.

At the most lagoonward edge of this shallow water flat the pitch of the fine sand (silt, sediment, etc.) changes rather abruptly to a steeper angle. This is the innermost line drawn on the maps reproduced in this report. The depth here is often near 6 fathoms. On downwind lagoon shores where a reef is present, this same line represents the lagoon edge of the reef. It is at about the lowest lagoon water level.

Mullet, of two species, schooled in the channel between the sandy lagoon shore and the shore reef (KAOA) at Oneroa. Common in this micro-lagoon area were various of the coronet fish species (Fistularia sp.) that would drift slowly near to investigate any operation and flopped around most confusedly upon realizing the situation. The convict surgeon fish, Acanthurus triostegus, with vertical black stripes was a common visitor in the area.

Attention is called to the reefs paralleling the lagoon shores at Oneroa (Fig. 2H and map). These had the biology, apparently, of shorebound and other reef patches. The inner was essentially similar in morphology to that illustrated in Figure 3. And like lagoon reefs in general termed PAPAE. The offshore reef was more or less connected to the shore at its (northern) end only and thus was a KAOA.

The PAPAE differed little from other lagoon reefs in the fish to be found and, indeed, there seemed to be little in the way of a specific fish fauna at all. Acanthurus triostegius was common here and as a new element found in our progress lagoonward the very common very dark brown Pomocentrus nigricans peered back at the onlooker from many of the crevices between the corals. No information was obtained on populations of the deep area between the PAPAE and the KAOA.

The barrier reef, or KAOA offshore, had little in the way of a fish fauna on its top. Two different labrids, however, were considered typical. The outer edge of the KAOA had a myriad of several species of parrot fishes feeding on or among corals and the algae there. It was in general morphology and population like a lagoon reef patch.

IV. REEF PATCHES

Under this heading the shore bound patches, or lagoon reefs, and the lagoon reef patches isolated from the shore were considered. Other terms for these latter are patch reefs, coral heads and coral patches. The reef patches of both subcategories were essentially of the morphology of the shore bound lagoon reef in the Homohomo transect area. The actual distance and proportions varied, except that in general the active coral edges or reef margins were uniform.

Two extensive areas of shorebound reef patch were studied outside the Homohomo area. These were the reefs at Oneroa and those between the town wharf and the old small boat harbor and wharf at Garumaoa. The former reef areas were so similar to the Homohomo transect area and the lagoon reef patches that they will not be discussed here in detail. Some of the features of the Garumaoa village area reefs should, however, be pointed out. While the living coral edge is about the same horizontal width as on the Homohomo transect the drop-off lagoonward to the sand below is in the neighborhood of 20 feet. Passing inshore from the outer edge there is little in the way of a dead coral zone (Fig. 3, D and E) and instead there is a pavement. This pavement seems to be of rounded pieces and grooved solid areas; as though eroded by moving sand. This might have been a development of such an algal pavement as "M" (Fig. 6) in the "B" zone on the Homohomo transect and at Gavarivari. It has patches of algae having the same appearance as 11831 from Tetou. This eroded pavement area is in general seven meters or more wide. It has cavities so arranged that one suspects loose chunks or coral growths have been overgrown by the pavement-making organisms. Inshore of the pavement area is a shallow sand flat which is quite extensive and, at least in the places seen, at a lower elevation than the pavement itself. This sand flat appears to slope up toward the low tide level on the shore and then slope more steeply through the intertidal region to high tide line. White tipped slender but dark colored sharks about five to seven feet long persisted in cruising around so that diligent exploration of the drop-off over the edge of the living coral area seemed unattractive. Sharks and fishes, particularly trumpet fishes (Fistularia sp.) were more abundant at Tetou and other Kereteki stations than elsewhere perhaps in relation to fishing intensity.

One case of fish work was seen on a Porites colony (but on less active parts?) growing on the pavement in the "D" or "E" zone. Other Porites colonies were unaffected; though many were looked at in this connection.

The lateral surfaces of stones, especially where they lay close together, as well as holes, were often outlined by a Gelidium (11928). Where this species was exposed to the light it was mostly quite yellow. It was in color a pale yellow green to green and browner where less exposed to light. Under the edges of the same stones what appeared to be this same Gelidium was dark red, but far under the stones where the fronds were longest the Gelidium appeared brown.

On the surface below intertidal levels little living was visible. Most of the algae to be found were growing under but near the edges of stones. Some stones there were ringed with Gelidium and a Codium (11980). Struvea was seen in one such place in the field. Microdictyon was common as was a coarse cladophoroid alga (11990) that may have been Rhizoclonium hookeri. Conspicuous on the lower surfaces of such stones were tunicates and encrusting sponges. However their area was exceeded by the incrustings of coralline algae (11985) and Zonaria (11984).

Shells (11982) and bones of a turtle plastron (11983) on the bottom near shore were conspicuously green with an algal coating as yet unidentified.

Morrison put out about 30 large shells of Lambis truncata to clean on July 31. He put them in a subtidal pen-like area, the unfinished end of the town wharf. They were taken up and brushed off and packed on August 27. At this time the algae were scraped off and preserved (11993, 11994, 11995). Jania, Cladophoropsis, Gelidium, Ectocarpus, Sphacelaria, and other genera were recognized. There were crustose coralline algal pink crusts up to 2 mm in diameter. There were several animal corals on the Lambis shells. The largest of these was about 0.5 cm tall and 2 or 3 cm in diameter. While this coral was rather whitish it seemed to have a slimy coating over the surface and was thus judged to be alive and to have grown during the one month immersion. A further study of this material will give us better ideas of growth rates on the lagoon reefs.

The lagoon reef patches that are free from the shore were among the most interesting biological features of the atolls seen. The Tuamotuan terms applicable to these are given by Danielsson (Atoll Research Bulletin No. 32).

At Raroia it was apparent from the air that as one approached the more upwind parts of the lagoon the reef patches were smaller and perhaps less closely placed. This seemed to be true of the atolls of Makemo and Tahanea as well. In the lagoons of both Raroia and Makemo the reef patches further downwind were often more elongate or tear-drop shaped.

The lagoons in the Tuamotus which were more open to the sea appeared to have more reef patches in them. Such closed rings as Hiti or nearly closed rings such as Tuanake, Tepoto and Taenga, appeared to have no reef patches. Nearly closed atolls having no good boat pass, such as the pearl shell atolls, Hikueru and Takume had far fewer coral patches than Raroia, which is relatively open. Other correlations between "openness" and "closedness" of the atoll ring became apparent to the team as time wore on.

Not only are the copra schooners able to bring in their blessings and curses through the ship passes, but the sharks come in through them, too. In working at Raroia, the team members who spent any amount of time in the water were run out many times by sharks. These were nearly all surface sharks, only two midwater sharks being caught during the summer. These were a seven-foot white shark feeding in a most unlikely place and manner in about two feet of water along the lagoon shore on a sand bottom. It was miles from the pass through which it had probably come in. The other midwater shark was a four-foot blue shark caught in the pass. The algologists' canoe man, Vaea a Timaeva, earned the undying gratitude of two workers by heaving his none-foot fish spear some twenty-five or thirty feet into a bothersome soup fin shark, some species of Galeorhinus. Probably the most exciting shark story is to be told by the ichthyologist, who avoided one possibly only curious elasmobranch by pretending to be a very sessile crust in a surge channel concavity while the shark drooled by, mouth open. The ichthyologist did not report the kind of shark beyond insisting that it was one of those with teeth. One rarely went more than a few minutes in the water at Raroia without being investigated by a shark. One member of the team worked at Takume, a more closed atoll just north or Raroia, for over a week and essentially saw no sharks. As a result while there is a lot of valuable pearl shell in many of the open atolls such as Raroia, only the essentially closed atolls such as Hikueru and Takume are also sufficiently free of sharks to make pearl shell fishing seem worthwhile. These shells are characteristic of the sides of reef patches.

Coelenterate corals, Pocillopora and Acropora and genera of similar appearance, dominate the edges of the reef patches. This edge comes just about to the low tide level of the lagoon. Often the edge appeared a bit better developed on the windward side. This led to a week of vigorous discussion during the summer relative to the origin of the elongated shape of the more downwind coral patches. During tradewind periods the water is calmer on the windward, or upwind, side of the lagoon. Could it be that this is correlated with the shape differences? Perhaps the normal higher effective tide level in downwind regions and larger waves, induce the development of the reef patches to greater elevations. Abnormal calms would then equalize the effective tide level over all the lagoon, leaving the downwind coral patches more exposed to air at low tide. Thus one could expect more death on downwind coral patches, especially on their lee sides where wave action would be least effective. Not only would one expect these lee sides to break down more, but the strongly calcareous detritus from the upwind sides could be expected to be carried over the lee sides as a suffocating blanket. The material from both edges would be deposited in the lee of the reef patch forming a substratum on which more corals could grow in that direction. The elongated patches would result. Numerous tests of this hypothesis were suggested. One was to view the contours of the patch reefs to see if there was a predominance of accumulated detrital material on the downwind side. Another was to note the nature of the patch reef surface for evidence of such greater breakdown and lateral growth of this leeward rim. In most cases only the most contrary conclusions could be drawn from the observations.

Reef patches in the lagoon were seen to be of all sizes and forms. The general forms are outlined in Figures I & II of Danielsson's report on Topographic terms (Atoll Research Bulletin No. 32). The smallest KAPUKU might be said to consist of one coral, usually a coelenterate, growing on a bit of shell or a tree limb or other solid particle on the bottom such as an old shoe or bottle. In some instances it appeared that the coral had grown to such a size that the base had been upset, the coral head toppled over; the lateral surface then coming to serve as the substratum where several forms had developed. Indications that this toppling process was repeated several times were seen variously, and KAPUKU were seen from a foot or so in diameter to those as large as a barn. If these develop sufficiently near the surface so that they can be seen, they are called MARAHI. Those coral patches at the surface depending upon size are called TIRARE, if small, PUTEU, if medium in size, with KARENA being the name for the largest, often as much as 100 meters across or over.

The smaller categories of coral patches are very irregular mounds. The large coral patches were in general in deeper water and in overall aspect truncated cones. However, in more intimate detail the upper twenty feet was apt to be quite vertical and the upper three or five feet an irregular, overhanging shelf. The vertical walls were likely to be densely covered with various species of Caulerpa. Sandy ledges below ten feet down could be expected to be covered with Halimeda. The sloping bases were to a large extent covered by fine white sediment, dotted with irregular chunks of coral material such as might have broken off the rim of the reef patch. On these chunks coelenterate corals and Caulerpa were abundant.

The surfaces of many of the reef patches reached low water level. There were no terrestrial forms on any of them though a very few had chunks of dead coral so placed that they protruded from the water even at high tide. Such appeared to be blackened by the same blue-green algae as cause the blackening of spray zone rocks along the sea reef shores.

The reef patches that approached the surface were flat on top. The smallest (TIRARE) were more or less alive completely across their tops. If one visits a succession of increasingly large reef patches one finds that they are progressively like micro-atolls in that the center is more apt to be a pool a few feet deep and the edge a rim a few feet wide more or less complete and higher, just below low tide line. Coral patches of intermediate sizes (PUTEU) were apt to have several smaller sand-bottomed pools in place of the one large pool area of big reef patches (KARENA).

Large reef patches had a rather consistent external anatomy. They were very much like the lagoonward edges of the lagoon reefs. The margin of the rim was usually irregularly rounded and almost entirely of animal corals; corresponding to the "G" zone of a lagoon reef. Horizontally this area was regular in form, usually less than one meter wide. Inwardly it could be expected to yield to a uniform flat region. Here the odd coral animal, Fungia, could be taken as an indicator organism. The branches of coelenterate corals, which at the edge of the patch top were separate, dendritically branched forms, were here (on "E" or "F" zone) a nearly solid mass of branches with but small cracks between. When near the surface these small cracks were filled with (or the branch surfaces encrusted with) a prostrate Zonaria and other similar algae.

Algae were not conspicuous on reef patch tops at Raroia, except locally near the rim edges where sometimes prominent areas of Polysiphonia (11015), Lophosiphonia (11016 and 11014), and Bryopsis (11011) were to be found. These populants were particularly abundant on windward edges. The windward rim edges were sometimes more loose in structure, often having holes through them, and often more overhanging than the lee rim edges.

The micro-lagoons, or pool areas in the reef patch tops, were as a rule s sand or sediment floored and a foot to a meter deep (as in the lagoon reef "C" zones). Scattered about could be expected dead coral animal fragments, often with living coral growths similar to the smallest reef patches (KAPUKU) described above. The inner edges of the rim (essentially equivalent to lagoon reef "D" zones) were full of small caverns, nasty looking eels and a host of other fishes. Algae such as Rhipilia choke many of the smaller holes among the dead animal coral branches, and through binding of sand grains tend to fill these holes in such a manner that a rather solid mass results.

At Raroia from the air it often appeared that the reef patches were in lines as though separated from each other by circulation cells radially arranged in reference to the downwind shores. On the map these show conspicuously on the most southwest lagoon shore near Oneroa. That their direction is radial or in reference to the prevailing winds is seen by the arrangement of the most southeasterly reef patches shown. Unfortunately, we did not have sufficient flight time available to take photographs of the lagoon itself and thus this was not followed through.

Piscatorially the reef patches were like the shore bound reef patch faces but neither so rich in species nor in numbers. The squirrel fish are rather common to the patch reefs and are the notable new element in the fish fauna as one passes from the shore out into the lagoon.

Phycologically the vertical faces of the reef patches were unique for Raroia. They were often covered by great quantities of a large-jointed Halimeda and by masses of relatively simple forms of Caulerpa pickeringii. Masses of Caulerpa bikinensis were favored pastures for turtles. Pendant from overhanging coral shelves one found upon occasion six to ten feet down Pseudotetraspora antillarum home. This in the field looked not unlike a thick gelatinous sheet of Ulva irregularly four to ten centimeters across.

V. VERTICAL DISTRIBUTION

Aspects of vertical distribution were pursued both on the land above and into the water of the reef edges in the lagoon and on the sea shore below the intertidal region. In respect to the intertidal regions we were particularly anxious to see whether or not there was a correlation between tides and the observed distribution of living things.

The intertidal region is a common point of departure for elevational studies and thus the tides received consideration first. It was quite apparent that determining rise and fall of the tides beyond the sea reef would be quite a feat with the materials at hand, thus a tide stick was set up on the wharf in the lagoon. It was very quickly determined that while the time factors were not so muchly affected the vertical components of the tide curve were very much affected by the wind and sea roughness. This was presumably a result of the water piling in over the reef and piling up against the lagoon shore more with some winds than others, the outlet through the pass remaining the same. It was determined that the mean tide range in the lagoon was probably a little over one foot. Our impression, and it was only an impression, was that the tidal variation of the sea outside the atoll was between two and three feet or about double that in the lagoon. Tides are reckoned from Apia, about a thousand miles away across certain factorial nodes. There was at least as much as fifteen centimeters difference in successive high tide levels, and similar differences between successive low tide levels during our period of observation.

The three basic zones observed (Figs. 7 and 8) can be called from convention, supralittoral, littoral and sublittoral. Upon occasion divisions of these or variations from this pattern were observed, but the observations were few, rather closely placed geographically and no accurate leveling means were available, and thus little can be said justifiably as to what these anomalous situations might signify.

Below the lowest levels exposed by the tides at the reef margin the biota was dominated by a smooth coating of Porolithon onkodes. This extended downwards at least eight meters (no one measured this) and covered over 95 per cent of the surface. On flatter tops of spurs an occasional area was conspicuously dotted with Pocillopora. This whole region dominated by Porolithon can be considered an upper sublittoral zone.

A coral animal zone below this level was reported by the geological members of the party. Such a zone would be a lower littoral zone, and correspond to what has been observed elsewhere by others and in general referred to as a ten to twenty meter terrace covered with a forest of coelenterate corals.

Vertical distribution along the sea shore near Garumaoa (Fig. 5) was noted sufficiently that the sequential events are rather certain. However, there are special problems involved in studying the vertical aspects of distribution on a coral reef. Firstly the sea breaks over the very irregular edge of the reef almost constantly. At low tides on calm days the reef pool is likewise calm with no waves. As soon as the tide is high enough that the waves are not completely broken at the sea reef edge they run across the reef flat and there is considerable wave action along the landward edge of the reef. Nowhere on the reef margin does there appear to be a regular sine relationship between effective water height and time.

In Figure 7 we have presented a summary of observations on the Homohomo transect sea shore and reef. To take account of the tide pool like nature of the reef and the desirability of different vertical scales the figure has been broken in the middle by an "unscaled" portion. For that portion of Figure 7 concerning the algal ridge and the spurs and grooves this unscaled portion includes the positive and negative changes in elevation met in passing up over and back down beyond any algal ridge (Fig. 3) or cuesta that may be present and the elevational changes within the pool itself.

The algal ridge and the organisms living on and in it can stand emersion but also are found dwelling constantly immersed. The algal ridge is thus considered to be a sublittoral fringe. As examples, the upper sublittoral fishes may feed here on the algal and other materials of the intertidal area but they are always immersed in the water. They, themselves, are not considered to belong properly to the sublittoral fringe.

Porolithon onkodes is a fine example of a typical fringe zone organism for it lives better here in this subzone under the unique circumstances of surf, aeration and bright light than elsewhere, though it is widely spread in its major zone, the sublittoral zone. It occurs below low pool level on the reef flat, in the channels, on the lagoon shore and beyond the algal ridge as a coating of the grooves and spurs down to a depth of at least four to eight meters.

The Amphiroa zone is regularly exposed by the low tides but briefly. It has, therefore, been treated here as manifest of a lower littoral fringe or more simply a lower littoral zone. The species of Jania found were in always-submerged localities. The Amphiroa species forming this turf at Raroia and Takume seems to be an elevational correlative to such jointed coralline algal species elsewhere as Corallina gracilis.

At the shore edge of the reef pool the fauna is not the same on the upper and lower parts of the brown intertidal area. For the present we accept the lower area occupied by Morula granulata as being equivalent to a sublittoral fringe. Thais hippocastaneum occupies the upper part of this shore area. The sea reef areas typified by the occupancy of Thais and Amphiroa have been (Fig. 7) considered as the lower littoral areas on the sea shore. It may very well be that this region should be treated as but a single bionomic zonal unit. There is not the clear break between them one usually finds between sublittoral and littoral zones and it would perhaps be better to treat this whole region as sublittoral fringe.

Higher in the intertidal area on the shore Nerita plicata ranges essentially over the lower edge of the black zone dominated by Entophysalis crustacea. Tectarius is higher on the black zone. Respectively these two have been taken (Fig. 7) as indicators of mid- and upper littoral zones. Melaraphe coccinea, on the grey rocks, was thought to be an indicator of a supralittoral fringe (Fig. 7).

Above the intertidal zone the atoll was covered with a rather ubiquitous coating of blue-green algae. These bound the sand or formed a grey to blackish coating on gravels and rocks, and even on bark and dead wood. The macroscopic vegetation was at its margin a bush zone. This had been described in our description above of the sea beach (Section B) and the lagoon shore above high tide line (Section D).

The bush zone was a wedge-shaped encircling zone, perhaps two meters high on the sea shores and one half to one meter high on the lagoon shores. On lagoon shores this zone was sometimes absent along the central portions of long islands. It occurred to us that the bush zone and sea beach might represent the horizontal extent of variation in the position of the Ghyben-Herzberg fresh water lens margin. This fresh water lens has been found on other atolls to approach or extend under high tide line on the lagoon shore. We presumed this to be true on some parts of Raroia, e. g. at Oneroa, for in such places the coconuts and Guettarda are found right at high tide line. In such places a supralittoral fringe is absent as well as the bush zone or lower supralittoral zone.

One must note here that the above explanation considers the trees as appearing at high tide line, though their roots must extend into the fresh water lens below. It is thought that the lagoon mean water level was higher in elevation than the sea. In correlation the intertidal zones were shifted upwards, but without the conspicuous fringe zones of the sea shore the final result being adjacent littoral and supralittoral zones without a place for the fringe organisms. Speaking of genera this means an absence of Melaraphe, Messerschmidia, Pemphis, and Suriana toward the centers of the lagoon shores of the longer islands. This is in line with the observations made on the distribution of these organisms.

Above the bush zone, or the intertidal zone where the bush zone was absent was the vegetational area normally occupied by Guettarda speciosa. Guettarda forests at Raroia and Takume and most other Tuamotuan atolls have been displaced by man with his coconut plantations. As a rule all but the highest parts of the islands were covered with coconuts. However, the smallest islands that were relatively very high showed in their highest regions a shift in vegetation to Pandanus distinctus. Only the smallest islands, e. g. Kumekume, Temari and Takeke in Figure 5, reached elevations over ten feet above high tide level, the elevation at which the coconuts dropped out.

At Takume it was noted that Pisonia grandis was restricted to the highest parts of the island, the ridges between the very large taro pits, and was thus at elevations of plus 15 or 20 feet. On Raroia the islands upon which Pisonia was growing were probably not as high. Similarly Cordia subcordata was found on the higher parts of islands, but the elevation of none was measured with the hand level.

The incomplete channels and lagoon shores presented but few opportunities for vertical distribution studies. Unconsolidated shores predominated and, e. g. at Mataira, were brown intertidally (probably Entophysalis crustacea) but little grew in such places that could be related to vertical distance. The village wharves and occasional conglomerate rock areas made a few sets of observations possible.

At Garumaoa (Fig. 8A) the lagoon beach had several rock outliers which while not continuous gave, when taken as a whole, a fairly continuous picture of the vertical distribution to be found on such a sandy shore. The highest marine algae were found in a small tidepool on the surface of a rock area on the shore. The sand in the bottom of this fifteen centimeter deep small pool was bound by algal filaments (11339). This pool was above the uppermost limits of macroscopic algal growth. About 15 cm below its edges a green alga covered the rocks followed lower by other organisms at other levels. Figure 8B illustrates the zonation on one of the few rather large isolated boulders found in the sand along the lagoon shore.

The vertical zonation found along the shores of an incomplete channel at Gake is illustrated in Figure 8C. As the black gravel (11431) extends along the shore of the channel lagoonward it gradually becomes smaller in diameter and less conspicuously gravel, e. g. the gravel graded into sand. At the lagoon end of the channel the shore was of sand and a black zone was no longer to be distinguished. The coarser sand of the lagoon shores (11440) seemed predominantly fragments of what may be Porolithon gardneri of the sea reef.

The Garumaoa village wharf provided the best opportunity for studying intertidal vertical distribution in the lagoon. Distribution was observed to be somewhat different on the two major sides of the wharf. Likewise there were some differences laterally along the wall the significance of which were not clear. Figure 8D illustrates such vertical distributional differences by the slopes of the lines.

In Figure 8 a five-zone arrangement of the biota can be inferred as a general rule. Where solid materials extend sufficiently high, a supralittoral zone can be said to be represented. The littoral zone below this is essentially divisible in turn into upper and lower zones; though in one case (Fig. 8B) where the size and position of the rocks prevented a real analysis, three littoral zones may have been evidenced, or the Sphacelaria may represent more truly a sublittoral fringe. A little consideration of the exposure of the habitats in reference to waves and wind leads us to suspect that the variable elevations of the breaks illustrated between the zones are due to wave action.

Two lower zones (Fig. 8) were in some places evident. These were considered to be a sublittoral fringe and an upper sublittoral region. While the biotic elements of these were present, they were in places not well sorted into separate zones. On the shores of the incomplete channels, only one zone, an upper sublittoral zone, could be found.

The coelenterate corals were active in lagoon areas in what is accepted here as the upper sublittoral zone. Beginning a very few meters below the surface Caulerpa bikinensis, C. pickeringii, Halimeda sp. and Pseudotetraspora antillarum became evident. These covered the sides of lagoon reef patches essentially to their bottoms. It was felt that these species were indicators of a mid- or lower sublittoral zone. Below about six meters, there appeared to be an increased abundance of individuals of Spondylus, Tridacna, etc. Whether this was a natural distributional phenomenon or due to fishing is questionable.

VI. CHANNELS

The areas between the islands dotting the reef are channels. These are seen in the illustration (Fig. 5) to be of two kinds. The three islands on the right are separated completely by one kind, complete channels. These are waterways connecting the sea with the lagoon. Toward the center of the figure three of the other kind, incomplete channels, show. They are water filled at their lagoonward ends but do not separate the above-tide land into separate islands and connect to the sea reef flat. Incomplete channels are related to the various pond types found on the atoll and described here below.

The bottoms of complete channels are essentially plane surfaces but often have protruding islands of conglomerate material in them. In general at low tide the channels are but perhaps thirty centimeters deep at the sea end, but deepen gradually toward the lagoon until at the lagoon end of the solid bottom they may be two feet deep at low tide level. The Raroians refer to the reef flat as AKAU and to them the AKAU continues between the islands insofar as the bottom is solid and has the general character and population of reef flat regions. Lagoonward of the solid bottom the channels deepen to a few meters and are in character, then, like the shallow lagoon bottoms. In downwind areas the mouths of such channels are often closed at their lagoonward ends by a bar of gravel, sometimes apparently capped with coral rock. The gravel bars as shown in Figure 5 interrupt the shore bound reef patches, or lagoon reef. In windward areas the lagoon mouths have sandy similar bars and there is no shore bound patch reef to interrupt.

Particularly near the edges of the complete channels there are often numbers of rather flat rocks under which there is almost always a population of grey spotted moray eels (Gymnothorax picta). These eels, common to the reef pools, were at most clearly timid, as were the black-tipped sharks (Eulamia) common to the same channels and pool areas. The same Goniolithon species as in the sea reef pool zone apparently, and Porolithon aequinoctiale are knobby corallines almost always found relatively undeveloped. The smooth general cover of everything that does not move, below low pool level, appears to be Porolithon onkodes, but this, too is undeveloped. Such organisms as Chama and the corals common to the inshore edge of the reef-flat pool area are likewise common biotic elements in the channels.

In the deeper of the complete channels there is a greater representation of corals and such other elements as Diadema and Porolithon aequinoctiale and a greater profusion of species. The Vermetus and Drupa species typical of the reef pool areas occasionally appear in the channels. In the channels near Gavarivari toward the lagoon fragments of coral were found with some surfaces actually covered with vermetids. Some channel areas just north of Tetou were entirely blackened with what was probably this same vermetid on their bottoms at the sea end. The same or a similar small vermetid grew in an interesting relationship with the coralline alga forming a shore bound pavement like that in the "B" zone of the lagoon transect at Homohomo.

Around the boulders on the bottoms of more central regions of the channels near Garumaoa (Fig. 5, e. g. between the three islands on the right) there were often Caulerpa urvilleana colonies (and e. g. at lagoon end of the channel at Kaea, 11890). Nearer shore what was apparently the same Microdictyon okamurai was the most conspicuous alga and under the edges of rocks below low pool level but very near shore what appears to be Dictyosphaeria cavernosa was the most abundant macroscopic alga. The more or less vertical intertidal shores other than for being coated more thickly with a brown scum of blue-green algae are like the shores of the sea reefs.

Incomplete channels appear to be closely related biotically to the lagoon. Certain typical lagoon species of clams and such gastropods as Cerithium breve were found commonly. While the holothurians common to low tide line elsewhere were seen again here, the yellow Porites common at this level on the sea reef was absent. In fact no living coelentrate corals were seen in the incomplete channels though they did appear on the gravel bars at their mouths upon occasion.

A rather detailed study was made of ponds and incomplete channels at Gake and a classification of them devised. These pond and incomplete channels associated with the lagoon shore were distinguishable as a series of biologically or physically distinguishable types. The most isolated of these (Type 1) were flat damp spots often covered by green strands of Phormidium papyraceum or Anacystis montana (11423). These spots were in the gravel between the sea beach rampart and the heads of incomplete channels, apparently considerably above high tide level.

One pond or damp spot (Type 2) near the lagoon shore end of the Gake transect was apparently water filled at exceptionally high waters (the collections had salt on them) or during rains. On the most moist bottom parts there was little other than a gelatinous yellow-brown coating (11433). On the most soil-like drier but protected areas were wefts of Calothrix pilosa incorporating Anacystis dimidiata and Entophysalis crustacea (11432). Moss-like tufts and coats of Calothrix pilosa (11434) in pure stands covered most of the remainder of the pond bottom. This pond was perhaps one left in a gravel hook more or less made permanent by a growth of Suriana maritima and Pemphis acidula on the sand beach front and between it and the lagoon.

About fifty meters inland from the center of the lagoon shore was a pond (Type 3) about 8 M by 20 M long. This was a freshish water pond. Newell says that sand along the lagoonward shore of this pond indicates that it may have originally been a low spot in the island shore cut off by shore sand and thus isolated from the lagoon. There were several similar ponds seen. The fine silt in this pond was consolidated at the surface into an orange red cake of Schizothrix lacustris, Entophysalis crustacea, Anacystis dimidiata, Plectonema nostocorum and Calothrix crustacea (11429). The Pemphis crab was common in such ponds.

A shallow (15 cm deep) pond (Type 4) was selected as belonging serially here. It was covered on the bottom by an orange algal crust and around the edges by more of this colored algal crust. Though probably not regularly receiving tidal water; the same mullet was found here as in the following pond type, Type 5.

The island areas of Teuramote and Tikagera were separated by an incomplete channel. This channel (pond Type 5) was shut off from the lagoon by a sand bar on which grew a number of Pemphis and Messerschmidia bushes. The pond thus formed was brackish. It was a repository for refuse and excrement. The water was green; as though with a chlorophycean algal bloom. No equipment was available for study or preservation of this plankton. The bottom (maximum depth of 2 meters) was covered by about 15 cm of very soft sediment over gravel. On this sediment were occasional patches of very soft brownish purple Phormidium papyraceum (11422). On the flat and near water level shores were large areas of the orange red algal coating discussed variously above. On beach rock isolated as a ledge in the pond was a fine green alga. Under water and on the beach rock around the edge of the pond there was an abundance of soft (Newhouse said "fluffy") orange material (11424). Gravelly sand shores in places in the water's edge had a dark colored blue-green algal mat that was in places broken into small pieces approaching balls in form but still somewhat angular in outline and distinctly dorsiventral.

On places where gravel and beach rock shelved into this pond there was a multitude of the small gastropod, Cerithium breve. In more sandy areas, similarly just below low water level, there was an abundance of one small clam. One sipunculid worm, perhaps peculiar to this environment, was found a few times. At night, and only then, a myriad small (2 cm) colorless shrimps were attracted to any slight disturbance at the bottom. A small crowd of one species of fish (Mugilidae) lived in this area.

Toward the east end of this wooded series of land areas a somewhat less isolated pond (Type 6) was discernable by the addition of Albula vulpeo, the mild fish, to the fish fauna described for the above ponds. The same clam and gastropod (Cerithium) were in abundance. The daytime investigations revealed none of the shrimps observed in the Type 5 region. Brackish water gastropods were generally abundant. The only two Raroian records for two species were obtained here. One of these was a Neritina found just beneath the then current water line. The other was a very active pink cap shell (not unlike the Hungarian cap-shell) found at similar levels on coral fragments somewhat buried in sandy mud.

It should be emphasized that none of the ponds in this series so far appeared to be a pond that ever has a free exchange of sea water other than perhaps by storm waves that sweep over the land to them over levels well above the highest tide levels.

Pond Type 7 as selected was of small ponds near one of Type 8. The Type 7 ponds were apparently in connection with Type 8 and the lagoon at the very highest tides through channels lying above the usual high tide levels. Though these were small relatively shallow ponds Acanthuridae appeared in the fauna in addition to the previously mentioned fish.

Pond Type 8 is represented by ponded channels regularly having a channel opening to the lagoon with the higher tides. Coral growth appeared meagerly here near the lagoon entrance. In addition to the previously mentioned fish fauna there were additionally members of the Scaridae. Not only was the fish fauna population distinctly larger there but the individuals, for example of Albula, were large. Balls of healthy Jania (11490), a filamentous green (11492) and a small clam (11493) were to be found. The water, though no measurement was possible, was seemingly nearly of the same salinity as the lagoon water.

Incomplete channels open at all tides to the lagoon appeared to the next type, Type 9, distinguishable biologically in the series. Here particularly near the lagoon end corals were abundant and there were some holothurians. The fish population was broadly variable but typified by a neon blue damsel fish (Pomocentrid) with a conspicuous yellow tail.

The more strictly intertidal region toward the heads of incomplete channels (pond Type 9) is dominated frequently by the red mud of Entophysalis crustacea (11435). Along the sides of such channels in flat areas probably covered by highest waters are crusts that seem to be transitional to rock. These are dominated by Entophysalis crustacea, Symploca kieneri, Mastigocoleus testarum, Plectonema terebrans and associated fungus filaments (11445). Lower and approximately one-third of the way to the mouth of such a channel the region below blackened by Entophysalis crustacea (11431) may be forming beach rock one form. This surface is a mixture of the "red mud" described above and stones that are predominately yellow brown with, again, Entophysalis crustacea (11447). On lower surfaces of one such stone were to be found 1 mm disc-like patches of blue-green algae (11448). Further toward the mouth of the channels this zone is entirely gravel, coated yellow brown with Entophysalis crustacea and Calothrix scopulorum (11441) on top and clean beneath. This forms a zone 20 cm broad vertically. At the lagoon ends of some such channels there is a transition to sand as in the case of the black zone; and there this yellow brown zone can be distinguished no longer. The channel below low tide line insofar as observed was sand, coral or boulder bottomed.

Above the black zone inside the channels of pond Type 9 the shore areas are dominated by gravel and sand, bound by such blue-green algae Anacystis montana, Calothrix scopulorum, C. parietina, Schizothrix longiarticulata, S. thelephoroides, Entophysalis crustacea, Symploca kieneri, Microcoleus acutissimus and what was taken to be a form of Mastigocoleus testarum (11442, 11443, 11444), there was a sandy-gravelly soil with little humus on top. Neither ferns nor mosses were observed here.

The lagoon shore itself may well form a terminal member, Type 10, in the local series of aquatic habitats associated with the lagoon shore. An additional discussion of this terminal member in the series is to be found under the discussions of the lagoon shores. The shore at Gake was covered by very find sand, has a fish population that most immediate to high tide line is characterized by the fish Chromis coeruleus, black-finned mullet and black-finned sharks. Two octopods were collected at Gake in the very shallow (15 cm) water as was one of two remoras seen.