Figure 1 The Dry Tortugas Bank

GEOCHEMISTRY AND MINERALOGY OF CARBONATE ROCK SAMPLES FROM ALDABRA ATOLL, INDIAN OCEAN

Stephen T. Trudgill[1]

INTRODUCTION

The stratigraphy and petrology of Aldabra have been described by Braithwaite *et al.* (1973) and Braithwaite (1975). Little is known about the geochemistry of the rocks present, apart from the analyses of two samples published by Stoddart *et al.* (1971). Accordingly, data are given in this paper which may contribute to the geological study of the island and also to the studies of soil chemistry and plant nutrition.

The samples were taken from the stratigraphic units identified by Braithwaite *et al.* (1973). These units are listed in Table 1, with the addition of beachrock. The numbers of samples within each unit are indicated. The sampling locations are given in Table 2 and shown in Figure 1.

METHODS

The rock samples have been analysed by X-Ray Fluorescence Spectrometry (Leake *et al.*, (1969)) for Ca, Mg, Na, K, Fe, Sr, Cu, Pb, Al, Zn, P, Ni, Co, Ba, S and Si. In the presence of very high levels of calcium the X-RF flowmeter became saturated and thus gave underestimates of the calcium present. Therefore analyses for calcium were also carried out by wet chemistry (acid digestion and EDTA titration; Bisque, 1961). Both data sets are reported. The wet digestion method also permits analyses of the amounts of acid insoluble residue to be carried out.

In addition, carbonate staining (Wolf *et al.*, 1967a) was also carried out on the hand specimens from which the samples for the X-RF analyses were taken. Acid Alizarin Red S solutions were used to differentiate aragonite and calcite from other minerals; a cobaltous nitrate boiling test to differentiate between aragonite and calcite and an alkaline Alizarin Red S solution to distinguish magnesium rich carbonates. As staining is not always a wholly reliable method of mineral identification, especially some shell materials, the mineralogy of seven of the samples was checked by X-Ray Diffraction using rock powders. The rocks were classified petrologically using the method of Folk (1959). The porosity of three samples was also estimated, using a

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Table 1. Stratigraphic units studied (after Braithwaite *et al.*, 1973)
(See Figure 1 for location of samples)

Unit No.	Unit Name	Samples Studied
1	Esprit limestone	1
2	Esprit phosphorites: oolites	2
3	Esprit phosphorites: conglomerates	3
4	Picard calcarenites	4a, b
5	Picard calcarenites + "soils"	-
6	Takamaka limestone	6
7	Soils filling subaerial fretting	7
8	Hard calcarenites	8a, b
9	Aldabra limestone	9a, b, c, d, e, f, g, h, i, j, k, l
10	Solution pit fillings	10a, b
11	Crab burrowed calcarenites	-
12	Algal stromatolites	-
13	Beachrock	13a, b, c, d

comparison of particle density and bulk density and a value of 2.7 for the specific gravity of calcite.

The samples were all near-surface samples but the actual surface was excluded from the chemical analyses (except for 13d which was a surface sample).

RESULTS

The petrology and mineralogy of the samples are shown in Table 2. The geochemical data are shown in Table 3a and 3b. The porosity data are shown in Table 4.

DISCUSSION

Substantive conclusions about each stratigraphic unit are not possible from the data presented since the samples are individuals from units which are often petrologically heterogeneous and which show considerable lateral and vertical facies diversity. However, some broad interpretations can be made. In terms of mineralogy and porosity, extreme diversity is evident. Frequently the samples appear to be simple bioclastic deposits, cemented by high magnesium calcite or aragonite.

Phosphates are present in small amounts in several rocks, as well as in the Esprit phosphorites. The X-Ray diffraction results suggest that a calcium phosphate form may be present (possibly $Ca_3 (PO_4)_2.nH_2O$ with peaks at d spaces of 3.446, 2.808 and 1.937 or $Ca_4P_2O_9$ at 2.784 and

2.716). Phosphate in these forms is relatively insoluble at the soil pH values encountered and this probably accounts for the formation of residual soils with a high total phosphate content but a low available phosphate content (Trudgill, 1978).

The main features of element distribution are summarised in Table 5 which lists those rocks in which relatively high concentrations occur. Two conclusions can be drawn. Firstly, that the rock element concentrations frequently bear relationship to the presence of carbonates laid down in association with organisms known for their association with particular elements (Wolf *et al.*, 1976b); secondly that the soils and solution pit fillings show markedly high concentrations of many elements, suggesting a residual origin for these deposits.

Silicon is of interest since it appears to be absent from many samples, apart from the pit fillings, soils and two samples of Aldabra Limestone. This is of interest in the context of the foliar chemistry of grasses which are known for their high silica content. Indeed Renvoize (personal communication) reports a scarcity of silica bodies in Aldabran grasses (Table 6). A specimen of *Sporobolus virginicus* from Esprit was analysed for silica by acid digestion and molybdenum blue spectrophotometry (Allen, 1974) and it was found to contain 0.16 mg/g (dry weight). This is low when compared with values of 0.1 to 1.5% for many U.K. grasses (Allen, 1974, Table A5).

These data are of use in indicating possible trends of concentrations of elements present in the rock samples. It is to be hoped that further work on the inputs, outputs and storage of elements may be made in the future because a geochemical study of a discrete island unit may prove to be a viable and interesting topic.

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Table 2. Location, petrology and mineralogy of samples

No.	Location*	Petrology	Mineralogy
1	Esprit	Calcarenite	1. A + HMC mix.
2	Esprit	Oolite	P 1. LMC cement 2. P + C
3	Esprit	Calcirudite	1. LMC, Fe 2. C + Fe
4a	Picard	Calcarenite	1. C + A in points
b	Picard	Calcarenite	-
6	Picard	Calcilutite	1. LMC + HMC, Fe
7	Dune Jean Louis	"Soil"	1. C 2. C
8a	Cinq Cases	Calcarenite	-
b	Cinq Cases	Calcarenite	1. C + A
9a	Anse Var	Calcarenite	1. grains HMC, cement A
b	Anse Var	Calcarenite	1. grains A, cement HMC
c	Passe Houareau	Calcarenite	1. HMC
d	Dune Jean Louis	Calcarenite	1. A
e	Picard	Calcirudite, corals	1. clasts A, cement C
f	Passe Houareau	Calcirudite, corals	1. HMC + A 2. C + P
g	Passe Gionnet	Calcirudite	-
h	Dune Jean Louis	Calcirudite, shells	1. C
i	Dune Jean Louis	Calcirudite, *Halimeda*	1. clasts A, cement C
j	Dune Jean Louis	*Chama* shell	1. A + C mix
k	Anse Var	*Goniastrea* coral	1. septae A, C between
l	Anse Var	*Platygyra* coral	-
10a	Picard	-	2. C
b	Ile Malabar	-	2. C + P
13a	Picard	Calcirudite	1. clasts A + C, cement A 2. A + HMC
b	Picard	Calcirudite	-
c	Picard	Calcirudite	-
d	Picard	Calcirudite	-

Abbreviations and key

*See Figure 1.
HMC = high magnesium calcite
LMC = low magnesium calcite
A = aragonite
C = calcite
P = phosphate
Fe = iron
1. = carbonate staining
2. = X-Ray Diffraction

Note: The first mentioned mineral is dominant over the second mentioned, unless the word 'mix' is used which implies roughly equal quantities

Table 3a. Geochemistry of carbonate rock samples. Ca and Mg in %; others in ppm
- = no data available 0.0 = below detectable limits
10,000.0 ppm = 1.00000 % A.I.R. = acid insoluble residue

No.	A.I.R.	Ca (1)*	Ca (2)*	Mg	Na	K	Fe	Sr	Cu	Pb	Al
1	0.62	28.9	35.0	1.6	0.0	177.1	3108.1	-	0.4	-	7973.1
2	2.38	22.2	22.0	0.8	1892.0	141.4	4762.9	313.5	133.5	13.9	1,3251.2
3	2.83	24.3	27.4	1.5	0.0	124.3	2538.2	467.1	15.1	3.1	5891.9
4a	0.19	31.6	37.2	0.9	0.0	1174.2	2281.6	389.8	111.4	5.5	5828.9
b	4.97	27.6	33.2	1.8	0.4	4198.0	2175.9	-	0.0	-	5937.6
6	-	19.0	28.8	1.9	0.0	3351.7	2272.8	1527.0	0.0	5.9	1,8882.5
7	18.34	3.1	3.0	0.1	37,1512.4	321.6	3,4829.5	151.5	68.4	23.1	1,3189.6
8a	2.21	29.8	35.6	0.7	0.0	206.1	2362.4	697.6	62.9	17.7	6880.1
b	1.45	24.3	30.0	1.0	0.0	251.0	4414.6	985.7	54.6	15.9	2,1861.7
9a	0.58	28.9	34.2	2.4	0.0	181.4	3548.2	1438.1	0.0	5.8	1,0410.4
b	0.71	26.9	32.8	2.2	0.0	212.6	2594.3	942.4	11.4	7.7	1,1098.6
c	1.70	38.2	-	1.6	0.0	289.1	2201.2	668.6	0.0	7.5	6154.0
d	0.42	38.3	36.4	1.7	0.0	138.9	2303.7	888.0	0.0	5.5	5879.4
e	2.37	24.9	30.8	2.0	0.0	299.9	2646.1	1782.0	0.0	8.3	9140.9
f	0.83	24.8	13.2	1.6	1128.7	338.3	2379.8	394.7	5.3	8.0	6115.3
g	3.20	28.1	34.0	2.5	7225.4	7469.0	2193.2	1040.2	0.0	0.0	5592.9
h	1.99	26.7	35.5	1.0	0.0	288.7	5908.9	-	18.6	-	1,3654.7
i	2.97	21.1	31.0	1.2	0.0	363.0	2857.8	839.3	0.0	8.9	1,3084.0
j	1.44	30.4	36.0	0.6	0.0	175.5	2215.4	533.7	4.6	5.6	5655.0
k	4.73	19.7	29.6	2.4	0.0	747.7	2248.1	-	0.0	-	1,4644.8
l	8.31	30.2	33.9	1.1	0.0	728.9	3926.8	-	16.4	-	1,1167.2
10a	1.16	29.4	35.5	1.4	3799.3	635.0	4748.4	1139.5	0.0	6.7	1,3986.1
b	9.86	25.3	31.7	2.2	7.8	3472.9	1,3054.3	913.5	0.0	0.0	3856.3
13a	-	29.4	-	2.0	0.0	359.5	2261.9	1701.0	-	8.1	5939.0
b	-	19.1	-	1.3	0.0	4168.0	4052.1	-	7.2	-	5481.6
c	-	28.5	-	3.9	0.0	153.5	2167.0	1498.8	0.0	0.7	8190.6
d	-	27.5	-	1.9	1,6169.0	632.9	2779.0	1655.0	6.5	6.5	5481.6

* Ca (1) = XRF; Ca (2) = wet digestion (Bisque, 1961)

Table 3b. Geochemistry (ppm) of Aldabra rock samples (continued)
(For notes see Table 3a)

No.	Zn	P	Ni	Co	Ba	S	Si
1	19.9	9,1864.5	17.2	6.3	0.12	1656.1	0.0
2	440.8	44,6340.0	6.6	8.2	0.11	1213.9	0.0
3	10.5	33,1202.3	9.3	7.0	0.10	2328.2	0.0
4a	2.9	1,2165.4	11.4	1.0	0.10	2363.6	0.0
b	1.5	3267.8	8.6	2.7	0.10	2320.7	0.0
6	0.23	6345.5	8.2	0.0	0.09	1669.4	0.0
7	18.6	2199.3	38.3	23.9	0.20	998.9	2338.8
8a	37.4	8,0180.9	10.0	1.6	0.09	1148.9	0.0
b	149.8	29,0165.0	14.7	0.0	0.13	2141.4	0.0
9a	134.4	7,3274.6	10.3	7.3	0.11	1322.4	0.0
b	27.1	17,0094.0	10.2	0.0	0.13	1682.0	0.0
c	0.0	6468.5	10.5	0.0	0.11	1908.3	0.0
d	2.5	3,2812.6	10.4	0.0	0.10	1297.7	0.0
e	16.7	5038.2	9.2	7.0	0.11	1516.9	0.0
f	0.0	3436.8	8.4	2.1	0.09	3373.7	0.0
g	9.5	9648.0	8.2	6.0	0.12	3069.0	0.0
h	343.2	1,8402.7	12.0	0.0	0.12	785.5	0.0
i	-	43,9886.2	8.2	0.0	0.12	1897.6	4870.0
j	-	1,7418.3	8.1	6.5	0.10	1947.2	0.0
k	68.0	4293.5	8.2	2.8	0.10	2178.1	0.0
l	82.2	1,8421.6	11.9	2.8	0.13	1709.8	1442.2
10a	39.2	5,4402.1	9.6	0.0	0.10	1248.5	1327.7
b	378.8	9,5065.1	25.8	3.4	0.20	2337.8	2,2025.8
13a	-	3018.7	8.7	1.6	0.10	1789.1	0.0
b	11.6	5993.4	9.7	1.2	0.09	2043.8	0.0
c	0.0	1978.5	9.9	1.0	0.10	1591.8	0.0
d	-	2057.6	9.0	4.6	0.09	2379.3	0.0

Table 4. Porosity of selected Aldabra rock samples (%)

Sample 9a		Sample 9f		Sample 9h	
	42		48		10
	19		12		16
	26		1		14
	30		7		12
	24		25		7
			1		7
					8
					26
mean	28.2	mean	15.6	mean	12.5
standard deviation	8.66	standard deviation	16.76	standard deviation	6.24

Table 5. Rocks with high concentrations of the elements measured (Approximate ranges of high values indicated in brackets)

Aluminium (over ca. 1000 ppm): shelly calcirudites, hard calcarenite, solution pit filling, Esprit phosphorites, beachrock, Takamaka Limestone

Barium: slightly higher (0.2 ppm) in solution pit fillings

Cobalt (ca. 10-20 ppm): solution pit fillings, phosphorites, some calcarenites, some shells and corals

Copper (ca. 100 ppm and over): phosphorites, some calcarenites, beachrock, solution pit fills

Iron (over ca. 2000 ppm): solution pit fills, phosphorites, beachrock, some corals

Potassium (over ca. 1000 ppm): shelly calcirudites, beachrock, solution pit fills, algal limestones

Magnesium (over 2 per cent): beachrock, shells, corals, solution pit fills, algal material

Sodium (over ca. 2000 ppm): beachrock, some corals, "soils"

Nickel (over 20 ppm): "soils", solution pit fills

Lead (over ca. 100 ppm): algal material, some calcarenites, Esprit phosphorites, solution pit fills

Sulphur (over ca. 2000 ppm): corals, shells, solution pit fills, phosphorites

Silicon (over 2 per cent): solution pit fills

Strontium (over ca. 1500 ppm): corals, beachrock, algal material

Zinc (over ca. 300 ppm): Esprit phosphorites, shells, solution pit fills

Table 6. Silica in Aldabra grasses (S.A. Renvoize, personal communication) (microscopal examination)

Stenotaphrum clavigerum	Sparse silica bodies and silica-containing cells, up to 8 μm long
Panicum aldabrense	No silica seen
Sclerodactylon macrostachyum	No silica seen
Sporobolus virginicus	No silica bodies seen but silica-containing cells, 4 μm long frequent

HISTORY OF GOATS IN THE ALDABRA ARCHIPELAGO

by D.R. Stoddart[1]

A summary of the history of goats on Aldabra was given by Stoddart (1971, 617-619), and references to goats on other islands are included in Stoddart (1970). In recent years further references to the early history of goats have been found, and this note summarises present knowledge on the history of goats in the Aldabra archipelago.

Assumption

Goats were said by Bergne (1901) to have been first introduced to Assumption in 1867 by Capt Bidenfield, R.N., H.M.S. *Wasp*; this is the earliest date at which goats are mentioned in the Aldabra group. Abbott (1893, 763) stated that at Assumption 'Numbers of goats run wild, having been introduced many years since from Europa Island'. Dupont (1907, 12) stated that they had been introduced about twenty years prior to his own visit in 1906.

Rivers in 1878 reported that there were some 500-600 goats of two to three 'species' on Assumption: 'they all seem to be in fine condition, they feed on shrubs such as the "Bois amanthe" [*Pemphis acidula*] but greatly prefer the "affouches" [*Ficus* spp.?] of which they even eat the bark'. In 1895 Baty estimated the numbers to be 300-400. He himself saw a party of 60 goats, and some of his group captured a further 30. He noted that 'their bellies are swollen to almost abnormal proportions'. Tonnet (1905) captured 70 in two days. In 1906 Dupont reported 'several thousands' (1907, 12), 'in spendid order' even at the end of the dry season; he thought of them as a major resource, and even suggested that a resident guardian be appointed on the island to safeguard the population and regulate cropping. In the same year Nicoll (1908, 112) found 20 very wild animals near the foot of the high dunes: 'some of the males were remarkably fine animals. They are excessively wild'.

By 1916, however, there were only 'a few' left on the island (Dupont 1916). Vesey-FitzGerald (1942) makes no mention of goats in the late 1930s, and in 1964 Gaymer found them to be absent. In 1968 Stoddart *et al*. (1970) saw none, but were told that some still existed in the north.

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Cosmoledo

In 1878 Rivers found 'a few goats' on Menai, together with 'a quantity of skeletons in bushes', which he attributed to lack of rain. Bergne (1900) reported goats 'in numbers'; but half a dozen earlier seen on Menai had been reported not to be doing well (Baty 1895). Griffiths reported at second-hand a comment by James Spurs in 1892 that there were 'large numbers of goats' at Cosmoledo (Fairfield, Griffith and Abbott 1893, 154).

There were no goats on Menai in 1968 (Bayne *et al.* 1970), though some were reported on North East Island by Piggott (1961).

Astove

Baty in 1895 drew attention to the absence of goats on Astove, and there is apparently no other reference to them on this island.

Aldabra

The first record of goats at Aldabra is that by Rivers (1878): 'There is also a few goats found at "Ile Picard" and some have been set loose on the other islands'. In 1895 Baty 'saw several goats'. He stated that one female and one kid had been placed on Picard in 1890, presumably by the lessee James Spurs, and by 1895 there were 40-50. In 1892 Griffiths had seen 'several specimens which had been taken to Aldabra' from Cosmoledo, again apparently by Spurs (Fairfield, Griffith and Abbott 1893, 154). Baty (1895) released eight more goats on Picard which had been brought from Assumption. He recommended that 'Goats should be placed on Aldabra Island, and especially on the plain near the Takamakas. There I feel sure they would do extremely well. It would however be necessary to shoot them when required for food'.

By 1900 it was reported that 'The goats introduced by Mr Spurs have thriven exceedingly, and now abound in great numbers on Picard Island'. In October 1901 Bergne saw 20-30 goats on Picard, and there were said to be several hundred. He reported Spurs's intention to capture them all.

By the time of Dupont's first visit in 1906: 'Goats... are thriving. Mr Spurs took them over from Assumption in 1890 and although they have been destroyed by the fishermen at Ile Picard I have come across herds which are scattered on the main island from Dune Jean Louis to the west end of Grande Terre (about 8 miles). They are extending every day and in the course of time they will reach the South East end where the ground and the water supply are much better' (1907, 22). In 1916 Dupont reported 'hundreds of them' at Cinq Cases, though they were very scarce in other areas, and by August 1929 'several thousands' (Dupont 1929, 14).

More recently Travis (1959, 178-181) describes considerable herds on the southern dunes, and Prosperi (1957, 198) also records goats at the east end of Ile Malabar. Goats were present on Grande Terre, Malabar and Ile Picard at the start of the Royal Society Expedition to Aldabra in 1967.

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ABBOTT'S BOOBY ON ASSUMPTION

by D.R. Stoddart[1]

Records on Assumption

Abbott's Booby *Sula abbotti* was first described by Ridgway (1893, 599) from a specimen collected by Abbott in 1892, apparently on Assumption Island. Abbott's own description of Assumption (1893, 763) does not mention boobies at all, but Ridgway (1895, 521) quotes notes supplied by Abbott. Under *S. abbotti* he quotes: '"Fou boeuf". A few breed on Assumption. Said not to be found on any other island in these seas'. Abbott (in Ridgway 1895, 520) also records *Sula sula* (as *S. piscator*) and *S. dactylatra* (as *S. cyanops*) from the same island. Of the latter he comments: '"Fou general"': 'A few breed in Assumption, laying a single egg on bare ground on sand dunes'.

In 1906 M.J. Nicoll visited Assumption. He collected *S. dactylatra* (Nicoll 1906, 697) and photographed *Sula sula* (1908, 112), but he does not mention *S. abbotti,* and in his general account of the island he does not mention boobies at all (1908, 107-113).

J.C.F. Fryer collected two specimens of *S. abbotti* in 1908, which he records 'inhabits the large dune, never descending to low parts of the island, and only going a few miles to sea to fish; it was never seen on Aldabra' (1911, 433). He further notes: 'This species is also recorded on Christmas Island. I have not compared my specimens with those from this island but if identical the distribution becomes even more curious'.

S. abbotti has not been seen on Assumption since.

Confusion with the Iles Glorieuses?

Gibson-Hill (1950) reviewed the literature on *S. abbotti* and suggested that there had been confusion over the labelling of the type specimen, which could have been obtained on Grande Glorieuse rather than Assumption. His argument was based partly on the apparent unsuitability of treeless Assumption compared with forested Grande Glorieuse for what is on Christmas Island an arboreal species, partly on what seemed to be ambiguities in Abbott's written accounts. Thus Abbott does not describe his booby in his account of Assumption itself; but in his description of Grande Glorieuse he mentions that 'Among sea-birds there is a booby, which seems to be peculiar to the island. They breed in large numbers upon the 'fouche' [*Ficus?*] trees, in company with frigates and common

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boobies' (Abbott 1893, 764). However, the only boobies he collected on the Iles Glorieuses were *S. sula* and *S. dactylatra* (Ridgway 1895, 524), locally called 'Capucin' and 'Fou général'. Gibson-Hill (1950) suggested that the 'peculiar' booby was in fact *S. abbotti*, and that Abbott's type specimen really came from Grande Glorieuse rather than Assumption. He adduced the further point that Nicoll did not find *S. abbotti* on Assumption, which was still uninhabited and undisturbed in 1906; whereas the fact that he did not find it on Grande Glorieuse either could be explained by the settlement and partial clearance of woodland on that island by the time of his visit. Nicoll (1906), however, stated that the most common booby on Grande Glorieuse was dark-phase *S. sula*. The *S. sula* collected by Abbott on the same island was also dark-phase (Ridgway 1895, 524), and this morph could equally be the 'peculiar' booby Abbott mentions, since white-phase *sula* are predominant on western Indian Ocean coral islands (other than Tromelin: Staub 1970, 203-205).

One further piece of published evidence, hitherto overlooked, is provided by R. Dupont (1907, 45), who visited Assumption in 1906. He lists only *S. dactylatra* (as *S. cyanops*) and *S. sula* (as *S. piscator*) from Assumption, while for the Iles Glorieuses he lists *S. sula* and *S. abbotti*. This latter he notes "exists only in Gloriosa" and gives as the Creole name 'Fou glorieuse'. However, there seems to be no record of Dupont visiting the Iles Glorieuses themselves.

Nelson (1974) repeats Gibson-Hill's habitat argument, and agrees with him that *S. abbotti* 'may have nested not on Assumption but on Glorioso'.

Further evidence on Assumption

This trend of argument tends to overlook the fact that in addition to Abbott's type, *S. abbotti* was also collected on Assumption in 1908 by Fryer (who did not visit the Iles Glorieuses). Fryer (1911, 433) refers to specimens, but these were not described until 1950 (Gibson-Hill 1950, 72). Bourne comments (1976, 122) that 'there really seems no need to question Abbott's specific statement... that his booby nested on Assumption', since nesting on Assumption and the Iles Glorieuses are obviously not exclusive possibilities. Nevertheless, it would be useful to have further confirmatory field evidence of the existence of *S. abbotti* on Assumption, and some rather fragmentary and allusive evidence is available.

The first additional notice of sulids on Assumption is provided by S.C.E. Baty in 1895. He states that '... to the North East of the big sand hills at about six hundred yards therefrom and close to the next [north] and lower sand hill... There is a camp of 'boobies' on the spot'. This appears to refer to a ground-nesting species, probably *S. dactylatra* as recorded by Abbott. Baty also says: 'Boobies or Fous of different kinds are to be found in the trees all over the island'. The implication of this is that there is more than one species of tree-nesting sulid: the only two possibilities would be *S. sula* and *S. abbotti*. Finally, he says: 'On the slopes of the big sand hills the trees are much bigger, and on their branches the Frigate birds and 'fous' make their nests'. This last reference could be to a single species, either *sula* or *abbotti*; but we may recall that Fryer (1911, 433) found that *abbotti* 'inhabits the large dune, never descending to low parts of the island'. Dupont (1907, 12) noted that 'boobies flock together in a plain of 30 acres' in the north of the island; but he lists only *S. sula* and *S. leucogaster* (which to add to the confusion he calls the Black Gannet and the Red-footed Gannet, respectively), and does not mention either the high dune or *S. abbotti*.

Fryer's published references to Assumption boobies are slight, but his manuscript diary adds more detail. On 6 September 1908 he records: 'There was a fresh species of Fou (*S. leucogaster*) and on the guano beds [word illegible] of ordinary Fou were breeding being continually preyed upon by a regular flock of Frigates of both species' (Fryer, 1908, 73). Gibson-Hill (1950, 69) has already noted that in his account of Aldabra Fryer seems to use the name *leucogaster* for *sula* (as did Dupont); but in the Diary passage the 'ordinary Fou' must be *sula*, and the 'fresh species of Fou' presumably *dactylatra*. *Leucogaster* has not been recorded on Assumption; Fryer used the name '*S. capucina*' for it on Aldabra.

On 7 September 1908, Fryer writes: 'A fresh kind of Fou (Fou Boeuf) was found: it was larger than the ordinary with a grey back tinged with pink: dark eyes and wings and *long coverts* black: its cry was very like a cow (from which it takes its name)' (Fryer 1908, 75). This is very clearly *S. abbotti*, and Fryer's specimens must have come from this population. Unfortunately his diary makes no comment on breeding. However, his reference to voice is remarkable. Neither Abbott (1893) nor Ridgway (1895) mention voice, though Abbott (in Ridgway 1895, 521) uses the name 'Fou boeuf'. The only reference to voice prior to Fryer's observation, with which Fryer was certainly unfamiliar, is contained in an anonymous French account of Rodriguez, ca 1730, on 'The Boeuf', said to 'bellow like a bull'. This was published by Milne-Edwards (1875, 8); Bourne (1968) tentatively identified it as *S. dactylatra*, but Nelson (1974) used the evidence of voice to determine it as *abbotti*. Nelson at Christmas Island found *abbotti* to have 'the deepest and loudest voice of any sulid, resonant and commanding' (1971, 436).

Comment

There thus seems little question, in spite of the ambiguities in Abbott's account and the clear statement by Dupont, that *abbotti* was definitely present on Assumption in 1892, possibly in 1895, and definitely in 1908. It cannot be stated with certainty that the species was breeding; but equally it is clear that its presence on the island was not inhibited by the absence of tall forest, *contra* Gibson-Hill and Nelson.

Whether *abbotti* formerly existed on the Iles Glorieuses remains unclear. Benson *et al.* (1975) suggest that Abbott's 'peculiar' booby (Abbott 1893, 764) is not *abbotti* as Gibson-Hill suggests but the 'capuchin' of Ridgway (1895, 532), i.e. dark-phase *S. sula*. Abbott (1893, 764) identifies 'capucin' as *sula*, as does Dupont (1907, 55): Gibson-Hill (1950, 69) is mistaken in saying, when trying to identify Fryer's '*S. capucina*', that Abbott used 'capucin' for *S. leucogaster*.

It is certainly possible that *abbotti* inhabited the Iles Glorieuses in spite of the absence of positive evidence. Bourne (1971, 188) speculated that this species would be found somewhere between Assumption and its present breeding station on Christmas Island, possibly in the Chagos Archipelago, and there has been some confirmation of this by sightings at sea in that vicinity (Bourne 1971; Hirons *et al.* 1976; Bourne and Nelson 1976). Bourne has also identified fossil material of *abbotti* from Mauritius and possibly Rodriguez, and has quoted historical evidence (1968; Nelson 1974) for the latter island. Becking (1976) gives a record of a foraging bird from Java. Bourne (1976, 122) particularly notes that the vernacular name (Fou boeuf) on Rodriguez in the early eighteenth century was the same as that on Assumption in the early twentieth, suggesting a previous wider occurrence and more numerous population.

When did *abbotti* become extinct on Assumption? Vesey-FitzGerald (1941, 521) says 1926, and Betts (1940, 501) says 1936, and these dates are quoted by Gibson-Hill (1950) and later writers. Settlement began at Assumption in 1908, and guano was then mined on a major scale (Stoddart *et al.* 1970). By the time that R. Dupont visited the island for the second time in 1916, he reported that the boobies 'have been all destroyed'; and in 1929, during a later visit, he stated that the land and sea birds had been destroyed by 1909. It thus appears that man and his activities, plus introduced predators, caused massive extinctions within a very short time of the first settlement. No boobies of any kind now breed on Assumption, though a few individuals of *dactylatra* and *sula* have been seen in recent years (Stoddart *et al.* 1970).

Acknowledgements

I was able to visit Assumption on 15-16 September 1967 during the Royal Society Expedition to Aldabra 1967-69, and the Iles Glorieuses on 9 December 1976 while a guest on board *Lindblad Explorer*. Literature and archival research on the faunas of western Indian Ocean islands has been carried out since 1966 as part of the Royal Society Aldabra Research Programme. I thank Lady Joan Fryer for access to Sir John Fryer's diary.

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PENETRATION OF THE HOST PLANT TISSUES BY THE STYLETS OF THE COCCOID *ICERYA SEYCHELLARUM* (COCCOIDEA: MARGAROIDEA) ON ALDABRA ATOLL

by S. Blackmore[1]

ABSTRACT

The path of penetration of stylets of *Icerya seychellarum* through tissues of *Euphorbia pyrifolia* Lam., *Avicennia marina* (Forssk.) Vierh., *Scaevola taccada* (Gaertn.) Roxb., and *Casuarina equisetifolia* L. was studied microscopically. Most stylets were seen to end in the phloem, others in the cortex, xylem or pith. Unlike other members of the Coccoidea *I. seychellarum* frequently penetrates thick walled cells such as sclerenchyma and xylem. This suggests that the anatomy of host plants, and the distribution of thickened tissues in particular, is not a restricting factor in host plant specificity.

INTRODUCTION

Stylet penetration has been studied in coccoids which act as vectors for virus diseases of economic plants, notably the potato (Smith, 1926), apple (Glass, 1944), and cocoa (Entwistle & Longworth, 1963). Most coccoids feed on the phloem of their hosts but a few are cortex feeders. Penetration is intracellular or, less commonly, within the cell walls (Entwistle & Longworth, 1963). Smith (1926) described the penetration of xylem vessels by *Dactylopius longispinus* but otherwise penetration of thickened tissues has not been observed.

This study was intended to establish whether *I. seychellarum* conforms to the known pattern, if any tissue damage is caused by the stylets and whether host plant anatomy might influence host plant specificity of the coccoid. The biology of *I. seychellarum* on Aldabra Atoll has been studied by Renvoize (1975) and recently by Hill and Newbery (publications in preparation). *I. seychellarum* infests a wide range of plants. More than half of the one hundred and eighty flowering plant species on Aldabra Atoll have been reported as hosts. Renvoize listed about thirty species which were subject to heavy infestations,

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including all the examples discussed in this paper. In the granitic islands of the Seychelles the coccoid is a pest of Citrus crops.

MATERIALS AND METHODS

The host plants studied were *Euphorbia pyrifolia* Lam., *Avicennia marina* (Forssk.) Vierh., *Scaevola taccada* (Gaertn.) Roxb. and *Casuarina equisetifolia* L. In each case a minimum of thirty stylets were studied *in situ* in sections of stems or leaves and petioles. The plant material was fixed in Formalin-acetic-alcohol, sectioned by hand or by microtome, stained in safranine and light green and mounted. Hand cut sections were particularly useful since with careful examination the stylets were visible in the plant before it was cut. The sections were examined microscopically and the length, width and path of the stylets and the salivary sheath they secreted were recorded.

RESULTS

A number of general points were noted; these are summarized in Table 1 and discussed below.

1. Leaves and petioles were usually penetrated from below. Penetration of the upper surface was only frequent in *Ficus nautarum* and *Thespesia populnea*. The stylets usually entered the leaf to one side of the midrib.

2. The mean length of stylets was approximately 800μm which is shorter than the 988μm reported in *Pseudococcus njalensis* by Posnette & Robertson (1950). The mean length of stylet inserted into the plant was 520μm.

3. Stylets were usually seen to end in the phloem but were also found in the cortex, xylem, laticifers and pith.

4. Penetration was intracellular except in thickened cells where it was intercellular. When the stylet first encountered such tissues it was often withdrawn and re-inserted in a different position. If the stylet did not locate a path through less resistant tissues it was usually eventually successful in penetrating the thickened cells intercellularly.

5. Stylets usually penetrated in a transverse plane and were often found in their entirity on one or two serial sections. Entwistle & Longworth (1963) found that the plane of penetration in other coccoids was related to the orientation of the insect and the stylet was rarely to be found in so few adjacent sections.

6. There was no evidence of tissue damage other than to the cells penetrated. Small groups of callus cells were occassionally found in *Scaevola taccada*.

Table 1. Summary of stylet penetration data for four host plants.

	Euphorbia Stem	Euphorbia Leaf	Scaevola Stem	Scaevola Leaf	Avicennia Stem	Avicennia Leaf	Casuarina Stem	Casuarina Leaf
Mean length Stylet sheath, μm	424	504	750	509	675	548	450	305
Mean number branches in sheath	1.6	0.5	2.5	1.2	3.3	3.2	1.75	0.8
% stylets ending in phloem	84	75	64	67	65	46	83	75
% stylets penetrating thickened tissues	20	23	25	13	87	83	95	85

Specific results are as follows:

Euphorbia pyrifolia

The leaves have little thickened tissue except a band of collenchyma along the midrib. Stylets enter to one side of this and frequently penetrated to the phloem without being withdrawn and relocated. Often several vascular bundles were penetrated in succession. The stems have a well developed cork which was sometimes penetrated intercellularly. Several stylets were seen to enter the stem through lenticels. Many ended in, or passed through, the abundant laticifers of the cortex. It is possible that the latex is an additional food source.

Scaevola taccada

Leaf penetration was similar to that in *Euphorbia*. The stem has more sclerenchyma around the vascular tissues which may account for the greater number of reinsertions of the stylet and resulting branching of the salivary sheath.

Avicennia marina

The undersides of the leaves have a dense cover of simple trichomes. The stylets pass between these and secrete a salivary sheath extending slightly out beyond the trichomes. The vascular tissues are completely surrounded by sclerenchyma and reinsertion of the stylets is more frequent. The stems have large cortical air spaces. Some stylets passed through the spaces but an equal number followed a sinuous course through the surrounding cells. Additional cambia within the xylem produce small groups of phloem within the xylem. About 20% of stylets penetrated through to these inner phloem cells.

Casuarina eqisetifolia

The leaves or, strictly, phyllodes have angular, ridged surfaces covered by a thick cuticle beneath which a layer of sclerenchyma overlays the chlorophyllous tissues. Between the ridges the cuticle is thin and the sclerenchyma absent and stylets entering here did not encounter so much mechanical tissue. Equal numbers of stylets entered through and between the ridges. Those passing through the sclerenchyma produced branced salivary sheaths, the others did not.

CONCLUSIONS

I. seychellarum differs from most coccoids in the ability of its stylets to penetrate thickened tissues. The ability of the stylets to locate the phloem, even if this requires passage through thickened cells, implies that the stylets are to some extent sensory.

Host plants of the coccoid on Aldabra Atoll range from fleshy leaved plants such as *Euphorbia pyrifolia* to others with heavily thickened stems such as *Casuarina equisetifolia*. The ability of the insect to feed on plants with such varied anatomy suggests that host anatomy is unlikely to be a limiting factor in the selection of hosts.

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METEOROLOGICAL DATA FROM ULUL ISLAND, NAMONUITO ATOLL

by John Byron Thomas and Mary Durand Thomas[1]

Meteorological observations were conducted on Ulul Island, Namonuito Atoll, Truk District, Trust Territory of the Pacific Islands from November 8, 1973 to September 30, 1974. A record was maintained of maximum and minimum temperatures, maximum and minimum relative humidity, and rainfall. Temperatures and rainfall were recorded daily at 6:00 p.m. Relative humidity was measured twice daily at noon and 6:00 p.m.

The meteorological station was located in a cleared area permitting unobstructed exposure to rain and sun. The maximum and minimum thermometers were housed in a louvered wood structure and the rain gauge was located about four meters distant. Relative humidity, obtained with a sling psychrometer, was measured at the same location. All instruments and their associated gear were supplied by the U.S. Weather Bureau at Moen Island, Truk District.

Informants considered that meteorological conditions during the recorded period were typical for Namonuito Atoll. The data presented in the accompanying table indicate the climate to be uniformly warm and humid. Extreme temperatures ranged from 20.5°C. to 35.0°C. (69°F. to 95°F.); relative humidity from 66% to 100%; and monthly rainfall, from 137.7 mm to 396.5 mm (9.45 in. to 15.61 in.). Generally, the daily low temperature occurred just prior to sunrise and the high during early afternoon. Daily relative humidity varied from a low at about noon to a high at about the time of sunrise. (Because a daily relative humidity measurement was recorded at 6:00 p.m. rather than at sunrise, the extreme high and average high relative humidity percentages were probably somewhat higher than indicated in the table.) With a few exceptions, daily rainfall was in the form of brief, random showers. By extrapolation, the total annual rainfall would have been approximately 3213 mm (126.5 in.).

As is typical for this area of the Pacific, the greatest seasonal climatic variation is reflected in wind velocity and direction rather than in temperature, relative humidity and precipitation patterns. Northeast trade winds prevailed during the winter months. Summer months were characterized by lower velocity variable winds and occasional thunder storms. Accurate wind velocity measurements could not be obtained but the periodic use of a hand-held wind meter at a

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TEMPERATURE, HUMIDITY AND PRECIPITATION SUMMARIES
FOR ULUL ISLAND, NAMONUITO ATOLL
NOVEMBER 8, 1973 — SEPTEMBER 30, 1974

Month	Temperature °C.				% Relative Humidity				Precipitation			
	Extreme		Average		Extreme		Average		Total (mm)	24-hour max. (mm)	Days with	
	High	Low	High	Low	High	Low	High	Low			None	Trace*
Nov	33.3	22.8	31.9	24.5	96	74	86	80	137.7	29.5	4	5
Dec	33.9	22.2	31.5	24.4	96	70	86	79	240.0	41.7	6	1
Jan	33.3	20.5	31.7	23.4	100	66	85	79	217.4	46.0	9	5
Feb	32.8	22.8	31.4	24.4	96	67	83	78	141.2	29.7	8	2
Mar	33.3	21.7	31.9	24.3	96	74	87	81	396.5	53.8	7	2
Apr	33.9	23.3	31.9	24.4	96	71	87	81	390.4	51.1	3	2
May	35.0	22.8	32.5	24.5	96	70	88	79	295.9	51.1	4	3
Jun	33.9	21.7	31.7	23.9	97	67	88	81	374.9	54.4	5	2
Jul	34.4	22.8	32.8	23.9	97	67	86	77	262.4	51.1	4	2
Aug	33.9	22.8	32.3	24.4	92	67	86	78	198.4	48.5	5	3
Sep	34.4	22.2	32.9	23.4	100	66	88	74	304.5	51.6	6	4

*Less than 0.25 mm.

windward beach site indicated that winter winds seldom exceeded approximately twenty knots per hour while summer winds usually ranged between five and ten knots per hour.

The meteorological measurements were compiled during the course of our respective anthropological researches at Namonuito Atoll. One of us (J.B.T.) would like to acknowledge the research support provided by Wenner-Gren Foundation for Anthropological Research Grant No. 2977 and National Science Foundation Grant No. GS-39878; the other (M.D.T.) would like to acknowledge the support provided by National Center for Health Services Rearch and Development special fellowship No. 5 FO3 HS50513. We would also like to express our appreciation for the assistance of Saul Price and the late William Tolliver of the U.S. Weather Bureau, Honolulu and for that of Lazaro Mayipi of the Trust Territory Weather Bureau, Truk District.

MARINE BENTHIC ALGAE OF KAYANGEL ATOLL, PALAU

by Roy T. Tsuda[1]

Introduction

During January 13-17, 1976, four faculty members from the University of Guam Marine Laboratory visited Kayangel Atoll in the Palau District to conduct a preliminary biological survey of the algae, corals and fishes. Our original plan was to incorporate all of the findings under one cover, but other research priorities of the faculty directed each member to work at his own pace in getting the results in print.

This paper reports on the 51 species of marine benthic algae collected on the barrier reef flat, channel and lagoon of Kayangel Atoll. All specimens cited here are deposited in the Herbarium of the University of Guam Marine Laboratory. Previous to our visit to Kayangel Atoll, only one paper (Lowenstam, 1955) mentions the algae from this atoll; this study reports on aragonite needles secreted by the calcareous green alga *Halimeda*. Based on the collections and observations of *Sargassum crassifolium* during our visit to Kayangel Atoll, Tsuda (1976) reported its presence on atolls and speculated why this genus is rarely observed on atolls as opposed to high islands. Five species of sea-grasses were also collected during our survey and are included in another paper, presently in preparation, on Micronesian sea-grasses.

Kayangel Atoll (8°05'N, 134°43'E), about 7 km long (N-S orientation) and about 4 km wide (E-W orientation), is the northernmost atoll in the Palau Archipelago. The atoll is almost completely encircled by a barrier reef with four islets present on the eastern side. The maximum depth of the lagoon is only 11 m. Gressitt (1952) provides a description of the atoll, as well as the four islets.

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Stations

The terminology of Tracey *et al.* (1955) is used to describe the different zones of Kayangel Atoll.

Station 1. Lagoon reef margin, northern end of atoll, .5 m deep, Jan. 13, 1976. (RT 5088 - 5098).

Station 2. Lagoon reef margin, northwest end of atoll, .5 m deep, Jan. 13, 1976. (RT 5099).

Station 3. Inner reef flat, coral mound off northwest tip of Ngariungs Islet, .3 m deep, Jan. 14, 1976 (RT 5100 - 5103).

Station 4. Lagoon, coral mound, 1.5 km south of main channel, 1 m deep, Jan. 14, 1976. (RT 5104 - 5117).

Station 5. Reef flat, 1 km north of main channel, 2 m deep, Jan. 15, 1976. (RT 5119 - 5122).

Station 6. Lagoon shelf, southwest of Ngariungs Islet, 1 m deep, Jan. 15, 1976. (RT 5124 - 5129).

Station 7. Lagoon, coral mound, 1 km northeast of channel, 9 m deep, Jan. 15, 1976. (RT 5130 - 5133).

Station 8. Lagoon, coral mound, 1 km west of southern tip of Ngajangel Islet, 9 m deep, Jan. 15, 1976. (RT 5134 - 5140).

Station 9. Reef flat, .6 km north of Ngajangel Islet, .5 m deep, Jan. 15, 1976. (RT 5144 - 5149).

Station 10. Lagoon, coral mound, west of mid-section of Ngajangel Islet, 2-8 m deep, Jan. 16, 1976. (RT 5150 - 5157).

Station 11. Reef flat, 2 km south of main channel entrance, .3 m deep, Jan. 16, 1976. (RT 5158 - 5159).

Station 12. South channel, just west of Gorak Islet, 2 m deep, Jan. 16, 1976. (RT 5161 - 5163).

Station 13. Slope of main channel, 1-10 m deep, Jan. 16, 1976. (RT 5164 - 5176).

Station 14. Inner reef flat, between Ngajangel and Ngariungs Islets, 1 m deep, Jan. 17, 1976. (RT 4773, 5177 - 5182).

Station 15. Slope of main channel, 2-9 m deep, Jan. 17, 1976. (RT 5183 - 5188).

Station 16. Inner reef flat, between Ngariungs and Ngaraplas Islets, 1 m deep, Jan. 17, 1976. (RT 4774, 5189).

Station 17. Reef flat, just northwest of the northwest tip of Ngajangel Islet, 1 m deep, Jan. 15, 1976. (RT 5190 - 5198).

Station 18. Lagoon shelf, sea-grass beds off Ngajangel Islet, 1 m deep, Jan. 17, 1976. (RT 5201 - 5203).

Species Listing

The species are listed alphabetically under their respective Divisions.

Cyanophyta

Calothrix confervicola (Roth) Ag. - RT 5132a (epiphytic on *Ceramium mazatlanense*).

Calothrix pilosa Harvey - RT 5162, RT 5198.

Microcoleus lyngbyaceus (Kütz.) Crouan - RT 5145 (epiphytic on *Halimeda incrassata*), RT 5203.

Schizothrix calcicola (Ag.) Gomont - RT 5111.

Chlorophyta

Avrainvillea lacerata Harvey - RT 5095, RT 5100.

Avrainvillea obscura J. Ag. - RT 5201.

Caulerpa antoenis Yamada - RT 5194 (on sand).

Caulerpa racemosa (Forsskal) J. Ag. - RT 5108, RT 5124, RT 5153, RT 5182.

Caulerpa serrulata (Forsskal) J. Ag. - RT 5096, RT 5114, RT 5129c, RT 5135, RT 5152, RT 5154.

Caulerpa taxifolia (Vahl) C. Ag. - RT 5138.

Caulerpa urvilliana Montagne - RT 5181.

Caulerpa vickersiae Boerg. - RT 5103 (on sand), RT 5133.

Dictyosphaeria cavernosa (Forsskal) Boerg. - RT 5167.

Dictyosphaeria versluysii W. v. Bosse - RT 5093, RT 5113, RT 5119, RT 5196.

Halimeda cylindracea Decaisne - RT 5104, RT 5131, RT 5183.

Halimeda discoidea Decaisne - RT 5144, RT 5150, RT 5184b.

Halimeda gracilis Harvey - RT 5088, RT 5165

Halimeda incrassata (Ellis) Lamx. - RT 5149, RT 5202b.

Halimeda lacunalis Taylor - RT 5091a, RT 5106, RT 5126a, RT 5134, RT 5184a.

Halimeda micronesica Yamada - RT 5089, RT 5105, RT 5129b, RT 5185a, RT 5192.

Halimeda minima (Taylor) Colinvaux - RT 5151, RT 5164, RT 5186.

Halimeda opuntia (L.) Lamx. - RT 5090a, RT 5107, RT 5125, RT 5187.

Halimeda simulans Howe - RT 5202a.

Halimeda stuposa Taylor - RT 5190b, RT 5202a.

Halimeda taenicola Taylor - RT 5126b, RT 5191.

Microdictyon okamurai Setchell - RT 5097, RT 5130, RT 5136, RT 5155.

Neomeris mucosa Howe - RT 5139.

Rhipilia orientalis A. & E. S. Gepp - RT 5173, RT 5189.

Valonia utricularis (Roth) C. Ag. - RT 5157, RT 5176, RT 5195.

Valonia ventricosa J. Ag. - RT 5127, RT 5172.

Valoniopsis pachynema (Martens) Boerg. - RT 5116.

Phaeophyta

Dictyopteris repens (Okamura) Boerg. - RT 5170b.

Dictyota bartayresii Lamx. - RT 5179.

Feldmannia irregularis (Kütz.) Hamel - RT 5158.

Lobophora variegata (Lamx.) Womersley - RT 5094, RT 5099, RT 5110, RT 5121, RT 5147, RT 5171.

Padina tenuis Bory - RT 5146.

Sargassum crassifolium J. Ag. - RT 4773, RT 4774.

Turbinaria ornata (Turner) J. Ag. - RT 5092, RT 5109, RT 5163.

Rhodophyta

Amphiroa fragilissima (L.) Lamx. - RT 5148.

Ceramium gracillimum v. *byssoideum* (Harv.) Mazoyer - RT 5112b.

Ceramium mazatlanense Dawson - RT 5132a.

Claudea multifida Harvey - RT 5161, RT 5168.

Endosiphonia spinuligera Zanard. - RT 5101a, RT 5156.

Galaxaura oblongata (E. & S.) Lamx. - RT 5180.

Gelidiopsis intricata (Ag.) Vickers - RT 5122.

Jania capillacea Harvey - RT 5178 (epiphytic on *Sargassum crassifolium*), RT 5197.

Laurencia cartilaginea Yamada - RT 5101b, RT 5128.

Laurencia majuscula (Harv.) Lucas - RT 5098 (intermixed with *Laurencia cartilaginea*), RT 5140 (epiphytic on *Halimeda opuntia*), RT 5169 (epiphytic on *Halimeda lacunalis*), RT 5188 (on dead coral).

Liagora pinnata Harvey - RT 5177, RT 5193.

Polysiphonia howei Hellenberg - RT 5112a, RT 5117, RT 5120, RT 5129 (mixed with *Polysiphonia scopulorum*), RT 5159, RT 5174.

Polysiphonia scopulorum Harvey - RT 5102, RT 5129 (mixed with *Polysiphonia howei*), RT 5132b.

Discussion

Claudea multifida (see Papenfuss, 1937) is the only alga collected from Kayangel Atoll which has not been previously reported from the Micronesian region. The rest of the algae represents an extension of the marine algae previously known from Palau proper or other Micronesian islands (see Tsuda and Wray, 1977).

The prostrate green alga *Microdictyon okamurai* is the dominant alga on the solid calcareous substratum of the barrier reef and on the coral mounds in the lagoon. This species covers about 23% of the consolidated substratum on the northern barrier reef and is equally abundant in the lagoon. *Lobophora variegata* and *Dictyosphaeria cavernosa* are also conspicuous in these same areas.

The calcareous green alga *Halimeda* is abundant in the channel and lagoon areas. Of the 11 species of *Halimeda* collected from this atoll, four species (*H. cylindracea, H. incrassata, H. simulans,* and *H. stuposa*) inhabit the sandy substratum which makes up the majority of the substrata type within the lagoon. Four species of *Caulerpa* (*C. antoensis, C. taxifolia, C. urvilliana,* and *C. vickersiae*) also inhabit the sandy areas of the lagoon. The turf community is developed on the coral mounds in the lagoon. *Polysiphonia howei, P. scopulorum, Jania capillacea,* and *Laurencia majuscula* are the dominant algae comprising the turf.

The small size and shallow depth of Kayangel Lagoon makes this atoll a perfect natural laboratory for distributional and seasonal studies of benthic algae, especially the *Halimeda* species, in a lagoon environment.

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QUALITATIVE ASSESSMENT OF THE ASTEROIDS, ECHINOIDS AND HOLOTHURIANS IN YAP LAGOON[1]

by Deborah A. Grosenbaugh

INTRODUCTION

A limited amount of work has been done on the echinoderm population of Yap. Two previous technical reports (Amesbury et al., 1976, 1977) list 16 echinoderms observed in two localized areas: one at the Donitsch Island sewer outfall site and the other at a proposed dock site in Colonia, Yap.

The only other observations of this group relate to the asteroids. Earlier reports (Hayashi, 1938a, 1938b) mention only Culcita novaeguineae and Fromia monilis as being identified from Yap. Clark (1954) recorded Protoreaster nodosus as also being found there.

During the period of time when Acanthaster planci infestations were a concern throughout the western and central Pacific, several separate surveys were made on Yap. Beginning in July of 1969, Chesher (1969) observed no large populations of A. planci. By late 1970 (Tsuda et al., 1970) two small populations (one consisting of 100 - 150 individuals and another of about 50 starfish) were identified outside of the barrier reef. A subsequent survey in 1971 (Marsh and Tsuda, 1973) noted an apparent increase in A. planci, but they were widely scattered with no obvious major concentrations.

This particular paper provides a qualitative assessment of the asteroid, echinoid, and holothurian populations in the Yap Lagoon, with particular reference to the latter.

The author wishes to acknowledge L. G. Eldredge and C. E. Birkeland for their aid in the identification of some of the echinoderms encountered in this study and for reviewing the manuscript, and R. L. Kock for providing the data concerning the stomach contents of Mespilia globulus and Tripneustes gratilla. Identification of most holothurians was obtained from Rowe and Doty (1977).

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METHOD

The observations made here were done during the course of a general reef survey, conducted during July 9-20, 1977, which covered a major portion of the reef flat in the Yap Lagoon. Most observations were made as a result of towing the observer from a small boat in a zigzag pattern from the seagrass beds near shore to the barrier reef margin. When unusually conspicuous populations of echinoderms (particularly holothurians) were noted, a closer examination was made by snorkeling in the area. Periodically, more detailed observations of randomly chosen areas were made in order to note less conspicuous species.

Two 30-m transects were run in a *Thalassia hemprichii* bed just east of Bik Island in Tomil Harbor. In this case, all echinoderms 0.5 m on either side of a 30 m-long transect line were enumerated.

RESULTS AND DISCUSSION

Four zonal habitats (seagrass, seagrass-live coral, live coral, and coral pavement) characterize the reef flats in the Yap Lagoon.

The seagrass zone is characterized by thick beds of *Thalassia* and *Enhalus* adjacent to shore, becoming patchy and interspersed with live coral heads (predominately *Porites*) as one progresses out toward the reef margin. This transitional zone is referred to as the seagrass-live coral zone in this paper. As the seagrass becomes less dominant other corals (notably *Acropora*) along with the *Porites* form a live coral zone. Near the reef margin, the live corals become replaced by coral pavement. Table 1 lists the various echinoderms found in these four habitats, as well as those found on patch reefs, holes, and channel.

The densest populations of echinoderms on the reef flat occur in the seagrass beds adjacent to land, though not all of the seagrass beds surveyed exhibited obvious numbers of echinoderms. Holothurians in the seagrass beds were either absent, rare (1-2 seen per hour of snorkeling), or unusually abundant.

Table 2 presents the results of the two 30-m long transects (1 m wide) run in the *Thalassia* bed. Transect A was located adjacent to Tomil Harbor channel and southeast of Bik Island. Transect B was situated just east of the island. The major components in both cases were the echinoid *Mespilia globulus* and the holothurian *Actinopyga echinites.* The unusually large numbers of *M. globulus* present had covered themselves with seagrass detritus. Examination of the stomach contents of 25 *M. globulus* and four *Tripneustes gratilla* that were also present, revealed that *Thalassia* was the only food item ingested. *Actinopyga echinites* seemed to be feeding primarily on the detritus. In some cases, *A. echinites* could be seen feeding on the detritus that was attached to

Table 1. Checklist of asteroids, echinoids, and holothurians observed in various reef flat zones and other habitats in Yap Lagoon. (1. seagrass zone, 2. seagrass-live coral zone. 3. live coral zone, 4. coral pavement zone, 5. patch reefs in Tomil, Mil, and Gofenu Harbors, 6. holes in reef flat, 7. Tomil Harbor Channel).

SPECIES	Reef Flat Zones				Other Habitats		
	1	2	3	4	5	6	7
Class Asteroidea							
Acanthaster planci (Linnaeus)					X		
Culcita novaeguineae Müller & Troschel		X		X	X	X	
Echinaster luzonicus (Gray)			X	X			
Fromia milleporella (Lamarck)						X	
Linckia laevigata (Linnaeus)				X			
Linckia multifora (Lamarck)			X				
Protoreaster nodosus (Linnaeus)	X						
Class Echinoidea							
Diadema setosum (Michelin)			X		X	X	
Echinothrix calamaris (Pallas)				X			
Heterocentrotus mammillatus (Linnaeus)				X			
Mespilia globulus (Linnaeus)	X					X	
Tripneustes gratilla (Linnaeus)	X						
Class Holothuroidea							
Actinopyga echinites (Jaeger)	X						
Bohadschia argus Jaeger					X		X
Bohadschia sp.	X						
Holothuria atra Jaeger	X	X		X	X		
Holothuria axiloga Clark							X
Holothuria edulis Lesson	X	X			X	X	
Holothuria hilla Lesson	X						
Holothuria flavomaculata Semper	X	X	X		X	X	
Holothuria leucospilota Brandt		X	X		X	X	
Holothuria nobilis (Selenka)		X					
Stichopus chloronotus Brandt	X	X			X	X	
Stichopus variegatus Semper	X				X		
Thelenota ananas (Jaeger)							X
Unidentified synaptid	X						

M. globulus. Actinopyga echinites exhibited the clumped distribution referred to by Amesbury et al. (1976), being found often in "piles" of five or more in close association. One small dark red holothurian, which the author could not identify, was observed in Transect A.

Table 2. Density of echinoderms along two 30-m long transects (1 m wide) in a Thalassia bed off Bik Island, Tomil Harbor, Yap.

SPECIES	A	B
Actinopyga echinites	164	450
Mespilia globulus	34	245
Holothuria edulis	11	3
Protoreaster nodosus	9	4
Holothuria atra	4	2
Stichopus chloronotus	2	4
Holothuria hilla	1	1
Unidentified holothurian	1	-
Holothuria flavomaculata	-	4
Tripneustes gratilla	-	1

In another Thalassia bed off Pekel Island in Tomil Harbor, Actinopyga echinites was also abundant, exhibiting the same tendency toward clumping that was observed earlier. Also present but not as abundant were Stichopus variegatus and S. chloronotus and a variety of occasionally observed holothurians such as Holothuria hilla, H. atra, and the asteroid Protoreaster nodosus, along with the scyphozoan medusa Cassiopeia sp. Large population densities of H. atra were also noted in an Enteromorpha bed west of Thilimad Island, near the northern tip of Map Island. Only one synaptid was observed during the entire survey, in a seagrass bed off the northeast corner of Map.

As one progresses out toward the reef margin into the seagrass-live coral zone, Holothuria edulis replaces Actinopyga echinites as the predominant holothurian species. Stichopus chloronotus was usually present in this zone, but, as in the seagrass zone, was not particularly common. It was seen mostly in sandy areas between coral beds. Holothuria leucospilota was occasionally seen with the anterior part of its body extended out from under the Porites heads. Other holothurians observed in the seagrass-live coral zone were an occasional Holothuria atra, H. nobilis, and H. flavomaculata. The "cushion star-fish" Culcuta novaeguineae was also seen.

In the live coral zone, the asteroids Linckia multifora, Fromia milleporella, and Echinaster luzonicus, along with the echinoid Diadema setosum, were common in among the Acropora, and under Porites heads.

Holothuria leucospilota was seen, as in the seagrass-live coral zone, extending out from under Porites heads, whereas H. flavomaculata was common in close association with stands of Acropora.

In the coral pavement zone out near the reef margin, only an occasional Holothuria atra represented the holothurians. The only other obvious echinoderms were Linckia laevigata and Culcita novaeguineae. The majority of the echinoderms in this zone were found in coral rubble and under rocks. These include an unidentified ophiuroid, Echinaster luzonicus, Echinothrix calamaris, and Heterocentrotus mammillatus.

Besides the general zonation across the reef flat, there exist distinct echinoderm populations in the deep holes that occur on the reef flat, and on patch reefs in the various harbor entrances. The holes are surrounded by a Porites-Acropora type community and the echinoderm fauna corresponds thusly. As the sides of the holes slope downward to a sandy bottom, those holothurians which prefer sandy substrate are seen, e.g., Holothuria edulis and Bohadschia argus.

Patch reefs in the three major harbors (Tomil, Mil, Gofenu) provide a diverse environment for a variety of echinoderms. Sandy areas with some seagrass are interspersed between areas of high coral density. The sandy areas of these reefs include the holothurians Holothuria edulis, H. atra, Stichopus chloronotus, S. variegatus, and Bohadschia argus. The holothurians H. flavomaculata and H. leucospilota were found associated with the corals Acropora and Porites, respectively. The echinoid Diadema setosum and the asteroid Fromia milleporella were found in the coral while Culcita novaeguineae was often observed in sandy patches between corals. On the downward slope of these patch reefs and along channels, the larger detritus-feeding holothurians, i.e., Thelenota ananas, Bohadschia argus, and Holothuria axiologa, were located.

While holothurians of major economic importance were identified within the reef flat (Thelenota ananas, Bohadschia argus, Holothuria nobilis), they were not observed to be present in such quantities that would make their export profitable. The Yapese, themselves, are not overly fond of the delicacy, but the Palauan community of Yap does occasionally utilize the above-mentioned species as a food source as well as Actinopyga echinites which is found in considerable abundance in some of the seagrass areas. Since the Palauan community is situated in the Colonia area, only edible holothurians in the Tomil Harbor area are likely to be harvested because of the strict reef tenure on Yap where the various villages have exclusive fishing rights on designated areas of the reef.

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ACANTHASTER IN THE CULTURES OF HIGH ISLANDS

by

Charles Birkeland[1]

Residents of high islands in Micronesia, Melanesia and Polynesia usually have their own special names for *Acanthaster*, each have similar advice on curing the sting of the spines, and each claim that *Acanthaster* has been abundant at certain times in the past. I believe that this familiarity of *Acanthaster* in some high island cultures implies that outbreaks are a naturally recurring phenomenon around high islands. An apparent lack of familiarity of *Acanthaster* in the cultures of atolls implies that outbreaks of *Acanthaster* are much less frequent around atolls (low islands).

In Palau (Micronesia), the *Acanthaster* is called *rrusech* (Birkeland, 1979) while other starfish are called *btuch* or *tengetang*. At Fiji (Melanesia), *Acanthaster* is called *bula* (a homonym of "hello") while the general terms for "starfish" are *gasagasan* or *basage* (Atelaite Smalley, pers. comm.). In the Cook and Society Islands (Polynesia), *Acanthaster* is called *taramea* and in Samoa and Tonga (Polynesia), *Acanthaster* is called *alamea* (Garlovsky and Bergquist, 1970; Birkeland and Randall, 1979; Flanigan and Lamberts, 1981).

In contrast, the languages from atolls appear to not contain terms for *Acanthaster*. There is no special word for *Acanthaster* on Pingelap (Spensin James, pers. comm.); the crown-of-thorns is merely referred to as *isu*, a term used for all starfish. Similarly, *Acanthaster* is called *talwalyol* on Ulithi, a general term for all starfish (Eulalia Harui, pers. comm.). Abo et al. (1976) list 12,000 entries with information on about 30,000 Marshallese words. Many fishes, three groups of sea cucumbers, and other marine organisms are mentioned, but there was no word for *Acanthaster*. It must not be important to the Marshallese.

The Gilbert Islands (Kiribati), the Ellice Islands (Tuvalu) and Fanning Island are all atolls. Lobel (1978) presented a list of 407 names of fishes and 95 names of marine invertebrates used by Gilbertese and Ellice Islanders on Fanning Island, but *Acanthaster* was not listed. These inhabitants of atolls had their own specific names for many species of fishes, mollusks and crustaceans and even distinguished between three groups of holothurians, but all seastars came under one name. *Acanthaster* may have never been abundant on these atolls.

There is an exception from the atoll of Mokil (near Ponape) at which the people do call *Acanthaster* by the name *larni*. Of course there may be other exceptions. However, there does seem to be a general presence of words for *Acanthaster* in high island languages and an apparent lack of words for *Acanthaster* in low island languages. These tendencies suggest that *Acanthaster* may be more common around high islands.

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People from atolls say they rarely, if ever, see *Acanthaster* and they have never heard of them being common (Matuatua Smit, Takapoto Atoll, Tuamotu, French Polynesia; Eulalia Harui, Ulithi, Yap District; Spensin James, Pingelap, Ponape District, pers. comms.). Around high islands, the people remember previous outbreaks. According to localfishermen, there was an out break in American Samoa in 1938 (Flanigan and Lamberts 1981). Vine (1970) reported that fishermen in the Solomon Islands (Melanesia) remembered large concentrations of *Acanthaster* about 1930, forty years previous to 1970. Chesher (1969) reported that Micronesians remember an outbreak on Ponape ju after World War II.

Michael Parke talked to an old Palauan fisherman who described an extensive infestation that took place just prior to World War II. Accordin to this fisherman, the *Acanthaster* soon disappeared, leaving algae in the place of coral. Then urchins became abundant during the early years of World War II. The fisherman felt that *Acanthaster* were transitory and no real problem. The abundance of urchins that resulted were a benefit. Old people could easily collect them for food within wading depth on the reef flat. We have not heard of other cases of an abundance of urchins followin *Acanthaster*. It will be interesting to see if herbivorous urchins become common following the present devastation in Palau. Except for areas around artificial sea walls, breakwaters and ramps, regular urchins are remarkably scarce in Palau at the time of this writing.

The people on high islands tell of dangers of stepping on *Acanthaster* when fishing at night at times when *Acanthaster* is abundant (Vaolui, pers. comm.; Flanigan and Lamberts, 1981). A cure for injury from stepping on *Acanthaster* is claimed by several high island cultures to be their own discovery. When I was studying an *Acanthaster* outbreak in Palau, I accidentall jabbed my knee strongly against an *Acanthaster* and came to the boat with a lot of blood dripping out of six cuts in my knee. The boatman, Ngirbauliad ("Yahd") Mineich, advised me to take one of the *Acanthaster* and place it mouth down on the bloody knee. (This was tried, but was not found to be of great help.) When asked if he heard of this cure from a Samoan or Fijian, Yahd said it has always been common knowledge in Palau. Ramon Rechebei, another Palauan, said that he knew of this cure since he was a boy.

Spensin James told me that this cure had worked for him when he tried it. This cure was common knowledge among Ponapean fishermen and it works if you are sure to use the same individual *Acanthaster* that harmed you as the individual to cure you. If you are jabbed by one *Acanthaster* and lift another to cure your pain, it will be of no use. (I am not sure I used the same individual in Palau.)

Laite Smalley told me that when Fijian fishermen step on *bula* on the reef flat, they turn over the same *bula* and put their food against the mouth so that the *bula* will suck out the poison. She said this was generally know by Fijian fishermen and there is no reason to believe it was learned from the Palauans or Samoans. Maybe the cure was discovered in Fiji.

This same cure has been known on Tonga (Richard Braley, pers. comm.), and as a proverb on Western Samoa (Garlovsky and Bergquist, 1970) and American Samoa (Birkeland and Randall, 1979; Flanigan and Lamberts, 1981).

he Secretariat of the British Solomon Islands Protectorate (1970) noted that his same cure by turning over and stepping on the underside of the *Acanthaster* as known in the Solomon Islands, New Britain, Manus Islands, and Gambier slands.

The apparent history of recurring abundances of *Acanthaster* around high slands but not around atolls may be explained by the causal mechanism of *canthaster* outbreaks as suggested in Birkeland and Randall (1979) and irkeland (1980). *Acanthaster* larvae may survive in much greater abundance ollowing heavy rainfall. This might be because phytoplankton blooms are riggered by terrestrial runoff and this provides an abundant food source or *Acanthaster* larvae. Terrestrial runoff resulting from rains on high slands trigger phytoplankton blooms (Marsh 1977), but it is doubtful that errestrial runoffs from low, sandy atolls carry an amount of nutrients into he coastal waters adequate to trigger blooms.

Acknowledgements

I wish to thank the Samoan fishermen who told me of the folklore of the *lamea*: Leuila Alaimaleata and Vaolui of Alofau, Upuese Taifane of Poloa, hief Faiaipa'u of Onenoa and Ierenimo Laupapa, Senior Biologists of the ffice of Marine Resources, Government of American Samoa. I am grateful to enry Sesepasara, Director of the Office of Marine Resources, and to the onorable Peter T. Coleman, Governor of American Samoa, for inviting me to ome to American Samoa to study the *Acanthaster* populations and for air fare nd per diem. I am indebted to Toshiro Paulis, Division of Marine Resources, overnment of Palau, for arranging for an airplane ticket to Palau. The niversity of Guam provided the air fare for Tahiti (Society Islands) by way f Rarotonga (Cook Islands).

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ACANTHASTER AS A RECURRING PHENOMENON IN SAMOAN HISTORY

by John M. Flanigan[1] and Austin E. Lamberts[2]

Verbal history, linquistic evidence and proverbs indicate that *Acanthaster planci* have been long known and endured in Samoa.

The Crown-of-Thorns starfish (*Acanthaster planci* (L.)) has been known to science since it was described by Rumphius in 1705. Only in the past decade and a half has it stirred popular interest after great numbers of these starfish were reported almost simultaneously from Guam, the Great Barrier reef province of Australia and from other Indo-Pacific coral reef areas. Significantly, this occurred at about the time that face mask and snorkel were becoming standard equipment for visitors to coral reefs.

Recently *Acanthaster* have appeared on the reefs of Tutuila, American Samoa, in impressive numbers. The fact that collection efforts which reportedly netted nearly a half a million starfish have not significantly affected the total number attests to the host of *Acanthaster* (Sesapasaro, 1978). In previous decades this animal was a great rarity locally. Between 1967 and 1973 one of us (JF) encountered only two of these creatures during hundreds of dives on the reefs of Tutuila. Nevertheless, there is evidence that these animals have occurred in great numbers in the past.

The specificity with which objects in the Samoan environment are named bears a relationship to the importance of those objects in the culture. Thus, Samoans have a single word to refer to all types of branching corals ('amu) but distinctive word for the less conspicuous massive coral (puga) and flat coral (lapa) used for burning to make lime. The language also has a single word for nearly all starfish (aveau) but *Acanthaster* alone has the highly specific name of *alamea*. It is noteworthy that a similar word, *taramea* is used for *Acanthaster* in the Polynesian Cook and Society Islands even though there had been

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no apparent contact between these subcultures for centuries before they were rediscovered. (The cushion starfish *Culcita* has a specific name, pālutu, but the Samoans do not recognize it as a starfish.)

Additional indication that *Acanthaster* have occurred previously in great numbers is provided by Samoan proverbs that mention it. "*E fofō e le alamea lana sale*" or "*E fofō e le alamea le alamea*" meaning "the alamea is its own doctor," or "*falau a alamea*" meaning "cure of the alamea" refers to the belief held throughout the tropical Pacific that the excruciating pain caused by the sting of the spines of the *Acanthaster* is relieved by placing the mouth of the same animal against the wound (Herman, 1953). One of us (AEL) missed an opportunity to confirm the efficacy of this treatment when he was stung by an *Acanthaster* before hearing of the purported cure. One would expect that an animal would enter a culture's folklore only if its nature was very familiar to generations of members of that culture. It seems probable that the sting of the alamea has been known and respected by generations of Samoan fishermen.

Several Samoan fishermen, all over fifty years old reported to one of us (AEL) that in their youth there were huge numbers of alamea on the reefs of Nu'uuli and Aua, Tutuila and that all of them disappeared quite suddenly. Mary Prichard, an astute and perceptive Samoan lady of 75 recalls this vividly and dates the infestation to about 1938. She was an avid shell collector even before this but insists that she saw not a single *Acanthaster* in the intervening years. The *Acanthaster* appeared in large numbers on several reefs, were present for a time, then were not seen again until recently.

Similarly, one of us (JF) interviewed an elderly fisherman in the village of Suano, Upalu, Western Samoa and was told that perhaps forty years before, when the man was young, so many alamea appeared on the reef fronting the village that it could no longer be fished in safety. (Typically, "fishing" refers to an activity involving deep wading or swimming near the reef edge by pushing from one coral head to another with the feet.) Reportedly there were so many alamea that a fisherman could not stand on the reef without stepping on one. Consequently, fishing was done at a more distant reef. Presumably, such numbers of *Acanthaster* would cause extensive damage to living corals, yet when visited by the author, the same reefs were found to be 90% to 100% covered with healthy corals. These reports tend to confirm the hypothesis that *Acanthaster* infestations are a recurring phenomenon, and that the resulting reef damage is temporary and of no lasting consequence.

Generations of Samoans have modified their fishing habits to accommodate periodic infestations of alamea. Samoan fishermen seem less concerned about a new infestation than non-natives who view with alarm from a background richer in formal education and concern for the environment but poorer in traditional knowledge and experience.

Our first priority in the study of increases in the numbers of *Acanthaster* should be to ask the people who have lived with the reefs for the longest time, and to study the natural history of the affected reefs with particular emphasis on the stages of coral damage, its ecological implications, and the progressive stages of succession during the recovery of the reef corals.

Acknowledgement

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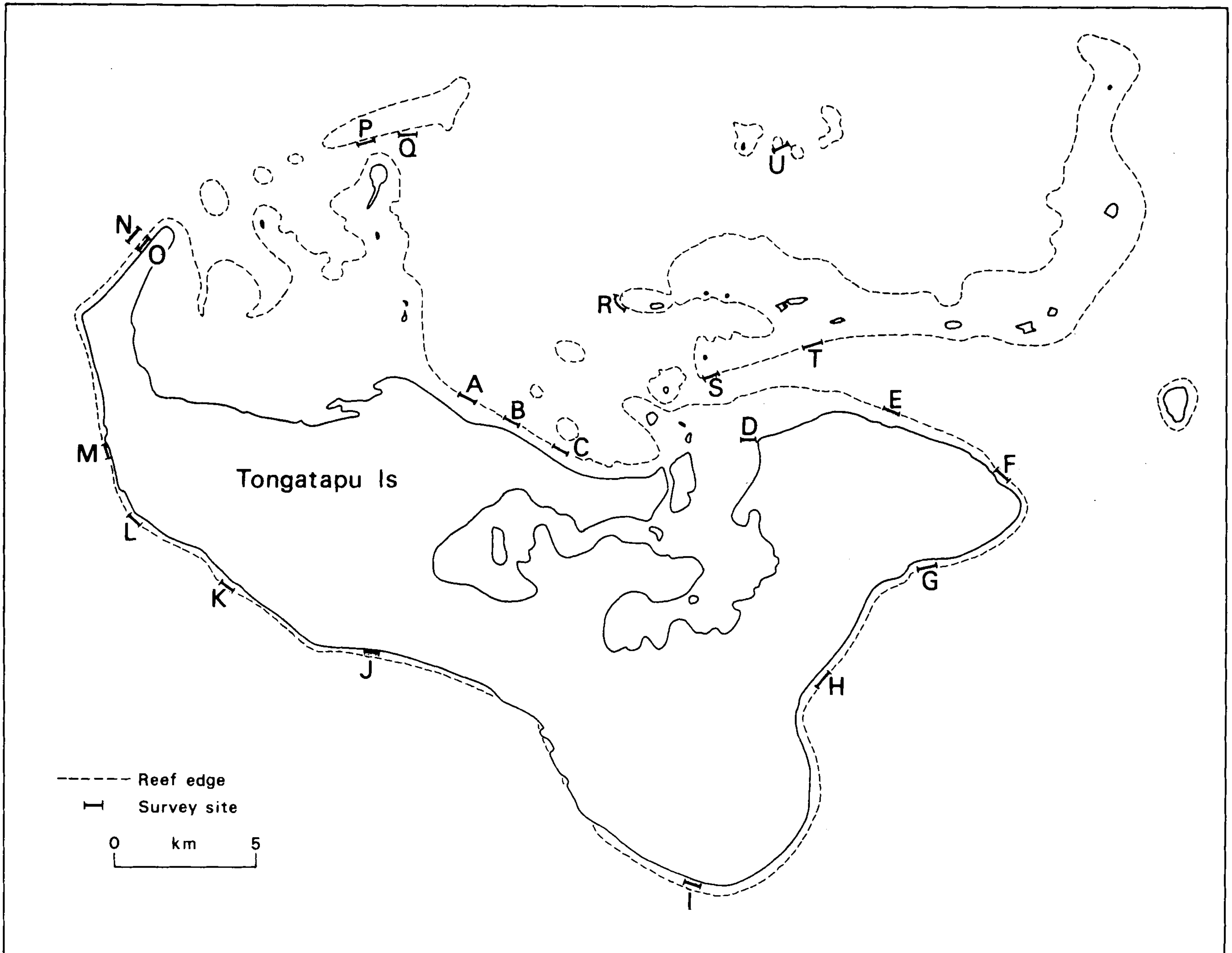

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DISTRIBUTION AND ABUNDANCE OF THE CROWN-OF-THORNS STARFISH (*ACANTHASTER PLANCI*) AROUND TONGATAPU ISLAND, TONGA

by M.P. Francis[1]

Introduction

Acanthaster planci infestations have been reported from many locations in the South Pacific Ocean but Tonga has attracted little attention because of its isolation. During six man-days of searching Weber and Woodhead (1970) found *Acanthaster* "rare to common" on Tongatapu Island where "common" was defined as 6 to 25 starfish observed per man-day. Endean and Chesher (1973) cite personal communication with the Tongan Department of Agriculture in 1970 regarding a proposed *Acanthaster* control programme. The programme, however, never proceeded. The present survey covers the situation six years later.

Method

The coastline and several reefs to the north of Tongatapu were surveyed between 16.4.76 and 16.6.76 by snorkel diving (see Figure 1). Survey site N was searched at depths between ten and twenty metres using SCUBA equipment. All observed starfish were recorded and intensive searches were made in the immediate vicinity of any feeding scars. At each site a subjective estimate was made of the abundance of live hard corals.

Tongatapu Island is surrounded by a wide shallow fringing reef. On all but the northern (sheltered) side of the island the reef edge is raised to form a barrier one to two metres above the level of the reef flat. Prevailing south-easterly winds hindered searches outside this barrier, and survey sites F to M were therefore situated on the reef flat.

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Results

Survey Site	Live Coral Abundance	*Acanthaster*[1] Relative Abundance
A	Abundant	0
B	Common	0
C	Rare	0
D	Absent	0
E	Abundant	0.5
F	Common	0
G	Rare	0
H	Rare	0
I	Rare	0
J	Rare	0
K	Absent	0
L	Rare	0
M	Common	0
N	Common (10-20 m depth)	3.0
O	Common	5.3
P	Rare	0
Q	Common	0.5
R	Rare	0
S	Abundant	0.7
T	Common	0.7
U	Common	0

[1]Relative abundance is the number of starfish seen per twenty minutes searching (see Pearson and Endean, 1969).

Discussion

No *Acanthaster* were found on the coast exposed to the prevailing winds (sites F to M). Coral growth is inhibited inside the barrier by exposure to air at low tide, and outside the barrier by heavy surge. The reef outside the barrier drops slowly to a shelf at ten metres, but live coral is stunted and scattered above this depth. *Acanthaster* may occur at greater depths. The absence of *Acanthaster* from exposed reefs, and their preference for sheltered reefs, is consistent with the observations of Dana, Newman and Fager (1972) who found the starfish usually associated with "leeward seaward reefs" and "areas of moderate to luxuriant coral growth".

More than 70% of the sites examined had no *Acanthaster* and the maximum relative abundance was 5.3. Pearson and Endean (1969) consider a relative abundance less than ten to constitute a normal population. By this definition Tongatapu has normal numbers of the starfish, and the presence of luxurious growths of *Acropora hyacinthus* and *Porites* spp. in sheltered areas suggests there has been no infestation in recent years.

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RATS AS AVIAN PREDATORS: DISCUSSION

by W.R.P. Bourne[1]

Since F.I. Norman concludes at the end of a review of the role of "The murine rodents *Rattus rattus, exulans* and *norvegicus* as avian predators" (Atoll Research Bulletin No. 182, 1975) that "it appears that the rats' role as an avian predator has been overestimated... the basic facts should be established before widespread control campaigns are undertaken", and this conclusion may be used as an argument for procrastinating over such campaigns, it should perhaps be made clear that many people have no doubt at all about the harm caused to birds by rats, and will refuse to accept such a cautious conclusion for a moment.

The situation is of course complicated, and the literature relating to it vast. Rats were introduced to many sites where the worst damage has occurred long ago, before reliable witnesses arrived, and those that were present commonly reacted by introducing cats, owls or other predators, which confused the picture. Rats do most of their work by night, and since it only takes them a few seconds to remove an egg or bird it may be hard to obtain direct evidence of their activities. They are inveterate scavengers, and may take abandoned eggs or birds which died of other causes. The extent to which they prey on other animals may vary with the relative size and numbers of the rat and its prey, the availability of alternative foods, and the occurrence of a seasonal climatic regime liable to lead to restrictions on the food-supply available to the rats at some seasons which limits the numbers able to act as predators when birds are present at other seasons. Their activities may also affect the ecology of other species indirectly, by competition for food, or through damage to the habitat, for example by eating the roots of tussock grass on subantarctic islands. It is dangerous to make facile generalisations about the situation except to say that a legion of witnesses have now reported for centuries that their presence has almost invariably been considered harmful.

The situation may be illustrated by taking a few examples:-

1. An exceptionally rich marine avifauna breeding on Amsterdam Island in the southern Indian Ocean may have been partly exterminated by hogs and cats at the beginning of the last century, but most of the surviving bones were found in rat-holes (C. Jouanin and P. Paulian, Proc. XII Intern. Orn. Congr. 368-372, 1960).

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2. Five native birds, *Gerygone insularis, Rhipidura cervina, Zosterops strenua, Apolonis fuscus hullianus,* and *Turdus xanthopus vinitinctus* disappeared from Lord Howe Island within twenty years of the arrival of *Rattus rattus* in 1918 (see especially a symposium on the island in Australian Natural History 18(2) for June 1974).

3. The havoc caused by rats among both land and sea birds in the New Zealand area is documented by a series of contributions from the Wildlife Service and Royal Bird and Forest Society to the forthcoming Proceedings of the XVI World Conference of the International Council for Bird Preservation. Norman is wrong in identifying the muttonbird virtually exterminated on Stewart Island as *Puffinus tenuirostris* since it was *Puffinus griseus*; the endemic Southern Saddleback *Philesturnus c. carunculatus* which he mentions was threatened when *Rattus rattus* reached the outer islets in 1964 was only saved by emergency transplantations elsewhere, while the local race of bush wren *Xenicus longipes variabilis* and snipe *Coenocorypha aucklandica iredalei* may have been lost entirely.

4. While the petrels *Pterodroma cahow* and *Puffinus lherminieri* do appear to have been eliminated from the main Bermuda islands and confined to outliers by the activities of rats among other predators, and rats may take occasional tropic-bird *Phaethon lepturus* eggs there, this exceptionally aggressive species has in fact managed to hold its own in the face of attacks by not only rats and cats but tens of thousands of people. Norman quotes R.C. Murphy (Oceanic Birds of South America, 1936) incorrectly in attributing the rat predation to *Rattus exulans,* since this was in fact a repetition of the original report by Gross (Auk 29:49-71, 1912) that he had seen one egg taken by *Rattus rattus*. *Rattus exulans* does not occur in the North Atlantic.

5. The impact of rats on birds in the British Isles is extremely variable. They are important predators on many species but especially those nesting on the ground inland where rat numbers are high, though it is not always easy to distinguish their work from that of other small mammals. They exterminate storm petrels wherever they go, but their impact on larger burrow-nesting birds varies. They exterminated a large Puffin *Fratercula arctica* colony on St Tudwal's Islands, North Wales, and severely reduced their numbers on Lundy, Puffin Island (also north Wales), and Ailsa Craig without exterminating them, whereas a large colony long continued to flourish in the presence of rats on the Shiant Islands. They exterminated the Manx Shearwater *Puffinus puffinus* at its type locality on the Calf of Man, and it only recolonised when they were controlled by poisoning. Small numbers survive in the presence of rats at a number of other sites, a larger colony suffers severely from predation in some years but not others on Canna, and a vast one in the hills of Rhum appears to escape it. Terns suffer severely in areas heavily infested with rats but may escape their attention elsewhere (references for some of these sites will be found in S. Cramp, W.R.P. Bourne and D. Saunders, "The Seabirds of Britain and Ireland", 1974).

The situation appears to have been particularly bad on many oceanic islands because there were no natural predators or inclement seasons to control the numbers of introduced rats, and the native wildlife had no innate defences against them. The petrels which bred there were particularly vulnerable because they leave their small, defenceless chicks alone in their burrows by day soon after they hatch. It will be noted that while Norman found that rats took the unguarded eggs of Short-tailed Shearwaters *Puffinus tenuirostris* but avoided encounters with the large, aggressive adults (J. Zool. 162:493-503, 1970) he did not investigate what occurred when the rats encountered small chicks. While the situation may often have been made worse by the introduction of alien predators in an attempt to control rats, there is an obvious correlation between a decline of the smaller and more defenceless seabirds in historic times and the introduction of rats throughout the world. However, I agree that it remains difficult to assess the full amount of harm they have caused because it is impossible to say how many insular landbirds they have exterminated as well. A rat may only need to eat two or three eggs or chicks a year to cause serious damage, whatever it eats the rest of the time.

LAYARD'S BIRD HUNTING VISIT TO TROMELIN OR SANDY ISLAND IN DECEMBER 1856

by R.K. Brooke[1]

This paper concerns the only known visit by a biologist to Tromelin Island in the XIX century.

That Edgar Leopold Layard, the Curator of the South African Museum, Cape Town, travelled as naturalist on the British Royal Navy survey ship H.M.S. *Castor* on a journey in the southern Indian Ocean in 1856 and 1857 was scarcely known at all until Brooke (1976) commented on some aspects of the journey and the bird records made on it. Subsequently Brooke (1978) reported on those birds' eggs collected on this journey which still survive in the South African Museum. He also deduced the approximate route and timing of the journey from the species collected, their known breeding seasons and migrations. As will appear below, these deductions were close to the truth. Since then I have had cause to examine in the South African Library, Cape Town, a run of the *Cape Monthly Magazine* (Series 1) published in Cape Town between 1857 and 1862. This magazine attempted to cater to the interests of the more educated residents of British stock by publishing scientific, philosophical and literary material.

In volume I of the *Magazine* the editors caused to appear on pp. 252 - 254 a notice entitled "Mr. Layard's cruise in the "Castor"." From this we learn that H.M.S. *Castor* left Simonstown on 10 October, 1856 under sail under the command of Commodore H.D. Trotter. They intended to land first at Rodriguez but extensive fog persuaded them to head for Mauritius where they spent five weeks and made several trips to nearby Round Island. Sandy Island as Tromelin Island was then often known (Staub 1970) and the focus of this paper was the next landfall (presumably in early December 1856). Then Farquhar Island was visited prior to reaching Africa at Fazi Island, Kenya, on 4 January 1857. Thereafter, Lamu, Melinda, Kisilundini, Zanzibar, Cabo Delgado and Dibo were visited before they put out to sea for a crossing to northwestern Madagascar via the St Lazarus bank and the Comoro Islands. Anjouan was reached on 1 February and a few days later a visit was made to Moheli. Two days were spent in Madagascar at Boyana Bay at a Jesuit Mission before recrossing the Mozambique Channel to Mozambique Town. After a substantial visit they set sail for home via Durban (departed 13 March), East London, Port Elizabeth (departed 19 March) and so back to Simonstown on 25 March 1857.

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Layard promised to write a full account of his journey and his collections for the *Magazine* but he did not do so, probably through pressure of work: he was only the part-time curator of the Museum being a nearly full-time civil servant as well. However, in 1858 in vol. III, pp. 289 - 296, appeared the following from Layard's pen:

SCRAPS FROM THE NOTE-BOOK OF A NATURALIST

SPORT ON SANDY ISLAND

BY E.L. LAYARD

"LAND, HO!" hailed the look-out man from the foretopsail yard of Her Majesty's ship *Castor*, as one lovely morning the Commodore and myself paced the deck of the good old frigate.

"Whither away?" went up the responsive query from the midshipman of the deck, who, stepping up to the officer of the watch and touching his gold-banded cap, reported the fact. In his turn, the officer reported to the Commodore; and, after a few questions, the order was given to head the vessel to the land, and we resumed our walk.

The low shores of the island now became visible, and the clear blue sky was dotted with birds, winging their way to and fro; some plunging headlong into the rippling water, that vied in the intensity of its azure with the sky above it, sought their finny prey, some returned to their nests heavy laden with food for their young, while others floated contentedly on the gently heaving bosom of the sea, or rose lazily out of the path of the frigate, as she majestically ploughed her way along, her white sails gleaming in the bright sunlight. One by one the studding-sails came home, and the noble ship cautiously felt her way to the rapidly rising land; and now, while the boats are told off, we descend to have a last look at *Horsburgh's Directory*, for landing instructions, hidden dangers, currents, etc.

For the benefit of such of my readers (and I suppose they are numerous) who do not know where Sandy Island lies, I transcribe the account given by the great hydrographer of its position and appearance:-

"Sandy Island, or L'Isle de Sable, in latitude 15° 52' S., longitude 54° 40' E., is a flat, sandy spot, about fifteen feet above water, half a mile long, from N.N.W. to S.S.E., and about a quarter of a mile broad, having a sand-bank projecting three quarters of a mile towards the S.S.E. It was discovered by the ship *La Diane*, in 1722, and in 1761, the *Flute l'Utile* was wrecked there."

After the men had got their dinners, the boats were reported ready, and the first cutter, attended by the dinghy to assist in landing, were soon off from the ship's side, well furnished with baskets, guns and ammunition, harpoons, fishing-lines, etc. The vessel had stood up as near the island as the light breeze permitted with safety, and on quitting her, she tacked and stood off, the Commodore trying for soundings (though finding none with one hundred fathoms of line), and practising reefing topsails and other manoeuvres, to exercise the men. The boats pulled cheerily along, the men eager for a run on shore and a supper of turtle steaks, the sportsmen anticipating no end of sport, and myself luxuriating in the idea of visiting the breeding place of the countless frigate birds, gannets, terns, and other birds that now filled the air with their piercing cries, and darkened the sky over the island.

As we reached the coveted shore, the water suddenly changed from blue to green, and presently the surf line showed itself, thundering on the sandy beach. The dinghy being signalized to pilot the way, the two Kroomen who rowed her, amphibious fellows equally at home in the water as on the land, urged their frail skiff in advance, and we soon descried a spit of land, under the lee of which the water lay comparatively smooth, and there we determined upon effecting a landing.

The dinghy soon lay high and dry; but our attention in the cutter was diverted by a tempting object that floated on the calm water, a few dozen yards ahead, and which we all, at once, and with an instinct worthy of city aldermen, knew to be turtle soup in its raw material. An old whaleman now crept forward to the bows and drew out the glittering harpoon, the boat's crew pulled noiselessly, the officer in charge gave his orders in whispers, and we stole on our prey. "Ah! old fellow, how many basins of soup will you make?" was in many a mind, and "What a splendid shell for the Museum," in *one* at least. Look at the harpooner, he stands upright, one foot on the gunwale, the barbed weapon poised; half-a-dozen strokes and he is — No, not a bit of it, — wide-awake is Master Turtle; and without a ripple, down sunk the huge bowl of soup and we saw him no more.

Disappointed with the failure of our first essay in turtle-catching, we turned our boat's head to the shore, and pulled in, avoiding with sailor's skill the huge rollers that ever and anon broke in masses of white foam on the beach. We ran in on the top of a wave, backed and let it break, and then pulled in. Out jumped the men who were appointed to run the boat up, and to our dismay, though only a few yards from the dinghy, our fellows found no bottom. Before they could recover the confusion into which this untoward accident threw them, and the men in the boat had recovered their oars, a huge surf broke right over us, washing two men out of the boat and throwing her on her beam ends. I held on to the guns and the benches, the rest made ready to spring out at a favorable moment; fortunately, the next wave had a "long-shore" course, and though it threw us about like a nut-shell, it drove us into shallow water. The men still clinging to the gunwale found footing; the rest of the crew sprang out, and the next moment saw us in safety, though at the expense of a good ducking, and, on my part at least, not being a swimmer, of a good fright.

After wiping our guns and spreading our superfluous clothing on the sand to dry, we walked up to what we at once saw to be the remains of a human habitation. We found the ruins of a hut, which had contained three rooms; in the largest was a square enclosure of blackened stones, which had formerly served for a fire-place; but which now held the nests of three or four noddies (*Anous Stolidus*), who, utterly heedless of our approach, pecked furiously at our hands when we attempted to possess ourselves of their lovely spotted eggs. We found the nests of these birds in every hole and corner of the ruins; they had taken possession of every stone, and while the male bird sat perched on the top, the female covered her solitary egg by the side in a depression in the soil, lined with a few seaweeds. The eggs were beautifully spotted with patches of various shades of a light purple on a delicate cream-colored ground. An average sized egg measured two inches by one and a half inches; but hardly two were of the same size, or colored alike; still, a practiced eye could at once separate them from that of *Onychoprion Fuliginosus,* which we found breeding on another part of the same island.

From the ruins, we walked to the east side of the island, which appeared covered with bushes about the height of a man's head. Up to this time, the frigate birds had kept well out of range; but now a rustling sound was heard above us, like the falling of some heavy body through the air, and glancing upward, I saw a frigate bird darting down as if to attack us. As he swept past, I leveled my gun at him, fired, and he rolled over; and now the guns had plenty of work, for the birds poured down, and the ground was soon strewed with dead and dying.

How many of the wished-for birds we might have slain, I know not, when one of the men called out, "Hold hard, sir, — don't shoot any more, — here they sit by scores on their nests." And now the truth flashed on my mind, — we had intruded on their "rookery," and the poor birds had lost their lives in their vain attempts to intimidate the two-legged monsters that had suddenly disturbed their domestic privacy. Eager to possess myself of their eggs, I dislodged bird after bird from her nest, by the aid of a long stick, — to approach one's hand, was the sure precursor of a severe bite. Every one, almost, had a callow nestling under her maternal wing; and I obtained but few eggs in a fit state for blowing.

The Tars, who roamed about, found one place where the incubation seemed not so far advanced, probably the nursery of the new-married and inexperienced couples. Jack seized the prize, and though the eggs were in most instances sat upon, they were all devoured: so much for taste! I heard one fellow say to his chum, as he gulped one down, "Dang it, Ned, there was a bone in that un."

The frigate birds (*Attagen Ariel* and *A.* ,) and the gannets, of which there were three species, — *Sula Fasciata, S. Personata, S. Fusca,* bred side by side, in patches. Their nests were huge structures of sea-weed, dung, and fishbones, their stratified appearance testifying that each successive year added to their size. The stench from this spot was dreadful, the ground being strewed with the debris of fish and young birds. I could not account for the numbers of the latter, till I saw a huge red and hairy hermit crab (*Pagurus*), inhabiting the dead shells of a large Turbo, which lay scattered in great abundance on the ground, deliberately descending the trunk of one of the bushes, with a writhing squab in his claws. I then saw that the branches were full of these cannibals, mostly laden with fish stolen from beside the nests. I presume, the robbers only occasionally manage the more dainty morsel of a tender chick, secured when the mother is absent from the nest, though doubtless sufficiently often to keep in check the rapid growth of the birds, — robbers in their turn, for from the mouth of one I shot was disgorged no less than seventeen fish, from three to nine inches long.

After forcing our way through the bushes, we emerged on the side of the island, opposite to that on which we landed, and found a reef, or ledge of coral and rock, extending along the shore, at the outer edge of which the surf broke in fearful splendour.

A hail from one of the men in advance, and the clustering of the lads as they reached the spot, induced us, who were leisurely advancing with prying eyes, to hasten our steps. We found, on arriving at the scene, that the men were busily engaged in examining two or three heavy iron guns, that lay half buried and jammed in between the rocks, and to seaward lay the timber of a vessel, with her huge anchor still with one fluke in the reef. These, then, were the remains of the ill-fated *L'Utile,* the French man-of-war alluded to by Horsburgh: the house now tenanted by the wandering sea-fowl had been the home of the survivors during their long imprisonment on this speck in the ocean; the fire-place in the large room had witnessed the gay laugh of the thoughtless, the bitter gloom of the despairing, and the high and manly thoughts of the undaunted and brave, each, perhaps, in his own way, pondering over the means of escape, or the question of to-morrow's food. The commander sat in the little room, overlooking the remains of his lost vessel: the officers crowded in the other room, and thought of those loved ones they might never see again; and now, how many of that band of men survived? Not one! and the place of their long sojourn would never again hear the sound of their voices.

We pushed onward to the northern end of the island, and crossed an open plain that lay between the bushes and a high bank of rolled stones, cast up by the storms of ages on that end of the island. In the centre of this plain, we came upon a circle of stones, placed round a spot, whose vivid green attested to the presence of water beneath: this was the place from whence the shipwrecked men drew their supplies. Near this spot we could hardly tread for young terns (*Anous Stolidus*) and eggs, and on turning over a stone, out sprang two mice; another and another followed from every stone moved, the place literally swarmed with them. They had probably come in the French ship, and had peopled the island. How to account for the presence of the vast quantities of huge black ants, that ran their galleries in all directions under the sward, was a more difficult matter; as also was the advent of a lizard (Gecko) that I captured, but which subsequently made his escape.

Advancing a few yards from this spot, we entered on the domains of another species of tern (*Onychoprion Fuliginosus*), of which we were first made aware by the fearless birds striking at our faces with their sharp pointed bills. As in the other places, we had not seen a single nest of this species, so now we saw not a nest or specimen of *A. Stolidus*. The noise of the congregated numbers was so great that we could barely hear the shouts of our nearest neighbor, and I was glad to escape over the high ridge of stones and gain the *quiet* of the dashing surf.

This is evidently the stormy side of the island, and the direction of the prevailing wind. The whole shore consisted of large rolled stones; not one of which possessed an angle; all as smooth as a cobbler's lap-stone, they irresistibly brought to mind hundreds of jolly Crispins busily tapping soles and welts. Here we found another wreck — a huge tree; from whence had this floated? Madagascar probably, and was the ark in which had come the ants, and the gecko; so are those ocean dots peopled.

Turning from the scene of speculation, we wended our way back to our boats along a broad road, cleared of every stone, and nicely smoothed. For what could the poor refugees have constructed this road? Perhaps their commander, a wise man, reflecting that idleness excited gloomy thoughts in such situations, had set his men to work to clear this road, to convey — what? Firewood from shipwrecked trees, stones thrown up by the waves to build their house, — what! as a carriage road it had certainly been used, for we found the broken wheel of a cannonade lying on a heap of stones.

While walking here, I had given my gun to the Chaplain, who wanted to try his hand at a shot. He had fired once and unsuccessfully, at an oyster catcher (*Hoematopus*); and now to my vexation, I saw a new lovely snow white bird, much resembling a tern, slowly passing him. "New bird!" I shouted; "shoot, parson, shoot!" Alas, my friend was a better hand with his Hebrew books than with Westley Richards, and that eminent individual's death-dealing tubes were leveled in vain at the lovely stranger. To the bright flash and loud report, the snowy creature made a graceful stoop, like a damsel in white muslin at an invitation to dance, and it floated over our heads and looked us full in our faces with its large black eyes. I was frantic: eagerly I crammed in a charge of powder; but alas, no shot had I, my *fidus achates,* "Ned," and "curio-man's Jack," as the sailors had dubbed him and me, was off to the boats with my pouch. But help was at hand, — the crack-shot of the ship, Lt. -----, was hastening to the scene, attracted by my shouts and vain attempts to knock the bird over with stones. Seeing another of the queer monsters running up, my white friend turned away, and was winging his course sea-ward. Oh agony! only known to the naturalist, who sees a new species slip away from his grasp. Inwardly, I resolved never more to trust my "shooting-iron" out of my hand on these unknown coasts. The white vision took another turn this time, land-ward — "run, run! — new bird! — long shot! — ah, my beauty, the parson does not hold that steady barrel: a deadlier eye is measuring the distance which you will fly over, ere the leaden messengers will reach you." And now, the sharp flash! — plump down falls the hapless bird. The reverberating report reaches my ears, and I dashed forward and the prize is mine; and oh, how beautiful the pure white plumage, without a speck, save the one pink spot on the breast, from whence oozed the ebbing life blood, the brilliant blue bill and the large dark eye now closing in death! And now, *quam mutatus ab illo*! its dry and shriveled skin and blackened bill grace the cases of the Museum, — a mockery of life; a burlesque on the loveliest bird I think I ever saw. Reader, you may see it labeled *Gygis Candida*.

The eggs of the *Onychoprion Fuliginosus* are rather larger than those of *A. Stolidus,* being about 2 inches and 2 lines long, by 1 inch and 7 lines broad, and more thickly dotted with smaller dots at the obtuse end. They are also generally darker, and may easily be distinguished by any one who has ever taken the two, though a written description would suit for either species.

The eggs of the frigate birds, *Attagen Ariel* and *A.* , are very similar in size and shape to those of the gannets; but are smoother and thinner in texture, and free from the thick incrustation of lime which at once distinguishes those of the latter. They are both pure white when fresh laid; but get sadly soiled amidst the filth in which they lie. They measure about 2 inches 7 lines long, by 1 inch 9 lines broad.

Just as we commenced our arrangements for the night, the old frigate which had been working up for the island, suddenly backed her topsails, ran up her recall flag, and fired a gun. Jumping into the dinghy, I went on board to ascertain the reason of this change of plan, while the cutter was launched and preparations made to return, if the recall should prove general.

"What sport?" shouted the Commodore, as we got within hailing distance. "Glorious!" was my reply. "What likelihood of turtle?" was the next question. "Very little! no marks on the land of the breeding ones." The little dinghy shot under the tall sides of the ship, when again thundered her signal gun, and the cutter's recall, in lanterns, ran up to her mast-head; and just as total darkness fell on us, the cutter dashed along side, and in another moment was swinging at her davits; the old ship filled her sails, bowed to the night breeze, and we stood off from the island.

"I don't like the current hearabout," said the Commodore, as I finished my narration of our afternoon's adventure. "We must not lay the *Castor's* bones alongside those of *L'Utile*."."

The rest of what Layard did, collected or saw on that journey is lost save for the fragmentary allusions in his 1863 paper, his 1867 book (brought together in Brooke 1976) and what little can be learnt from the surviving eggs discussed in Brooke (1978).

It is possible now to present a picture of the bird life on Tromelin Island as it was in December 1856, 98 years before Brygoo's (1955) visit, believed to be the first ornithological visitor by Staub (1970). As Mr. A.S. Cheke has pointed out (in litt.) Brooke (1976, 1978) was mistaken in assuming that Layard's Sandy Island was the Sandy Island off Rodriguez. The Rodriguez records in those publications were all made on Tromelin Island (Layard 1858).

Sula dactylatra: a youngster and adults brought back to Cape Town (Brooke 1976), young in the nest (Layard 1858 sub nom. *S. personata*). It still breeds here (Staub 1970). The nest site fidelity described by Layard should be noted.

Sula sula: a pair and two youngsters brought back to Cape Town (Brooke 1976), young in the nest (Layard 1858 sub nom. *S. fasciata* for normal birds and *S. fusca* for dark phase birds). I know of no other usage of *S. fasciata,* let alone who proposed the name if, indeed, it is not just a misconception in Layard's mind. It still breeds here (Staub 1970).

Fregata ariel: adults collected, most nests held young but a few held eggs, usually well incubated (Layard 1858). Staub (1970) is uncertain whether it still breeds on Tromelin.

Fregata minor: as for *F. ariel* (Layard 1858). It still breeds here (Staub 1970).

Haematopus ostralegus: shot at but missed (Layard 1858). Not recorded on any Indian Ocean island by Watson et al. (1963) and there are no subsequent records (A.S. Cheke in litt.).

Larus cirrocephalus: an adult brought back to Cape Town (Brooke 1976). He gives reasons for not rejecting the record even though the specimen no longer survives and there are no later records. Presumably it was a vagrant from Madagascar nearly 400 km to the west.

Sterna fuscata: eggs collected (Layard 1858 sub nom. *Onychoprion fuliginosus*). Not recorded by Staub (1970) whose visit was in late August when the birds would not have been breeding.

Sterna dougallii: Staub (1970) suggests that the terns described by Morris (1964) as "with light grey mantles and black crowns" were this species. They might equally have been *S. bergii thalassina* since no indication of size is given. Layard (1858) makes no suggestion that either species was present during his visit.

Gygis alba: an adult brought back to Cape Town (Brooke 1976). It does not appear from Layard (1858) sub nom. *Gygis candida* that it was breeding at the time of his visit. Not recorded by Staub (1970).

Anous stolidus: a youngster and adults brought back to Cape Town (Brooke 1976) as well as eggs (Brooke 1978). They had both eggs and young in their nests (Layard 1858). Not recorded by Staub (1970).

Anous tenuirostris: adults brought back to Cape Town (Brooke 1976) but it does not appear from Layard (1858) that he realised that two species of *Anous* were present. Not recorded by Staub (1970).

As for the fauna other than birds it appears from Layard (1858) that *Mus musculus* was by then well established and it has remained so (Staub 1970). Layard's belief that they had come from the wrecked *L'Utile* is likely enough. He does not mention *Rattus norvegicus,* the other well established rodent noted by Staub. Hermit crabs *Pagurus* sp. were common both in the 1850s and 1950s: Layard's remarks on their predation on the young of *Sula dactylatra* should be noted. Layard's gecko (Reptilia, Gekkonidae) was probably, as he said, a drifted vagrant since there is no mention of lizards in Staub. I am unable to equate Layard's (1858) "huge black ants" with Skaife's (1953) description of *Pheidole megacephala,* the only ant recorded by Staub (1970).

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A SUBMERSIBLE, RECHARGEABLE, ELECTRIC DRILL

by W. H. Easton[1]

Abstract

A light weight, cordless, rechargeable, electric hand drill mounted in a submersible plastic case is linked by a shaft through the housing to an external bit extension. Tungsten carbide masonry bits or small diamond core drills can be attached to the end of the bit extension without opening the underwater housing. The assemblage has been used to set survey points used in measuring shoreline erosion and to take core samples for radiometric dating and for determining growth rates of corals by X-radiography. Other applications have been suggested.

Design

The prototype model (Figure 1) was designed to accommodate the smallest rechargeable drill in order to reduce weight and volume taken on flights to distant islands. A submersible housing was constructed of 3/8" and 1/2" acrylic plastic to fit two inter-changeable models of drills — the Craftsman Rechargeable 1/4" Model No. 135.111100, and Skilshop Model 1702 Type 1 Cordless 1/4" Reversing Drill. The assemblage weighs 3 kg (6.7 lbs) and will float. General information and materials used in the construction of plastic housings can be obtained from hobby shops, plastics salesrooms, and Toggweiler (1970). Prefabricated control glands with O-rings, and levers, shafts, and stud retainers with studs and nylon wing nuts for closing housings are available from some dive shops and Toggweiler.

A few special requirements must be met in designing the apparatus. The acrylic plate in front of the drill chuck must be at a right angle to the axis of the chuck, because the control gland containing an O-ring through which the shaft of the bit extension passes also must be aligned perfectly with the axis of the chuck after the gland has been cemented to the front plate of the housing. The rear of the drill case must just touch the inner surface of the rear plate of the housing so that a thrust applied to the housing by the operator will

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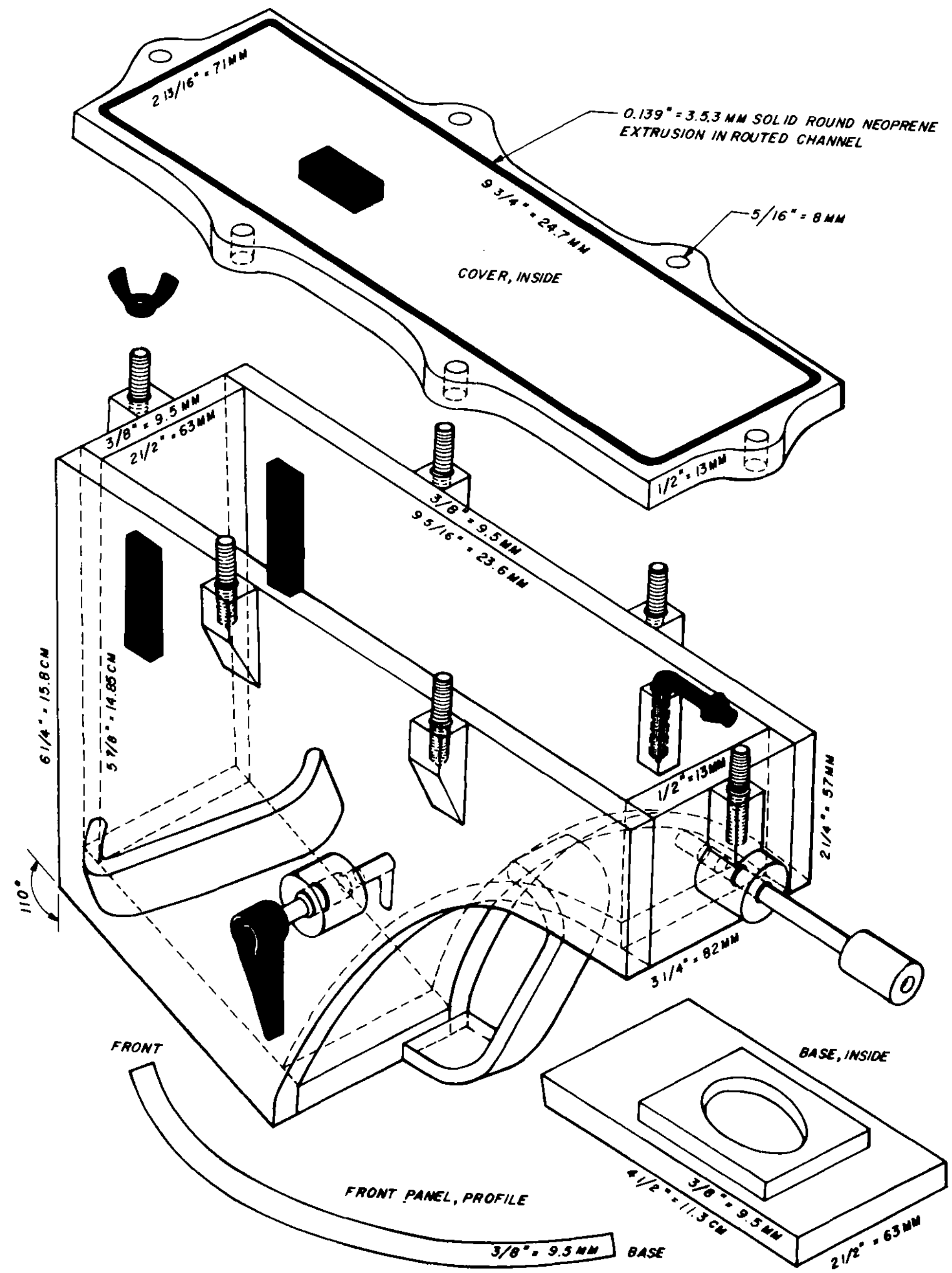

Figure 1. Submersible housing with bit extension attached.

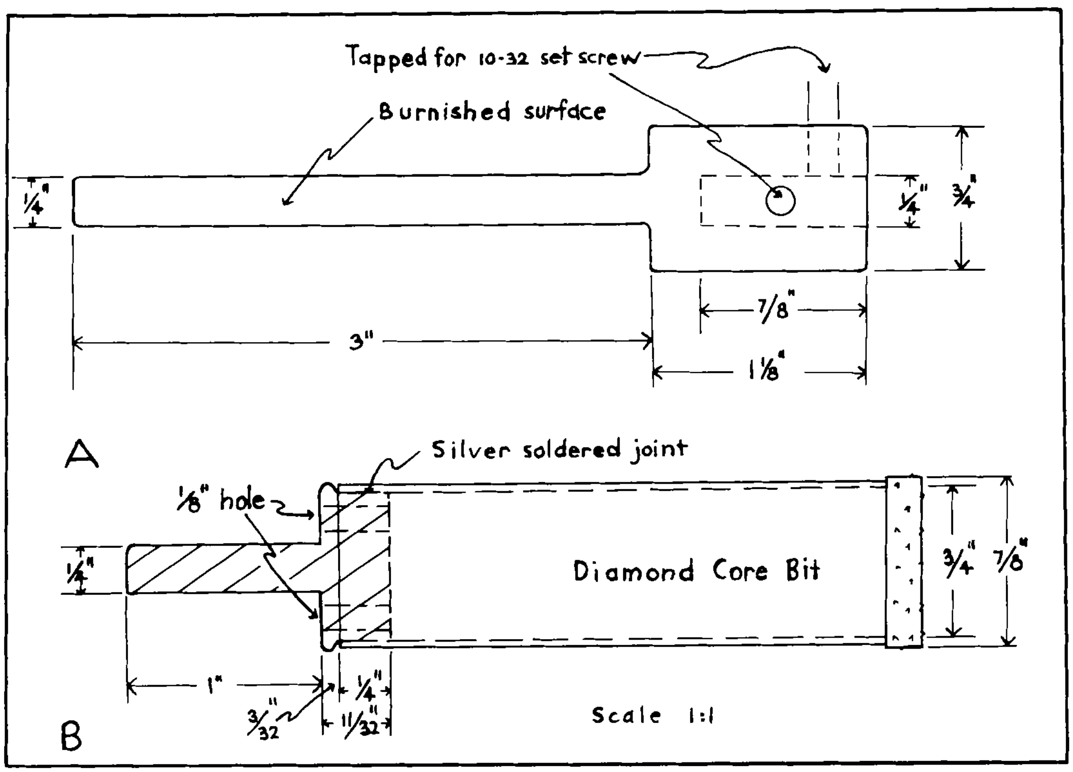

Figure 2. A. Specifications for the bit extension.
B. Specifications for the diamond core bit assemblage.

be transmitted to the electric drill. Lateral wobble of the drill handle is controlled by the oval receptacle in the base and by cushions of vinyl foam cemented to the two side walls of the housing and to the inside of the cover. The chuck key is stored inside the housing.

A short bevelled piece of shaft brazed to the long trigger release shaft at a right angle provides the contact with the trigger switch. If the case is designed with the greatest economy of inner space, the trigger release shaft will be too long to be inserted through the control gland from inside the housing. In this event a small hole can be drilled laterally through the plastic trigger on the drill and a thin diameter screw can be threaded through the hole and extended about 3/8" (=9.5 mm) to the right side where it will be engaged by the bevelled flange brazed on the control shaft. No provision was made for external activation of the on/off safety switch or the reversing switch on the motor case.

The bit extension (Figure 2) is fabricated from stainless steel stock, including the two set screws. The shaft must be 1/4" in diameter in order to pass through the prefabricated control gland. However, the hole for the reception of the shank of the masonry bit or the diamond core bit may be of different diameter, depending upon the size and brand of masonry bit. Some bits are of uniform diameter from the tip, along the twist, and on the shank. Others are of smaller diameter behind the tip, so the bit must be selected before the receptacle in the bit extension is bored. Furthermore, the shank of stainless steel brazed on the diamond core bit must be the same diameter as the shank of the masonry bit if these tools are to be interchangeable. Machine shop experience indicates that it is advisable first to turn the 1/4"-deep recess on the shank assemblage and braze it into the rear opening of the diamond core bit before machining the 1/4" shank. This ensures that errors of alignment causing wobble when the apparatus is operated will be eliminated.

The diamond core bit is Type SICD, Serial N. 55955, without collet, 7/8" O.D., available through Felker Operations, Dresser Industries, Inc., 1900 South Crenshaw Boulevard, Torrance, California, 90509. Other core bits are available in sizes as small as 1/8" and larger than the one selected, so there is a wide selection of sizes enabling a choice of bits calculated to provide the volume of material required. In ordering any brand of core bit one must specify that the bit must not have anything fastened to the open end opposite the cutting edge.

Uses

The apparatus was designed to facilitate collecting coral samples for three lines of research being conducted on various islands in the Pacific Ocean. Growth rates of some corals (for example, species of *Porites*) can be determined by X-radiography of slices taken normal to the direction of growth (Knutson, Buddemeier, and Smith, 1972). The length of the cores (about 7.5 cm or 3") and the facility with which variously oriented and positioned samples can be obtained are ideal for this line of research. Growth rates also could be determined by the ^{228}Ra, ^{90}Sr, and ^{210}Pb methods if two or more cores of 7/8" diameter were taken, or if a larger core bit were utilized (Moore, Krishnaswami, and Bhat, 1973).

Cores 7/8" in diameter weigh about 25 grams and contain enough material for either ^{14}C or uranium series ($^{230}Th/^{238}U$ and $^{234}U/^{238}U$) analyses (Barnes, Lang, and Potratz, 1956; Thurber, *et al.*, 1965). Radiometric dating of samples by these techniques is used to determine ages of raised shorelines containing corals, ages of certain reefs, and changes of sea level.

Masonry bits were used to drill holes in coral, limestone, and several kinds of igneous rocks. Bronze nails driven into plastic molly fasteners (hollow wall hangers) inserted in the drill holes serve as reference points against which amounts of erosion can be measured from time to time alone shorelines.

The fully charged prototype assemblage drilled as many as 20 1/4" holes of four 3" cores in coral. Four drill holes or one core one inch long can be cut in hard, siliceous limestone or in moderately hard igneous rock. A spare motor was carried in order to accomplish more work and to ensure against motor failure in remote places. Although the electric drill lacks the power of the commercial pneumatic drills and impact wrenches, it has the advantages of light weight, portability, low cost, and replacement of parts from hardware stores. Furthermore, it can be recharged almost anywhere that electricity is generated.

Biologists and geologists who observed the drill in operation suggested additional uses. In the tropics a drill must be insulated from normal high humidity, rain, and water splashed around boats, even if it is not used underwater. This light drill could be equipped with circular core saws or scroll saws to cut plugs of wood encrusted with lichens, mosses, algae, and other plants. Plugs are transplanted from one tree to another when studying recovery of vegetation, adaptations of plant communities, and certain environmental problems.

Attachments such as screw drivers, routers, grinding wheels, mills, and facing plates could be employed, particularly if an adjustable drill chuck were added to the bit extension.

Operation and Maintenance

Both the masonry bit and the core bit cut most effectively if the holes are kept free from cuttings. Otherwise grooves in the twist of the masonry bit become solidly packed with fine debris, preventing the cutting edges of the bit from biting into any hard ground. The core bit does not become jammed as readily as the masonry bit. Debris can be flushed from holes quite effectively using a rubber ear syringe.

It is difficult to maintain a force against a solid object when thrusting underwater, but bits cut most effectively when a steady pressure is maintained. Instructions with cutting tools warn against letting them rotate ineffectually against the surface to be cut, lest the cutting edge of the tool be damaged. Fortunately, the drill is so light or buoyant that borings can be completed in awkward situations by holding on to the work surface with one hand and operating the drill with the other.

Heat created by the motor warms the air inside the housing,causing a pressure increase. This is a beneficial development to a certain extent because the pressure differential tends to prevent leakage around the O-rings in the control glands and the cover. It is possible, although not personally observed, that long-continued operation of the motor might raise the interior air pressure to unacceptable levels. Intermittent running of the motor seems to permit adequate radiation of heat through the acrylic housing when the apparatus is submerged. It is probable that careful attention should be paid to the O-rings in cold water, for if air should leak out under high pressure, then possibly water might bypass the O-rings when the apparatus cools off. So far I have not observed any leakage in either direction in shallow water.

The O-ring around the drive shaft is subject to increased wear if it becomes dirty. Drilling generates fine abrasive material, so it is beneficial to maintain an excess of thick lubricant such as silicone grease between the shaft and the control gland. Evidence of wear appears as a grey or black stain in the lubricant near the O-ring. Periodic replacement of the O-ring and grease in the drive shaft control gland is advisable.

The steels from which both bits are made rust quickly so they should be given protective coatings of grease when not in use. Moreover, rust-prone shafts should not be left in the receptacle of the bit extension.

Modifications

The two models of drills used in the prototype require from 16 to 20 hours for total recharging. However, a later model, Skil Model 2006, is 3/8" cordless drill requiring only one hour for complete recharging. Furthermore, it has much more torque capability, greater battery capacity, and other special features, yet it has the same dimensions as the 1/4" models used in this project and therefore will fit the same housing.

Other slightly larger models of various brand names may be provided with removeable battery packs so that spare packs can be attached to the motor unit. If two drills are to be provided, it is important to verify their dimensions, because dimensions of the plastic motor cases of one model are significantly different, yet they both bear the same model number.

Some persons who have examined the drill indicate that they might tap the motor with leads that could be fastened to battery packs either in an enlarged submersible housing or carried externally.

Commercial belt packs of batteries are available for under-water photography and might be adaptable for the drill. In any case it would be necessary to ascertain the electrical engineering specifications of any motor being modified.

Acknowledgements

John Wilson fabricated the bit extension and core bit shank. Anna Dillon drafted Figure 1. The manuscript benefitted from constructive criticism by A. C. Hine and D. Hubbard. This project is an outgrowth of National Science Foundation grant EAR 77-13680.

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Addendum

Skil Corporation recently introduced two models of 3/8 inch rechargeable drills that are interchangeable with the 1/4 inch drill originally used. The newer drills have much more torque and much faster recharge times than the 1/4 inch drill. Skil model 2003 can be recharged in three hours, whereas model 2006 can be recharged in only one hour and also has a ready light that indicates when charging is complete. The dimensions of all three drills are identical.

ARTIFICIAL REEFS IN DISCOVERY BAY, JAMAICA

by Michael J. Risk[1]

Introduction

Many studies have been done of artificial reefs placed in the marine environment. In some cases, the emphasis has been on augmentation of nearshore fisheries (for example, see Turner *et al.*, 1969). In other studies, the motivation has been largely to gain insight into the ecology and ethology of reef fishes (Randall, 1963; Luckhurst, 1972).

Present-day coral reefs are not only highly productive in themselves, but frequently act as a rampart or barrier, protecting coastal lagoons and bays which in turn may be highly productive (Odum, 1957). The submarine vegetation in these embayments (usually *Thalassia,* in the Caribbean) is typically under-utilized by herbivorous fishes and invertebrates due to lack of refugia from predators. Where small patch reefs occur in lagoons, they are commonly surrounded by "halos" of bare sand from which the vegetation has been completely grazed. These halos have been attributed to grazing by fishes (Randall, 1963, 1965; Luckhurst, 1972) and by sea urchins (Ogden *et al.*, 1973). The scarcity of hiding-places in lagoons is probably a result of the relative inability of corals to attach and grow on soft substrates in murky water (for a review of factors affecting corals, see Endean, 1976).

As one of the many unpleasant things which the future has in store for us is undoubtedly increasing shortages of high-protein food in Third World countries, many of which are located in or on tropical oceans, it would be valuable to investigate the possibility of utilizing more fully the vegetation in shallow coastal areas. Artificial reefs which attract fish populations may be a means of essentially converting the high-carbohydrate plant material into high-protein fish. The total productivity of the system would, of course, not be changed, but less carbon would be incorporated into the sediments.

The topography of reefs (both natural and artificial) dictates that modern high-yield fishing methods cannot be used; the common Antillean fish pot "is still the most effective way to catch bottom fish around the Caribbean" (Brownell, 1972, p. 29). Several designs

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of trap exist, of which the Jamaican "Z-trap" seems to be the most effective (Crossland, 1976). Trapping by individual local fishermen would seem, therefore, to be a reasonably efficient way of "harvesting" artificial reefs.

As a necessary preliminary, the morphology of various types of artificial reefs should be investigated, as should the relative cost (both in money and in labour) of building different types. This paper is a preliminary report on three such reefs, constructed in Discovery Bay, Jamaica, W.I.

Methods

(a) Reef construction

The artificial reefs had to fulfil two criteria: the construction materials had to be locally abundant and relatively cheap, and the finished reefs had to present a wide variety of available interstices and crevices. Therefore, the reefs were constructed out of various combinations of beach boulders and cinder blocks.

Three reefs were constructed on December 10, 11 and 12, 1973, on the east side of Discovery Bay, Jamaica (Fig. 1), equidistant from each other, in 4.3 m of water. The precise location is 100 m directly offshore from a concrete retaining wall and dock painted pink, and is marked with a small white buoy. (The author's last visit to the area was in early 1975, so both landmarks may have changed or disappeared.) The reefs are readily visible from the surface, and are located in a large *Thalassia* bed. A description of each of the three reefs follows (from south to north):

Reef One (Organized Reef) was constructed solely of concrete blocks, placed in such a way as to maximize the amount of holes and spaces available (Plates 1 and 2). Approximately 35 blocks were used in construction. The finished reef was rectangular, long dimension parallel to the shoreline, and 2.8 m long, 1.0 m wide, and 0. 7 m high.

Reef Two (Rock Reef) was constructed of subrounded boulders of Pleistocene beachrock, average diameter approximately 25 cm, placed so as to maximize the porosity. The finished reef was elongate parallel to the shoreline, 2.2 m long, 0.9 m wide, and 0.7 m high (Plate 3).

Reef Three (Veneered Reef) combined both construction materials: there was a core of beach rock, over which was placed a layer or veneer of about 15 concrete blocks. The finished reef was elongate parallel to the shoreline, 2.5 m long, 1.8 m wide, and 1.0 m high (Plate 4).

Cost of concrete blocks was $20 Canadian (1973), and total time for construction of all three reefs was two man-days' shore time (loading and transporting materials), and 6-8 man-hours' underwater labour. All rocks and blocks were placed by hand, underwater; the original research plan called for construction of a fourth reef by simply throwing beachrock overboard, but a family emergency forced the author to return to Canada before this could be accomplished.

(b) Reef monitoring

Return visits to the reefs were in late June, 1974, and late February, 1975 (or at 6- and 14-month intervals). Fishes were identified and counted on both occasions. On each visit, several censuses were taken of each reef on successive days, sometimes with two operators. Estimates of the length of the more abundant fishes were made by comparison with the length of the concrete blocks (20 cm). Fish were identified with the aid of Randall (1968), and the boring sponges were identified using Pang (1973) and Rützler (1974). Major invertebrates in and around the reefs were also identified, in some cases to major group only.

Data were supplemented with observations made by biologists working at the Discovery Bay Marine Laboratory.

Results and Observations

A summary of the fish census data is given in Table 1.

The day after construction, Reef One had attracted two fish: a small Dusky Damselfish (*Eupomacentrus fuscus*) and a Spotted Moray (*Gymnothorax moringa*). Within a few weeks, all three reefs had attracted fish, and had grown a covering of algae (Paul Sammarco, personal communication).

Two spiny lobsters were seen on Reef Three in June, 1974.

After 14 months, the reefs had attracted a wide variety of organisms other than fish, including calcareous and fleshy algae, sponges, hydroids, anemones, sabellid polychaetes, hammer oysters, arrow crabs, *Stenopus*, tunicates and urchins (*Diadema antillarum, Eucidaris tribuloides, Tripneustes ventricosa* and *Lytechinus variegatus*). In addition, the concrete blocks of Reefs One and Three supported small colonies of the corals *Porites astreoides* and *Dichocoenia stokesii*, and colonies of *Millepora alcicornis* up to 20 cm high. Coral colonies occurred on the beachrock, but much less frequently.

Both the concrete blocks and the beachrock were infested with boring algae and boring sponges (*Siphonodictyon coralliphagum, Cliona lampa, Cliona laticavola*). Infestation was highest in the beach rock; amount of material removed from the exposed outer part of some rocks was estimated to be about 8%. Some samples of beach rock contained fossil (Pleistocene) *Montastrea annularis*. Sponges boring into these fossil corals exhibit the same boring pattern as does *Cliona vermifera* in living *Montastrea annularis*: the sponge colony advances up the vacated corallite, cutting back the septa to the septathecal wall (Ward and Risk, in press). Boring pattern is evidently a response to substrate hardness.

TABLE 1. SPECIES COMPOSITION AND ABUNDANCE OF FISHES FOUND ON ARTIFICIAL REEFS IN DISCOVERY BAY.

	JUNE 1974			FEBRUARY 1975		
	Reef 1	Reef 2	Reef 3	Reef 1	Reef 2	Reef 3
Grunts (mostly *Haemulon sciurus;* some *H. flavolineatum*)	9	73	155	58	175	256
Squirrelfish (mostly *Holocentrus rutus*)	2	7	6	5	5	8
Apogon binotatus			4		4	5
Hypoplectrus puella	1	1	1	1	1	1
Amblycirrhitus pinos		1				
Priacanthus cruentatus		1	1			
Petrometopon cruentatum	3					
Pseudupeneus maculatus	2	1		1	1	1
Eupomacentrus fuscus			1	1		1
Halichoeres bivittatus		2	3	2	4	5
Halichoeres maculipinna	1				1	1
Hemipteronotus martinicensis			1			
Sparisoma rubripinne	4	2	3		2	4
Scarus croicensis	3	1	2	4	2	3
Acanthurus chirurgus	2	2	2	1	2	2
Acanthurus coeruleus				4		2
Bothus lunatus		1				
Synodus sp.			1			
Chaetodon capistratus				1	1	
Total no. species	9	11	12	10	11	13
Total no. individuals	27	92	180	78	197	290
Estimated average length of grunts (*Haemulon* sp.), cm:	12	8	4	11	8	7
Estimated average length of squirrelfish (*Holocentrus* sp.), cm:	11	9	9	12	9	10

(Fish numbers are averages of at least three separate estimates; fish lengths are averages of several hundred underwater length estimates, checked with photographs.)

Although no grazing halo was developed around any of the reefs, comparison of 6-month and 14-month bottom photographs suggests a decrease in length and density of *Thalassia* blades in the immediate vicinity of the reefs. Grazing marks were common on the concrete blocks, but not on the beachrock.

Trapping by local fishermen around the reefs began after about six months.

Discussion

Most of the fishes on the reefs were carnivores or microcarnivores, an observation made previously by Randall (1963) and Luckhurst (1972). It is likely that the reefs were exploited more for shelter from larger predators than for the fact that there is some *in situ* food production.

Reef Three (beachrock core, block veneer) supported the highest density and the largest number of species of the three reefs at both 6-month and 14-month visits. The average size of the dominant species of fish was greater on Reef One (concrete blocks), however; Reef Two (beachrock) was intermediate in all respects. Reef One had fewer nocturnal fishes, perhaps due to its open construction, and also supported more large carnivores.

The relationships among reef size, crevice size and shape, fish density and fish diversity remain obscure, due largely to the limited scope of the experiment and the short observation span. It is likely, however, that most of the fish attracted to the reefs are those which are nocturnal transients over the sand and grass flats of tropical lagoons. These fish would readily take refuge in the large cavities in the concrete blocks. The open construction of Reef One may account for the lower density of smaller fish (lack of small holes) and the larger average size. The relationship between fish populations and reef morphology has been emphasized by several authors (Bardach, 1959; Hiatt and Strasburg, 1960; Randall, 1963; Risk, 1972).

Longevity of artificial reefs also remains unknown. Rates of infestation by boring organisms seem comparable to rates observed in live corals. Undermining by *Callianassa* was also observed to cause some foundering. Bioerosion and bioturbation, therefore, would seem to set an upper limit on the age of the reefs. On the other hand, settlement and growth of corals on the reefs could prolong their life as shelters. Coral growth on artificial reefs is rarely observed (Luckhurst, 1972). Growth of corals on the reefs under discussion may be a result of relatively clear lagoon waters and a high resident diversity and density of corals (Goreau and Wells, 1967).

Artificial reefs may be constructed relatively quickly and inexpensively. Results of this study suggest only that the construction of an artifical reef affects the fishes attracted to it. Further monitoring of the reefs in Discovery Bay is necessary. It would also be important to undertake a major experiment, based on these preliminary results, using larger reefs in sets of replicates, in order to determine the degree in which fish size and species may be influenced by the type of reef construction.

The author regrets that financial restrictions terminated his site visits. Persons visiting Discovery Bay are invited to observe the reefs, as this is the only way in which further information may be obtained.

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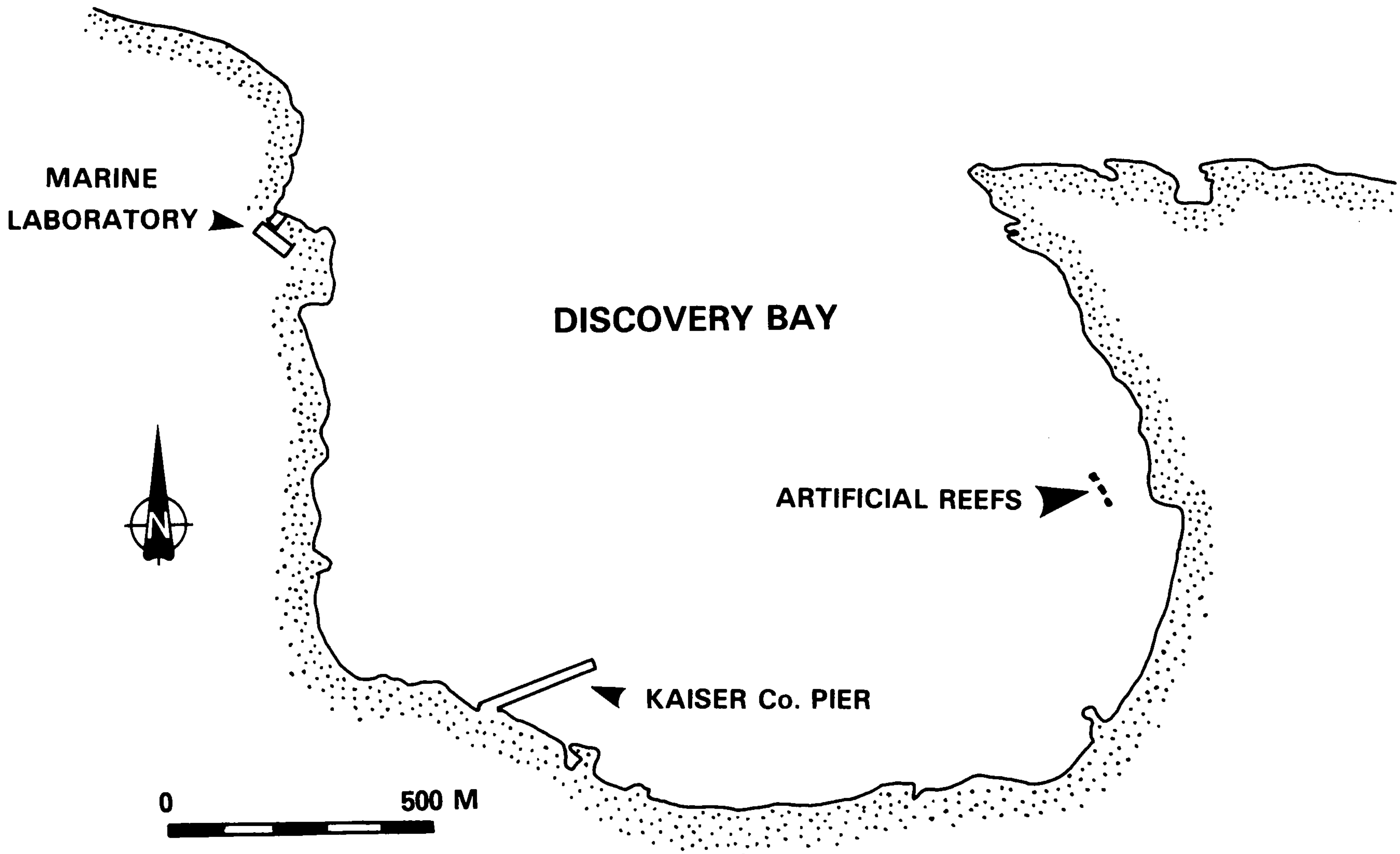

Fig. 1: Map of Discovery Bay, Jamaica, showing the location of the three artificial reefs.

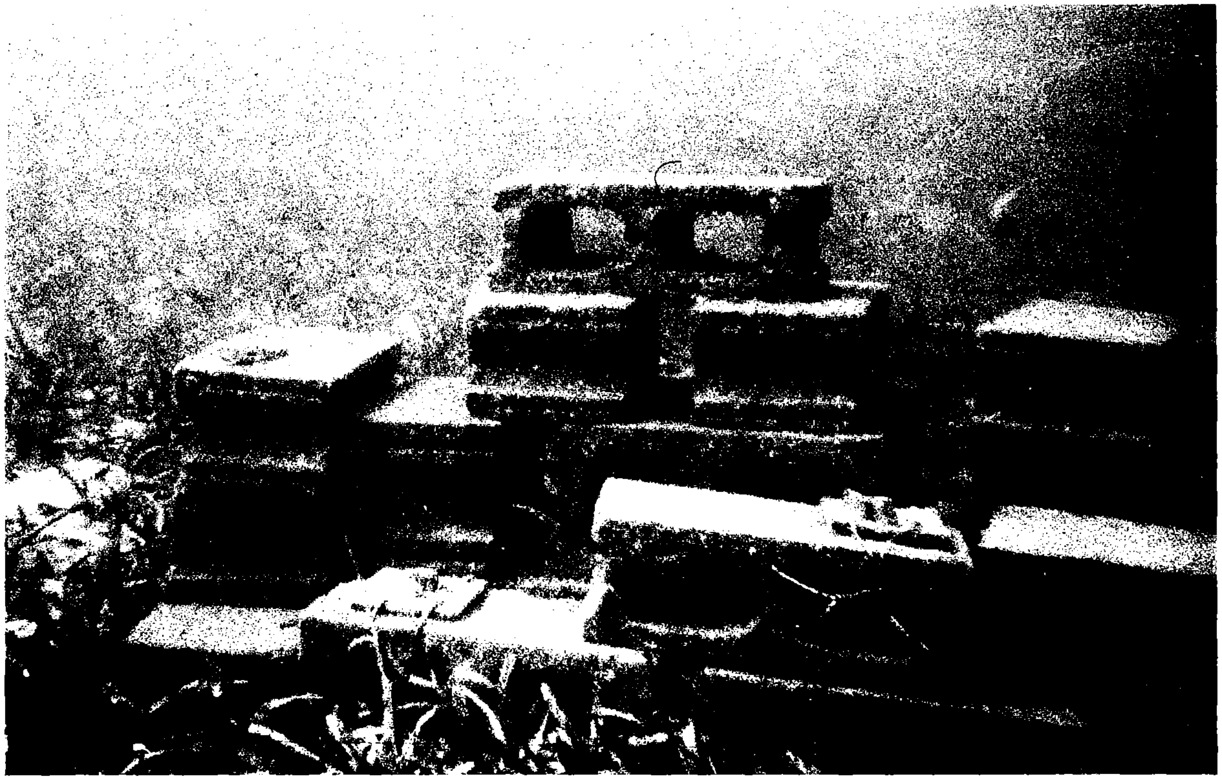

Plate 1: Reef One in June, 1974.

late 2: Reef One in February, 1975; note increase
in encrusting organisms.

Plate 3: Reef Two in June, 1974.

Plate 4: Reef Three in June, 1974.

DISTRIBUTION OF THE DECAPODS BRACHYURA AND ANOMURA (EXCLUDING PAGURIDEA) OF THE CRYPTOFAUNA IN THE REEFS NEAR TULEAR

By Mireille Peyrot-Clausade[1]

This study of the distribution of the Decapods Brachyura and Anomura (excluding Paguridea) is a part of a broader work about the whole cryptofauna of the reef flats of Tuléar. The Great Reef of Tuléar, two zones of which were studied in detail, is the principal field of my investigations. Some samples were also extracted from the reefs of Sarodrano, Nosy Tafara, and Songoritelo (map 1).

Cryptofauna consists in all the small fauna of mobile invertebrates which shelter in the little holes on the organic tracts of the reef flats; these holes are 0.5mm to 5 centimeters in diameter. The cryptofauna was extracted from the blocks of hard hollowed-out substrate, the volume of which is $1 dm^3$. This volume of $1 dm^3$ has been defined as the minimum in which it is possible to obtain almost all the species present in the biota studied (Clausade, 1970). For every station studied, 5 samples of $1 dm^3$ have been extracted.

Altogether 34 stations, which represent $170 dm^3$ of hollowed-out substrate containing cavities, subsequently broken into pieces, yielded 84 species of Brachyura and Anomura. The determination of these species has been confirmed by Mr. Serène. Those which appeared particularly interesting from a systematic point of view formed the subject of a separate paper (Peyrot-Clausade and Serène 1976).

The areas studied on the Great Reef are shown in map 1. In the northern area (here called Sector 1), 9 stations have been studied. Fig. 1 shows their localities (for clarification of terminology, refer to *Téthys* suppl. 2, 1972). In the area situated in the center of the Great Reef (Sector 2) at the place named Antseteky, 12 stations have been studied (fig. 2): 4 in the outer reef flat, 3 in the boulder tract and 5 in the inner reef flat. Samples have been studied on the other reef flats where some formations have appeared new in relation to those of the Great Reef.

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The reef flat of Sarodrano is subjected to the alluvial deposits of the river Onilahy, rich in clay particles in suspension. Moreover, it is situated in an unstable zone and is tilting more and more towards the open sea (J. Picard, personal information). The different formations present on this reef, in order to stay at the degree of dampness which is suitable to them, counterbalance this tilting by an upper growth or elevation. Thus, the little Vermetus *Dendropoma* sp., which form only simple veneerings at the base of the blocks of the boulder tract of the Great Reef, forms at Sarodrano thick pads rich in cavities, on the upper part of the blocks. For this reason, I have studied two kinds of samples in this zone: the first among the blocks of the boulder tract, the second among the *Dendropoma* sp. formations. At the back of the reef flat, micro-atolls are present. Five samples have been taken at the base of these formations which are widely covered with Algae and rich in sandy particles.

The reef of Songoritelo results from the junction of two initial shields (J. Picard, personal communication). The boulder tract, present on the old shields, is absent from this junction zone. This zone is used as an out-fall through which the water of the channel situated between the reef and the Mangrove flows out at ebb-tide. This sea water, rich in sandy earthy particles coming from the river Fiherenana, promotes colonization and growth of the Sabellariids *Idanthyrsus pennatus*. Between this area of *Idanthyrsus* and the boulder tract are found layered Melobesiae formations. They are calcareous Algae, more or less intermingled, and creating interstices partially filled up by sand. It is in this zone that the boulder tract later forms, when the reef has reached a certain degree of evolution. Seven sations have been studied at Songoritelo: two on the outer reef flat (one on the spur upper platform, one on the outer moat rich in Algae) and two others around the outer creeks (on the edge and towards the back among madreporarian coral colonies covered by Zoantharian colonies). The last third are distributed in the following manner: one in the boulder tract,one in the *Idanthyrsus* formations and the last one in the layered Melobesiae.

Nosy Tafara can be distinguished from other reefs by its boulder tract which is a boulder-rampart.

At each station, the abundance and average dominance of the species present have been determined and is shown in table 1.* From this table, I have constructed tables 2, 3, 4 in which is recorded the dominance of the different Brachyura and Anomura families, for each station.

Figs. 3 and 4 show in the two sectors of the Great Reef, the evolution of the settlements from the spur upper platform to the blocks of sea grass bed basins. The population of each station is represented by a circle in which each family is represented by an arc in a direct ratio to its average dominance.

*Table 1 not reproduced here, available from author.

POPULATION OF THE OUTER REEF FLATS

For this study, I deal with 60 samples from 12 stations: 8 from the outer reef flats: 2 from Sector 1, 4 from Sector 2, and 2 from Songoritelo (fig. 5). The last 4 come from the flat around the outer creeks of Sector 1 and Songoritelo. For all the outer stations, the total populations vary from 209 for the settlement of the station of the glacis in Sector 1 to 47 in the station on the edge of the outer creek in this same Sector. The average population is 17.8 individuals for $1dm^3$ of hollowed-out substrate; the number of species varies considerably: 4 in the station of the spur upper platform in Sector 2, and 24 for the one in the glacis of Sector 1.

The Sector 2 shows an increase in the diversity of species of Brachyura as we move away from the front of the reef. The number of species varies from 4 to 19. Indeed, in station 12, 97% of the settlement belong to the single sub-family of Chlorodinae and are *Liocarpilodes integerrimus* (Dana 1852) 71%, *Pilodius paumotensis* (Stimpson 1858) 18%, and *Chlorodiella laevissima* (Dana 1852) 8%. *Daira perlata* constitutes the remaining 3%.

In the next station (no. 13), ten species have been collected. The Xanthidae family still represents 85%, the dominant species are *Chlorodiella laevissima* and *Pilodius paumotensis*. *Liocarpilodes integerrimus* is absent but I find *Liomera rugata* (H. Milne Edwards 1834) and *Zozymus aeneus* (Linné 1758) that will be found again in the next two stations. This is true also, for the two species of Anomura *Pisidia delagoae* (Barnard 1955) and *Pachycheles penicillatus* (Heller 1862).

Station 14, established on the outer moat, contains 13 species but they are not abundant. Indeed, in the $5dm^3$, I number only 58 individuals. Among Xanthidae, *Liocarpilodes integerrimus* and *Pilodius paumotensis* are not very abundant. The dominant species is still *Chlorodiella laevissima*, and near the species already mentioned, I collected *Pilumnus purpureus* (A. Milne Edwards 1873), the dominance of which will increase twofold in the next station as will the Pilumninae ind. The Porcellanids are also enriched by a new species: *Petrolisthes lamarckii* (Leach 1820). I note for the first time the presence of Portunidae with *Thalamita* at a juvenile stage.

Station 15 is on the outer reef flat just in front of the boulder tract, in an area of layered Melobesiae; 19 species or 101 individuals were collected. Porcellanidae (with essentially *Petrolisthes lamarckii*) have an increasing dominance at the expense of Xanthidae. In this last family the two more abundant species are *Chlorodiella laevissima* and *Actaeodes tomentosus* (H. Milne Edwards 1839). I note an increase of *Liomera rugata* and a complete disappearance of *Liocarpilodes integerrimus* and *Pilodius paumotensis*. Portunidae are represented by *Thalamita gloriensis* (Crosnier 1962) and Grapsidae by some individuals of *Pachygrapsus minutus* (A. Milne Edwards 1873).

If I compare the population of the stations of the outer reef flat of Antseteky (Sector 2) with that of the station of the outer reef flat of Sector 1, I see a real similitude of settlement between the station 14-15 and the stations 1-2. Thus, in station 11 on the spur upper platform, I found 133 individuals belonging to 17 species. In station 2, on the reef glacis rich in Algae *Turbinaria,* there are 24 species and 209 individuals. Twelve species are common to these two stations but their dominances vary. *Liocarpilodes integerrimus* (16%) and *Pilodius paumotensis* (18%) are dominant in station 1, whereas *Pilumnus purpureus* (23%) is more abundant in the 2nd station. In this last station, I find also *Liomera rugata* and *Actaeodes tomentosus*. Three species are collected solely on the outer reef flat of Sector 11. They are: *Actumnus elegans* (de Mann 1888), *Domecia glabra* (Alcock 1899) and *Pachycheles garciaensis* (Ward 1942).

The settlement of the outer reef flat of Songoritelo appears quite different from those previously studied. Indeed, the diversity is more important in the station of the spur upper platform than in that realized on the outer moat. Contrary to previous recordings, the abundance and average dominance of *Liocarpilodes integerrimus* also increase in the inner station. *Chlorodiella cytherea* (Dana 1852) and *C. laevissima* are abundant, but *Pilodius paumotensis* and *Pilumnus purpureus* are completely absent.

The station around the outer creeks have settlements which resemble more closely those of the outer reef flat stations. Indeed, at Songoritelo, Xanthidae represent in the two stations more than 96% of the individuals collected. Chlorodinae are the most abundant with essentially the three following species: *Liocarpilodes integerrimus*, *Chlorodiella cytherea* and *C. laevissima*. In sector 1, Xanthidae constitute only 70-78% of the settlement of these stations around the creeks. The outer station contains: Dromiacea, Oxyrhyncha, Grapsidae and Porcellanidae, the inner one has no Grapsidae nor Dromiacea but 8% of Portunidae.

All the settlements of the outer reef flat show a certain homogeneity, despite some variations. Among Xanthidae, Chlorodinae dominates with three species more particularly abundant: *Liocarpilodes integerrimus*, *Pilodius paumotensis* and *Chlorodiella laevissima*. Fig. 6 shows the dominance of these species in the different stations of the outer reef flats. Although the extension of *Chlorodiella laevissima* is not limited to the outer reef flats, the dominance increase from the outer station to the inner one and is non-existant in the boulder tracts. At Antseteky, after a peak of dominance in the dead madreporian colonies, it is clear that this species diminishes in importance up to the boulder tract. The dominance of *Pilodius paumotensis* diminishes regularly as we move from the front to the back of these outer reef flats.

Liocarpilodes integerrimus, is, of these three, the most abundant species. It is seen on fig. 6 that in all the biota studied, its abundance and its dominance decrease towards the back of the outer flat, except on the reef of Songoritelo. On this reef, the dominance of *Liocarpilodes integerrimus* is lower on the outer station that in the inner one (although its value is similar to that recorded on the other outer stations); but on the inner station (situated on the outer moat) the value of dominance is greater than on homologous stations (about twice as great as that on homologous stations). An explanation of this abundance can be found in the fact that, the front of this reef being in a phase of very fast growth, the outer moat is not very old. This outer moat is very rich in burrowing organisms (small sipunculids). The size of the network and of cavities is very well suited to the *Liocarpilodes integerrimus* which are very small individuals. This area is between two phases of colonisation: the first colonisation characterizes zones exposed to the beating of the waves (at present in the outer station, on the spur upper platform) and the second characterizes a well degraded substrate (found in Sector 1 of the Great Reef of Tuléar, in the zone rich in Algae Turbinaria). Among the "no carpilodea", *Liomera rugata* seems also to characterize quite well the settlement of the outer reef flats. This species is absent from the biota the most exposed to the beating of the waves. *Zozymus aeneus* (Zozymoidea) is never abundant, but is present in almost all the stations studied. *Pilumnus purpureus* and *Actumnus elegans* are also linked to this zone of the reef. They are still more abundant in the calmer biota. Among the Anomura, I find essentially Porcellanidae with *Pachycheles natalensis* (Krauss 1843), *Petrolisthes lamarkii, P. penicillatus, Pachycheles garciaensis* and *P. pisoides* (Heller 1865). The last third are solely recorded on the outer reef flats.

A problem is posed by the Oxyrhyncha. Some of them are known to live in the thallus of Algae but *Acanthonyx quadridentatus* (Krauss 1843) alone is limited to the biota very rich in Algae, thus species is not included in the cryptofauna.

POPULATION OF THE BOULDER TRACTS AND OF THEIR BIOTA SUBSTITUTES

As has been seen in the first part of this paper, the structure of the boulder tracts varies on the reef flats; the various stations were established according to these variations in structure. So, in Sector 1, samples were collected on the crags. In Sector 2, over and above the station identical to that of Sector 1, two others have been established: one in the gravel tail and the other in the filtering dike. On the reef of Songoritelo, I have three stations: one on the crags, one on the *Idanthyrsus* formations and the last in the layered Melobesiae. On the Sarodrano reef flat, I studied the settlement of the crags and of the little Vermetus *Dendropoma* sp. formations. At Nosy Tafara, one station is in the gravel sheet at the back of the boulder rampart.

All these stations in the boulder tracts are qualitatively poor. From 4 to 13 species are found. The two stations on the crags of the Great Reef have very similar settlement. Grapsidae are dominant (56 and 44%) with only two species: *Pachygrapsus minutus* (A. Milne Edwards 1873) and *Nanosesarma minutum* (De Mann 1887). Among Xanthidae, I find *Zozymodes xanthoides* (Krauss 1843) *Actaeodes tomentosus, Eriphia scabricula* (Dana 1852) and *Pilumnopeus trispinosus* (Sakai 1965). This last species represents from 16 to 18% of the settlement.

Porcellanidae, with only one species — *Petrolisthes lamarckii* — constitute 5 to 9% of the individuals present. The station on the filtering dike differs from those of the crags by a considerable decrease in Grapsidae and increase in Xanthidae (*Pilumnopeus trispinosus* 32% and *Actaeodes tomentosus* 24, 5%) and in Porcellanidae (*Petrolisthes lamarckii* 17%). On the gravel tail, 71% of the settlement is constituted by Porcellanidae (still *Petrolisthes lamarckii*). *Pachygrapsus minutus* constitutes only 1% of the individuals collected on this station. *Chlorodiella cytherea* is, of Xanthidae, the most abundant species (15%). If I compare this settlement to that of the gravel sheet of Nosy Tafara, I see that they are quite identical. On this station, *Petrolisthes lamarckii* represents 67% of the population, *Chlorodiella cytherea* 22%, *Pachygrapsus minutus* 6% and *Pilumnopeus trispinosus* 4%.

On the reef of Songoritelo, the crags have settlements similar to those of the crags of the Great Reef, yet with a greater diversity of species. Some species come from settlement of the outer flat (*Pilodius paumotensis, Liomera rugata, Liocarpilodes integerrimus*) and some species come from the inner reef flat such as *Pilodius spinipes* (Heller 1861). None of them have a high dominance. In these crags, Grapsidae are represented only by *Pachygrapsus minutus* 27%. *Nanosesarma minutum* (de Mann 1887) is absent. It has been senn supra that at Songoritelo, in absence of the boulder tract, we find *Idanthyrsus* formations and layered Melobesiae. These formations have very different populations. In the cavities between the tubes of the *Idanthyrsus pennatus,* Grapsidae are very abundant and constitutes 49% of the individuals collected. Porcellanidae are less abundant: *Petrolisthes lamarckii* does not reach 5,5% of settlement.

The population of layered Melobesiae differs by the very feeble proportion of Grapsidae (1,4%), the presence of Portunidae (14%) and of Ocypodidae-*Macrophtalmus boscii* Audouin(et Savigny) 1825 7%. Xanthidae family is the most important (68% of the individuals) with essentially three species: *Chlorodiella cytherea, Actaeodes tomentosus* and *Pilodius areolatus* (H. Milne Edwards 1834).

The last two series of samples are those of the boulder tract of Sarodrano, among the crags and the formations of little *Dendropoma* sp. In these two stations, the most abundant species is *Pilumnopeus trispinosus* which constitutes 54% of the settlement of the first and 87% of the second. The crags of the boulder tract are characterized by the absence of *Pachygrapsus minutus* and by the quite important number of *Macrophtalmus boscii.*

Among the boulder tracts, four species have an important part in the settlement. They are: *Pachygrapsus minutus, Nanosesarma minutum, Pilumnopeus trispinosus* and *Petrolisthes lamarckii.* In examining the first three species, I note that *Pachygrapsus minutus* is a very mobile species whereas *Nanosesarma minutum* and *Pilumnopeus trispinosus* are more or less non-mobile. The study of table 1 shows that *Nanosesarma minutum* is present only on the Great Reef and more abundant in the biota in the highest part of the mid coast-level. Its abundance decreases in the filtering dike which is lower. In the same three stations, *Pilumnopeus trispinosus* has an opposite behaviour and is more abundant in the filtering dike. When this species reaches its maximum of dominance in the stations of the reef of Sarodrano, I see the diminution and absence of *Pachygrapsus minutus*. I think that this absence can be explained by the salinity of the sea-water around Sarodrano reef being often very feeble, owing to the river Onilahy. On the hard substrate on the coast Plante (1964) did not find this *Pachygrapsus* where it would normally be collected, and it is also absent from the hard substrate of the mangrove. In the absence of *Pachygrapsus minutus*, *Pilumnopeus trispinosus*, which is no doubt more resistant to the variations of salinity, inhabit all the little cavities. Porcellanidae — *Petrolisthes lamarckii* — have an abundance and dominance which increase as we move from the crags to the gravel sheet or tail of the boulder tracts, this species goes deep into the chips of dead Madreporian as the sea-water level gets lower, and so protects itself from drying up at low tide. Apart from *Pilumnopeus* already cited, I find also *Actaeodes tomentosus* in all the stations. *Zozymodes xanthoides* is only collected on the crags.

POPULATION OF THE INNER REEF FLATS

It has been possible to study these settlements by means of the eleven stations (five in every Sector of the Great Reef) and one in the zone of micro-atolls of the reef of Sarodrano. The average number of individuals collected in $1 dm^3$ of hollowed-out substrate is about 16. However, if I suppress the two series of samples from the branched Melobesiae which constitute a special biota by the abundance of very little cavities between the thallus of these calcareous Algae, there are only 10 individuals per dm^3 in the other biota. The number of species is situated between 6 and 19 and reaches 23 in the branched Melobesiae. All the families found on the outer reef flats and on the boulder tracts are represented in this part of the reef flats, but it seems that Xanthidae are more abundant. Anomura, particularly Galatheidae, play in some biota a very important in the inner reef flats and particularly with the species *Macrophtalmus boscii*, in the compact reef flat in the two sectors studied. This species is also found abundantly in the blocks of the sea-grass bed basins of Sector 2. Among Xanthidae, the two most important sub-families are Actaeinae and Chlorodinae. In the first sub-family, *Actaeodes tomentosus* in the dominant species. It has its maximum abundance in the branched Melobesiae, but they are chiefly individuals at a juvenile stage. *Actaea cavipes* (Dana 1852) is also frequent but not very abundant in Sector 2. In Chlorodinae sub-family, *Chlorodiella cytherea*, *C. laevissima* and *C. barbata* and *Pilodius spinipes* are the most abundant. The last two species are only recorded on the inner reef flats and have their maximum average dominance among the branched Melobesiae. The "no carpilodea" are also represented by some species gathered only in the inner reef flats. They are: *Liomera bella* (Dana 1852), *L. cinctimana* (White 1857), *L. semigranosa* (de Mann 1888) and *L. monticulosa* (H. Milne Edwards 1873). Among Anomura, one can notice a gradual replacement of Porcellanidae by Galatheidae, as we move off the boulder tracts towards the sea-grass bed basins. The most abundant Porcellanids are: *Pisidia delagoae*(Barnard 1955) which reach their maximum in the branched Melobesiae. Galatheidae are represented by several species. The most frequent is *Galathea humilis*(Nobili 1905) which is present in 7 of the eleven stations studied, the maximum dominance is recorded in the micro-atolls of Sarodrano. *Galathea affinis*(Ortmann 1892)is the species dominating in the biota of the blocks in the sea-grass bed basins of Sector 1. *Galathea platycheles* (Miyake 1933), like many other species, reaches its maximum dominance in the branched Melobesiae.

This study of the population on the different reef flats allow us to make certain inferences about the distribution of the families even of some species of brachyura and Anomura. The Dromiacea are represented by only one species in these samples; it is *Dynomene hispida*(Desmarest 1825) exclusively found on the outer reef flats. It is also on the outer reef flats that the majority of Oxyrhyncha are recorded: *Menaethiops natalensis*(Barnard 1955),*Hyastenus aff. elongatus*(Ortmann 1893),*Daira perlata, Elamena matthei* (Desmarest 1825) and more particularly among the places rich in Algae. Among Portunidae, *Thalamita gloriensis* is the only species determined. The three biota in which it is the most abundant are, in an increasing order: the layered Melobesiae of the outer reef flats of Sector 2, the madreporian colonies on the edge of the outer creeks of Sector 1 and layered Melobesiae of the reef of Songoritelo where it represents 13.7% of the settlement. In almost all the stations, juvenile forms of *Thalamita* have been collected, and above all on the spur upper platform of the outer reef flat of Songoritelo. Xanthidae family is the most important qualitatively and quantitatively of all the families of Brachyura in these cavities.

(a) no Carpiloidea

Liomera rugata seems to be particularly well adapted to the outer reef flats just behind the spur upper platform, the other species of *Liomera* — *L. bella, L. monticulosa, L. semigranosa, L. cinctimana,* all came from the inner reef flats and more especially from the branched Melobesiae.

(b) Zozymoidea

Five species belong to this group: *Zozymus aeneus, Zozymoides xanthoides, Atergatis aff. subdentatus*(de Mann 1835), *Platypodia cristata* (A. Milne Edwards 1865) and *Platypodia anaglypta* (Heller 1861). The first species of this list, which is found above all in the outer reef flat biota, like *Zozymoides xanthoides* settled only on the boulder tracts, are the most abundant.

(c) Xanthoidea

The five species of this group are never abundant. The best represented is *Leptodius nudipes* (Dana 1851) which come from the gravel tail of the boulder tract of Sector 2.

(d) Galenoidea

Actaeinae and Chlorodinae are the most frequent and abundant.

(1) Actaeinae includes 9 species: *Actaea quadriareolata* which come from the boulder tract is not abundant. Excluding *Actaea consobrina* and *aff. Pseudoliomera varialosa* (Borradaile 1902), which are only samples on the outer reef flats, the other species are collected in the different biota. The most abundant is *Actaeodes tomentosus* which is found at all the stages of growth from a few mm to several centimeters, in all the stations, the branched Melobesiae having in their cavities an important concentration of juvenile forms.

(2) Chlorodinae are, with 12 species, the richest group. It has been seen that *Liocarpilodes integerrimus* and *Pilodius paumotensis* are quite localized exclusively on the outer reef flats. On the other hand *Liocarpilodes armiger* has been collected only in the inner reef flats. The most abundantly represented genus in all the reef flat formations, except on the boulder tracts, is the genus *Chlorodiella* with three species. *Chlorodiella laevissima* although present in all the stations, dominates especially on the outer reef flats where it can represent up to 56% of the settlement (such as in the Zoantharian zone of Songoritelo creek) *Chlorodiella cytherea* is the one of these three species which resist best to drying-up, for it is the one collected in the gravel tail and sheet. *Chlorodiella barbata,* never sampled on the outer reef flats, is abundant on the inner reef flats and particularly among the branched Melobesiae. In the Chlorodinae, the genus *Pilodius* is also well represented. With *Pilodius paumotensis* collected in the outer reef flats, Pilodius areolatus present in the inner reef flats and reaching its maximum abundance in the *Idanthyrsus* formations and the layered Melobesiae, there is also *Pilodius spinipes* which plays an important role in the settlements of the biota of the inner reef flats and more especially in the blocks in the sea-grass-bed basins and reef flat with scattered coral growth. *Pilodius pugil* Dana 1852 is nowhere abundant. Among the *Phymodius,* only one species — *Phymodius ungulatus* (H. Milne Edwards 1834) is quite well represented in the inner reef flats. *Paretisus globulus* (Ward 1933), not abundant, is collected in 4 different biota.

(e) Cymoidea

Eriphia scabricula seems to characterize the settlement of the boulder tracts.

(f) In the Hyperomista, only the Pilumnidae are abundant.

Domecia glabra (Alcock 1899), on the spur upper platform is the only Mennipinae collected. Among the Piluminae, only two species have been determined: *Pilumnus purpureus* and *Actumnus elegans*. Both occupy only the cavities in the outer reef flats. The extension of *Actumnus elegans* is however limited to Sector 1. *Pilumnopeus trispinosus* is among the Heteropanopeidea, the most abundant species. If some rare individuals are on the outer reef flats, it reaches very high dominance on the boulder tracts particularly in the reef of Sarodrano on the Vermetus *Dendropoma* sp. where there are 18 individuals per dm^3. *Lybia leptochelis* (Zehntner 1894) is essentially present in the inner reef flats, but always in very feeble number.

Ocypodidae family is represented by one species – *Macrophtalmus boscii* – which is particularly abundant in the inner reef flats, in calm biota where colloidal suspension can form a deposit in which this species makes its hole. This *Macrophtalmus* is also recorded in the boulder tract of Sarodrano, where as we have seen the water of the river Onilahy covers the reef.

Grapsidae. *Pachygrapsus minutus* is the most abundant of this family. It occupies all levels of the mid-coast level and takes shelter in the highest part of the reef constituted by the boulder tracts. As it is a very mobile species, at low tide, it moves away and so can be collected in the biota surrounding the boulder tracts. In the absence of boulder tracts at Songoritelo the highest biota is the *Idanthyrsus* formations where the *Pachygrapsus* are abundant. The samples realized at Sarodrano show that this species does not like fresh water, but reappears when the degree of salinity increases (as at Nosy Tafara). *Nanosesarma minutum* lives at the high part of the mid coast-level and is collected only on the Great Reef.

Anomura

Two families are abundant in the cryptofauna: Galatheidae and Porcellanidae.

(a) Porcellanidae family, is, with 11 species, the most important. A succession of species is clearly found moving from the front to the back of reef flats. *Petrolisthes penicillatus* is strictly localized on the outer reef flats, as are *Pachycheles garciaensis*, *P. pisoides* and *P. natalensis*. *Petrolisthes lamarckii*, which is found also on the outer reef flats, reaches its maximum dominance in the boulder tracts and particularly in the gravel tail and sheet where it constitutes 67% of the settlement. *Pisidia delagoae* is recorded on all the reef formations and more abundantly in the inner reef flats. It is also in that zone that *Polyonix triungulatus* (Zehntner 1894) and *P. aff. maccullochi* (Haig 1965) are found.

(b) Galatheidae. Six species are collected essentially in the inner reef flats, and their dominance increases as we move from the boulder tracts to the sea grass bed basins. The most two abundant species are *Galathea humilis* and *G. affinis*. The 1st is frequent on the whole of the Great Reef, and very abundant in the micro-atolls of Sarodrano; the 2nd dominates the settlement of the blocks in the sea grass bed basins in Sector 1 representing more than half of the local cryptofauna.

From this study, some settlement appear quite typical of certain reef zones. Thus, for a stabilized reef, it is possible to define an outer reef settlement which increases in diversity as we move away from the breaking waves. In the outer stations, *Dynomena hispida, Liocarpilodes integerrimus, Pilodius paumotensis, Actumnus elegans, Pilumnus purpureus* and *Petrolisthes penicillatus* are sampled. *Liomera rugata, Zozymus aeneus* are added to the species already cited in calmer zones. In the boulder tract, it can be said that the classic population of the crags is composed of: *Pachygrapsus minutus, Zozymodes xanthoides, Eriphia scabricula, Petrolisthes lamarckii* and *Pilumnopeus trispinosus*. This last species increases very much when, because of the weak salinity of the sea water, *Pachygrapsus minutus* disappears almost completely. In the gravel zone, *Petrolisthes lamarckii* and *Chlorodiella cytherea* are the dominating species. In the inner reef flats, *Pilodius spinipes, Chlorodiella barbata, Actaeodes tomentosus, Galathea humilis* play an important part in the populations. It is in this zone that the highest density of individuals per dm^3 is found among the branched Melobesiae which are also quantitatively very rich.

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Tables

Table 1: Abundance and average dominance of the species in the different stations. (Not reproduced here).

Table 2: Average dominance of the different families on the outer reef flats.

Table 3: Average dominance of the different families on the boulder tracts.

Table 4: Average dominance of the different families in the inner reef flats.

Table 2. Outer Reef-Flats

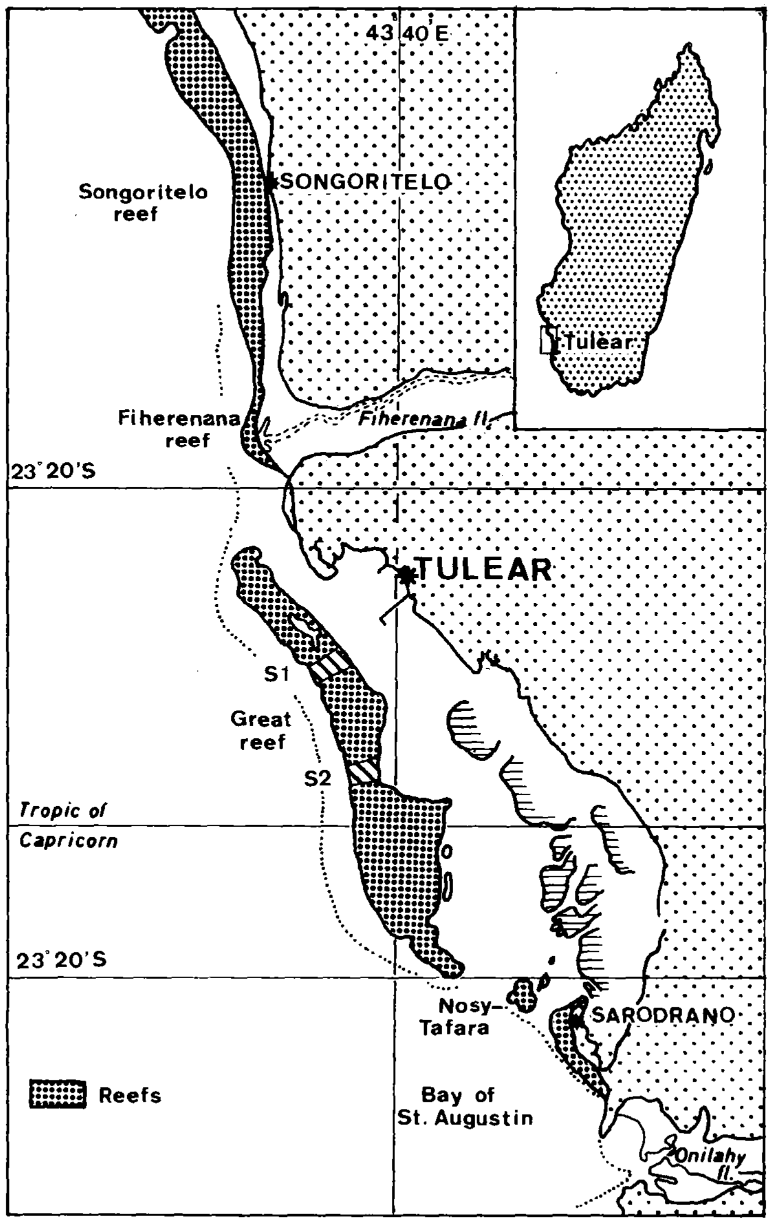
STATIONS		1	2	10	11	12	13	14	15	27	28	29	30
Number of individuals		133	207	47	97	77	60	55	101	63	76	78	58
Number of species		17	24	13	19	4	10	13	19	13	9	11	7
Dromiacea		3.00	0.96	2.12			8.23			1.51	3.94		
Oxystomata													
Oxyrhyncha		2.25	9.47	6.38	4.12	2.59		7.12	2.97	7.57	1.31		
Brachyryncha:	Portunidae	0.75	3.82		8.24			5.4	5.94	10.60		1.28	3.45
	Xanthidae	78.91	67.22	78.68	70.07	97.32	84.96	70.63	63.36	77.25	88.13	97.38	96.50
	Ocypodidae												
	Grapsidae			10.63					1.98	1.51	2.63		
Anomura		15.03	17.69	2.12	16.48		6.66	12.32	25.74	1.51	3.94		
Xanthidae													
Hyperolissa	No Carpiloida	0.75	4.79		1.03		5.00	1.72	6.95	1.51			1.72
	Zozymoida		0.96	2.12			1.66	1.72	0.99		1.31		
	Galenoida - Actaeinae	15.03	5.26	12.76	20.62		3.33	6.88	14.85	9.09	5.26	7.68	15.51
	Chlorodinae	41.34	29.18	59.56	40.12	97.32	74.97	41.36	27.76	66.64	81.57	88.42	79.31
	Cymoida	0.75											
	Lyboida												
Hyperomista	Menippinae	0.75											
	Pilumninae - Pilumnoida	15.78	24.17		8.24			15.51	11.88			1.28	
	Heteropanopoida		2.87	2.12				1.72					
	Trapezinae	4.51											
	Carcinoplacinae								1.98				
Anomura	Galatheidae				1.03		1.66		0.99				
	Porcellanidae	15.03	17.69	2.12	15.45		4.99	11.45	24.75	1.51	3.94		

Table 3. Boulder Tracts

STATIONS	3	16	22	24	25	32	33	34	38	41
Number of individuals	43	55	53	107	37	78	80	36	141	46
Number of species	7	8	8	9	6	12	12	13	6	4
Dromiacea										
Oxystomata					2.70					
Oxyrhyncha				1.40		1.28		2.72		
Brachyrhyncha-Portunidae							0.62	13.70		
Xanthidae	39.52	47.24	64.12	92.99	64.86	65.33	46.66	68.47	27.59	26.09
Ocypodidae										
Grapsidae	55.80	43.63	18.86	1.40		26.92	49.37	1.36	1.41	6.52
Anomura	4.65	9.09	16.98	4.21	27.01	6.41	3.75	6.84	70.92	67.40
Xanthidae										
Hyperolissa No Carpiloida				0.47		1.28				
Zozymoida	9.30	9.08				1.28				
Xanthoida							0.63	1.36	4.22	
Galenoida-Actaeinae	9.30	16.36	28.29	1.40	10.81	23.06	11.26	20.55	4.22	
Chlorodinae			1.88	3.74		23.06	22.50	42.46	15.59	21.73
Cymoida	4.35	3.63	1.88							
Hyperomista Menippinae										
Pilumninae - Pilumnoida										
Heteropanopeidea	16.27	18.17	32.07	87.39	54.05	16.66	11.88	4.10	3.54	4.35
Trapezinae										
Carcinoplacinae										
Anomura - Galatheidae										
Porcellanidae	4.65	9.09	16.98	4.21	27.02	6.41	3.75	6.84	70.92	67.40

Table 4. Inner Reef Flats

STATIONS	5	7	8	6	9	17	18	19	20	21	26
Number of individuals	25	61	32	184	56	40	46	259	102	45	44
Number of species	9	14	8	23	11	7	12	23	19	8	6
Dromiacea											
Oxystomata											
Oxyrhyncha	8.00			3.25	1.78		2.17	1.59	1.96		9.09
Brachyrynchia: Portunidae		1.63		0.54	1.78			0.79			
Xanthidae	56.00	94.96	96.11	85.25	57.10	62.50	82.48	88.03	91.16	88.85	52.25
Ocypodidae	16.00					37.5	2.17		0.98	11.11	
Grapsidae								0.39	0.98		
Galatheidae	20.00	3.26	3.84	10.86	39.27		13.03	9.12	3.92		38.63
Xanthidae											
non Carpiloida		1.63		1.62				1.96	1.96		
Zozymoida			3.84	1.08				1.18			
Xanthoida Galenoida: Actaeinae	40.00	34.41	34.60	20.64	12.49	17.50	28.17	28.17	43.13	13.32	34.08
Chlorodinae	16.00	50.77	53.83	59.21	41.05	42.50	54.31	55.54	45.09	75.53	15.90
Cymoida											
Menippinae											
Pilumninae I		1.63			1.78			0.79	0.98		2.27
Heteropanopeida											
Lyboida			3.84						0.98		
Trapezinae		4.91			1.78						
Carcinoplacinae		1.63		1.08		2.50		0.39			
Galatheidae: Galathea		1.63	3.84	8.69	39.27		19.03	3.96	2.94		38.63
Procellanidae	20.00	1.63		2.17				5.16	0.98		



Map 1: The coral reef in the vicinity of Tuléar.

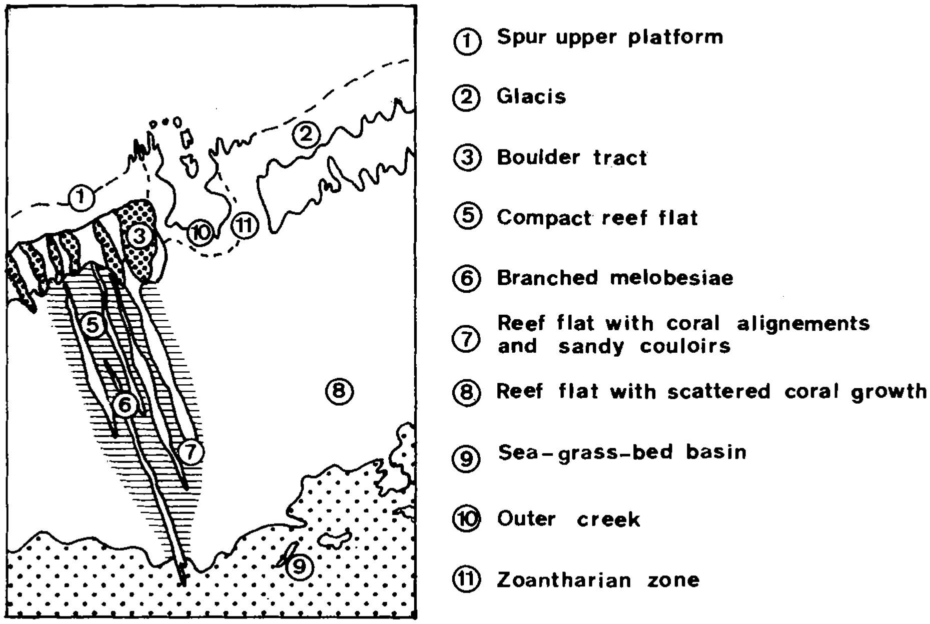


Fig. 1: Localities of the stations in Sector 1.

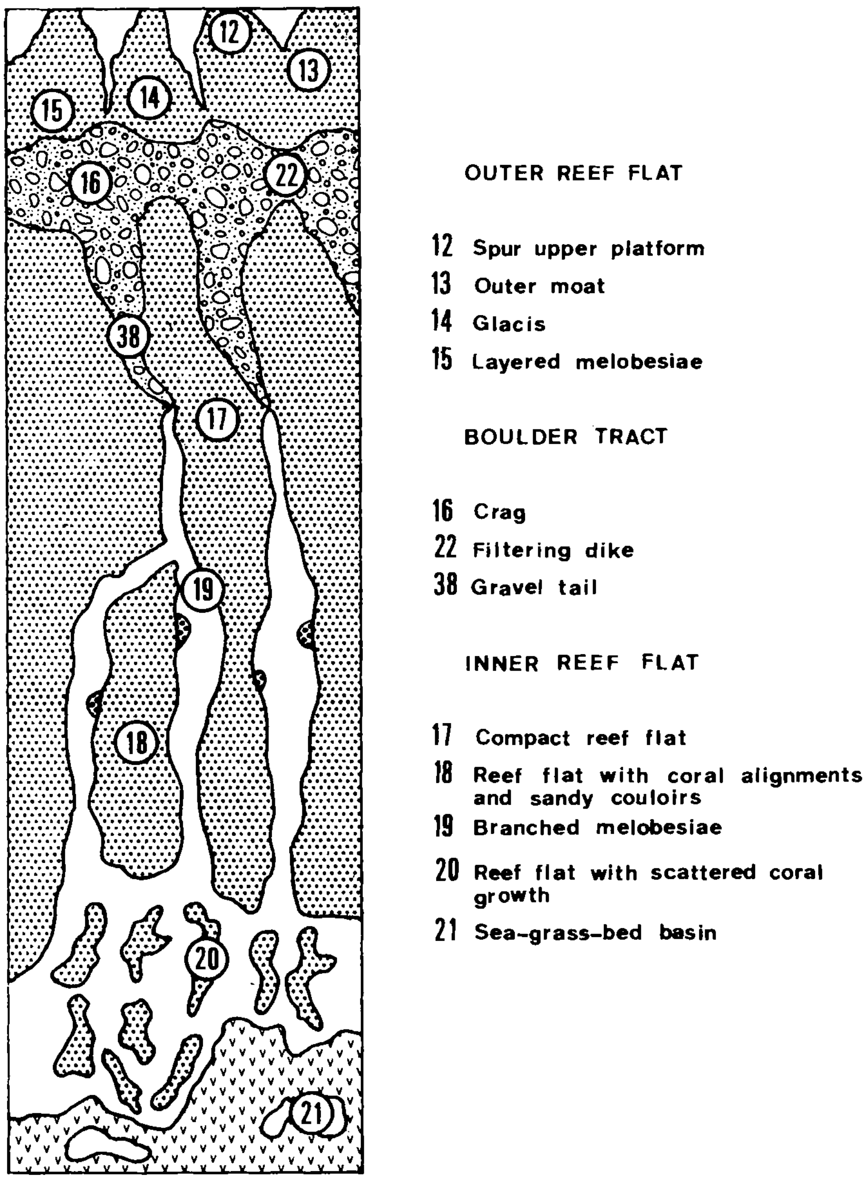


Fig. 2: Localities of the stations in Sector 2.

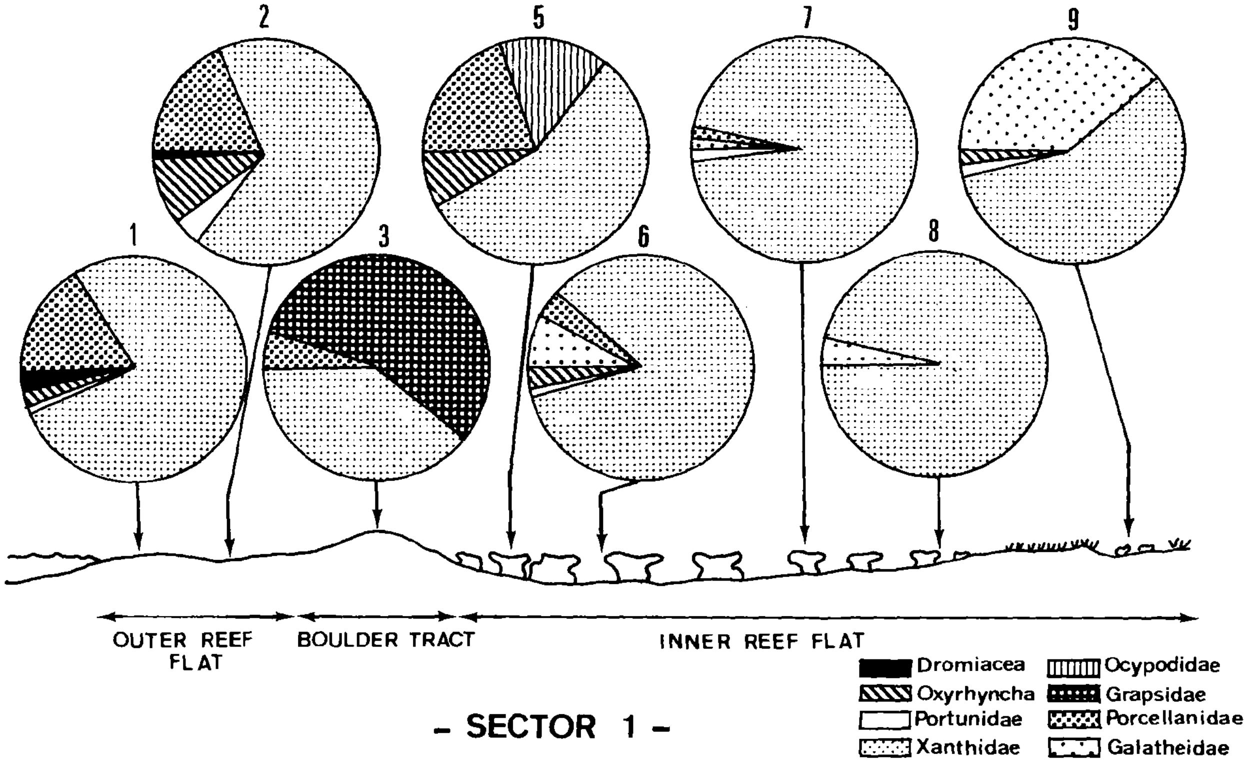


Fig. 3: Distribution of Brachyura and Anomura in the different stations in Sector 1.

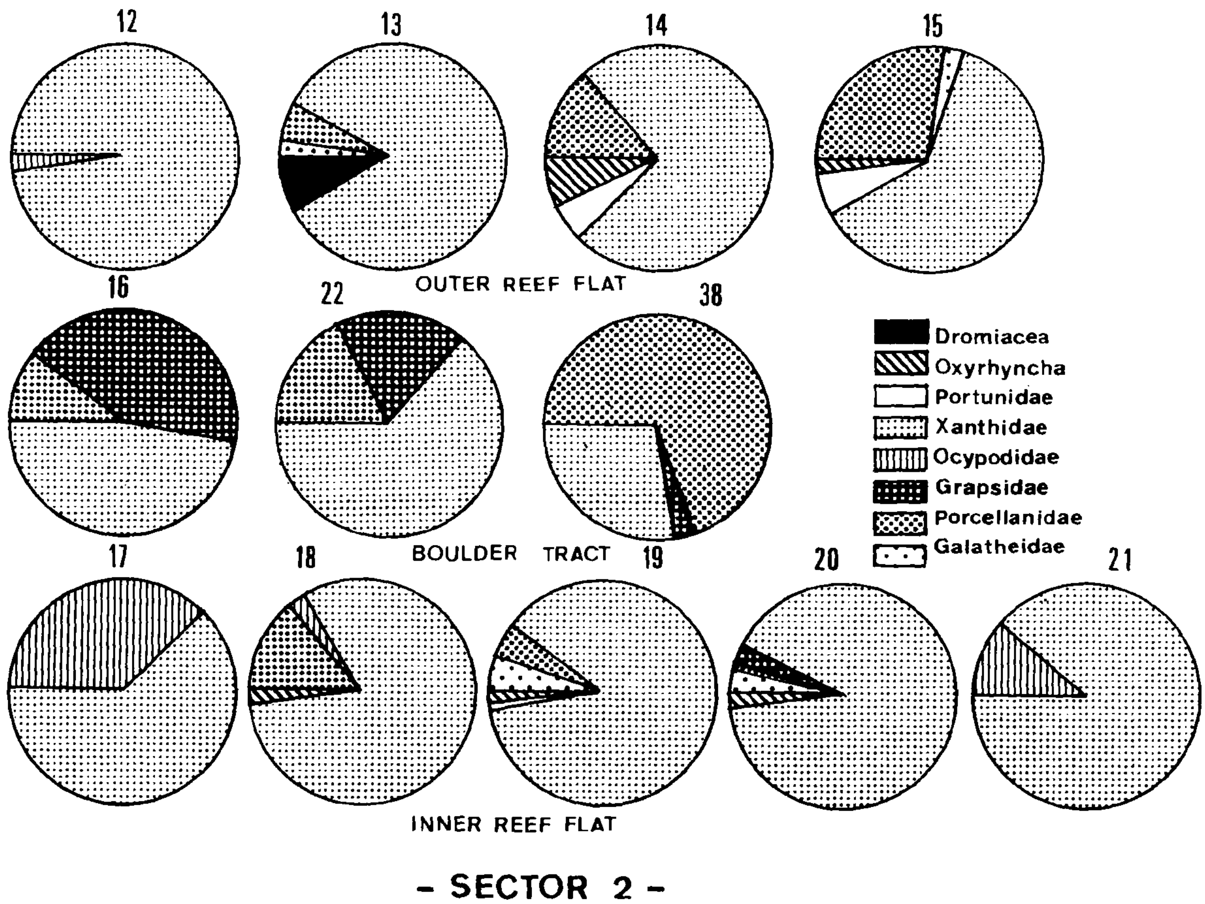


Fig. 4: Distribution of Brachyura and Anomura in the different stations in Sector 2.

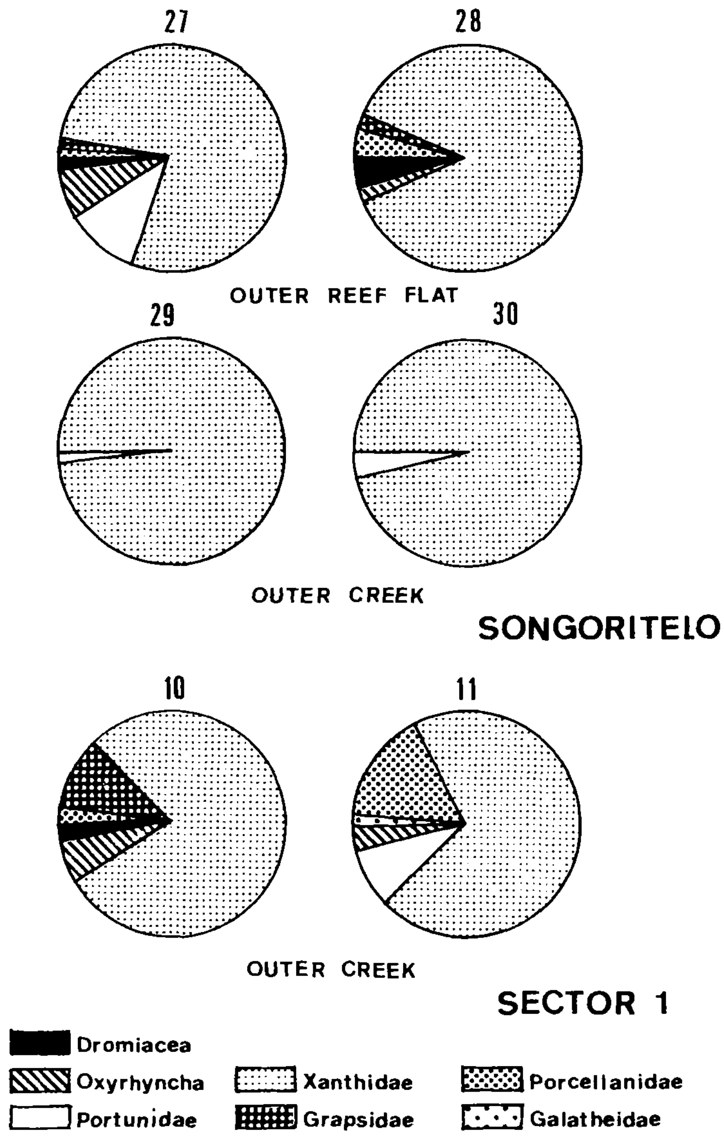


Fig. 5: Distribution of Brachyura and Anomura in the outer reef flat and outer creek of Songoritelo and of outer creek of Sector 1.

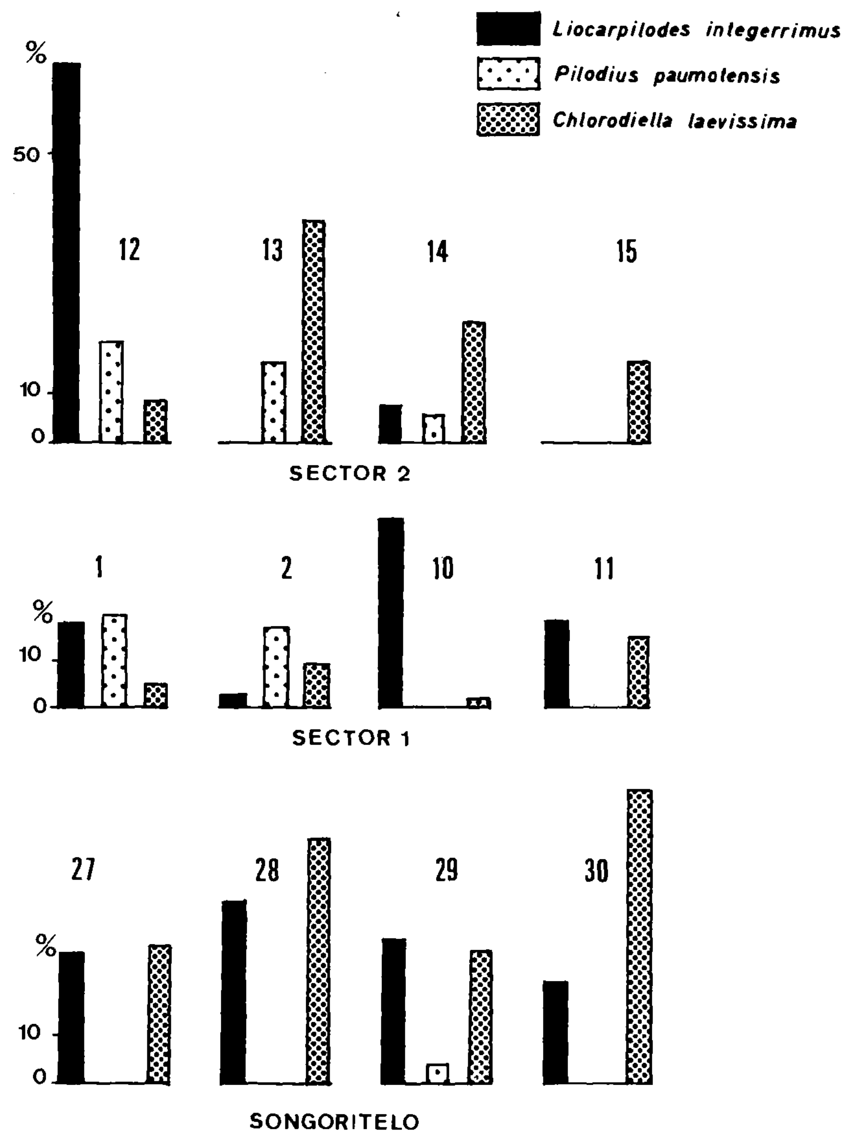


Fig. 6: Dominance of the three more abundant species of Chlorodinae in all the stations of the outer reef flats.

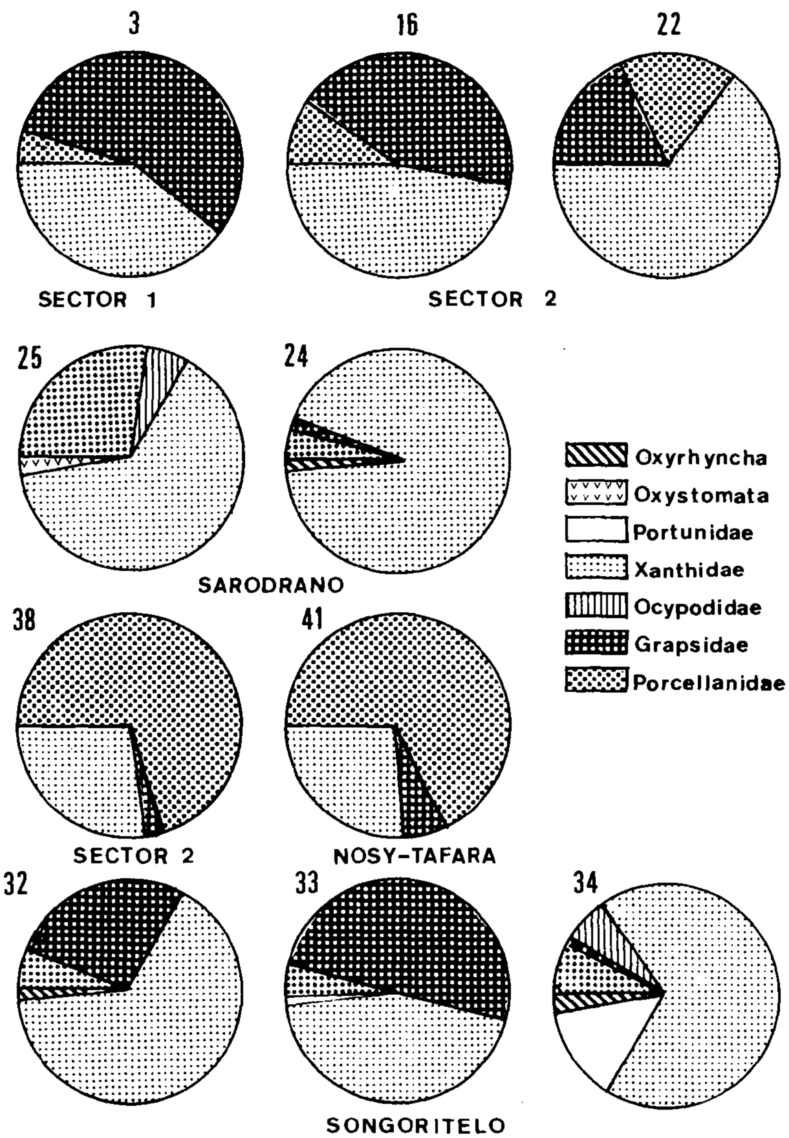


Fig. 7: Distribution of Brachyura and Anomura in the different stations on the boulder tracts.